SYMPOSIUM JJ

Magnetoresistive Oxides and Related Materials

November 29 – December 2, 1999

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* Invited paper

SESSION JJ1: SPIN POLARIZATION AND TUNNELLING IN MAGNETIC OXIDES
Chair: Stephan von Molnar
Monday Morning, November 29, 1999
Room 202 (H)

8:30 AM *JJ1.1
THE SPIN POLARIZATION IN La-MANGANITES AND RELATED OXIDES. R.J. Soulen, Jr., B. Nadgorny, M.S. Osofsky, J. Byers, P.R. Broussard, M. Rubinstein. NRL, Washington, DC.

A new class of electronics is emerging which relies on the ability of ferromagnetic materials to conduct spin polarized currents. The performance of devices based on this phenomenon is greatly enhanced as the spin polarization, P, of the ferromagnetic material approaches 100%. Thus much work has been done on the development of several new materials. However, determining their spin polarization is generally very difficult. We have developed a very simple method to measure the spin polarization of materials in which a superconducting point is placed in contact with the candidate ferromagnetic material. The Andreev reflection process at the interface between the two metals is influenced by the spin polarization of the ferromagnet enabling the determination of P through measurement of the conductance of the contact. In a very short time we have been able to measure the spin polarization of several metals and conducting oxides: NixFe1-x;Ni. Co, Fe, NiMnSb, La0.7Sr0.3MnO3; CrO2, whose spin polarization ranges from 25% to 90%. Our results compare well with tunneling spectroscopy measurements of P.

9:00 AM JJ1.2
MAGNETOTRANSPORT AND INTERFACE MAGNETISM IN MANGANITE HETEROSTRUCTURES: IMPLICATIONS FOR SPIN POLARIZED TUNNELING. Moon-Ho Jo, Neil D. Mathur, Jan E. Evetts and Mark G. Blamire, Dept of Materials Science, Univ of Cambridge, UNITED KINGDOM.

The electronic and magnetic structure at surfaces and interfaces in mixed valence manganites is an active area of research. For example, there is evidence of decreased spin polarisation at surfaces, which is a vital factor in spin polarized tunneling devices. To study localized properties of interface magnetism in heterostructures we have conducted both current in-plane and current perpendicular-plane measurements in multilayers and trilayer tunnel junctions, respectively. Initial study of the transport in multilayers, consisting of alternating $La_{0.7}Ca_{0.3}MnO_3$ and $SrTiO_3$ with different layer thickness provided information on vertical inhomogeniety in the manganite layers and disordered interfaces. The physical origin of inhomogeniety was studied in different heterostructures, focusing on the effect of replacing $SrTiO_3$ with different insulators such as normal paramagnetic insulators and structurally compatible antiferromagnetic insulators. Issues of lattice mismatched strain, structural and chemical inhomogeniety were addressed. Trilayer tunnel junctions have been fabricated with the aim of correlating tunneling magnetoresistance to the interface magnetism deduced from multilayer measurements. This work has implication for the optimisation in spin tunneling junctions based upon half metallic oxides.

9:15 AM JJ1.3
SPIN-POLARIZED TUNNELING IN WEAKLY COUPLED FERROMAGNETS. Z.G. Ivanov, R.A. Chakalov, M. Taslakov and T. Claeson Department of Microelectronics and Nanoscience, Chalmers University of Technology and University of Gothenburg, Gothenburg, SWEDEN; R. Mathieu and P. Svedlindh Department of Materials Science, Uppsala, SWEDEN.

Grain boundaries (GB) in perovskite manganites are responsible for the observed high magnetoresistance at low magnetic fields. We have studied magnetoresistance of manganite bicrystal grain boundaries as function of the grain boundary misorientation angle in a broad range of temperatures and magnetic fields. The highest magnetoresistance was observed for the 45 degree GB. A method to fabricate 1D- and 2D-arrays of weakly coupled manganites based on biepitaxial growth on different templates was developed. The arrays consist of 45 degrees GB connected in series/parallel by manganite grains with predetermined size. The magnetoresistance dependence on grain size was investigated. A strong in-plane anisotropy was measured for these devices.

9:30 AM *JJ1.4
COLOSSAL MAGNETORESISTANCE MAGNETIC TUNNEL JUNCTIONS GROWN BY MOLECULAR BEAM EPITAXY. Jim ODonnell, Maitri Warusawithana, Eugene Colla, Jim Eckstein, University of Illinois, Department of Physics, Urbana, IL.

The mixed valence manganite materials of the form $La^{+3}_{1-x}A^{+2}_{x}$-$Mn^{+3/+4}O_3^{-2}$ where A is a divalent dopant are expected to be nearly half-metallic (i.e. 100% spin-polarized conduction electrons) at ~30% doping, and should therefore exhibit very large tunneling magnetoresistance at low fields in spin-valve type structures. Furthermore, these materials are epitaxially compatible with a wide range of perovskite-based compounds. Successful growth of single-crystal thin film heterostructures would open the door for spin-polarized tunneling spectroscopy of several highly correlated electron systems, as well as investigation of spin-injection devices. Using molecular beam epitaxy (MBE) growth techniques, we have synthesized ferromagnet/insulator/ferromagnet trilayer heterostructures with the "colossal" magnetoresistance material $La_{0.7}Sr_{0.3}MnO_3$ as the ferromagnet and either $CaTiO_3$, $SrTiO_3$, or $LaAlO_3$ as the insulating barrier. In-situ reflection high-energy electron diffraction (RHEED) allows the film quality to be monitored during growth. Subsequently, the ex-situ tunneling properties can be correlated with RHEED data. The trilayer films were fabricated into magnetic tunnel junctions which exhibit magnetoresistance $\Delta R/R(H)$ of 450% in 200 Oe applied field at 14 K. The 450% magnetoresistance at 14 K decreases to zero at ~250 K. This temperature corresponds to a transition in the tunneling process from direct spin-polarized tunneling at low temperatures to an activated tunneling process. Noise measurements indicate charge trapping sites in the barrier which may provide defect-mediated tunneling channels. We observe a zero bias anomaly in the tunneling conductance at low temperatures, the strength of which is correlated with the quality of the growth as judged by RHEED. We will discuss the connection between the loss of magnetoresistance and the device microstructure, and the implications for the use of the manganites as a general source for spin-polarized electrons in solid state heterostructures.

10:30 AM *JJ1.5
SURFACE ELECTRONIC STRUCTURE AND MAGNETIC PROPERTIES OF DOPED MANGANITES. Luis Brey, M.J. Calderón and F. Guinea, Instituto de Ciencia de Materiales CSIC, Madrid, SPAIN.

We study the electronic and magnetic properties of the surface of $La_{1-x}A_xMnO_3$ perovskites. At the surface there is a oxygen deficiency and we assume that at the outermost layer, the environment of the manganese ions does not have cubic symmetry. The e_g orbitals are split and the double exchange mechanism is weakened. The charge state of the manganese ions is modified, and the magnetic ordering of the spins tends to be antiferromagnetic. We have analyzed the temperature dependence of the surface magnetization. We find that the magnetic disorder at the surface can be considerably larger than in the bulk. We have also computed the transport across the interface. We find that an applied magnetic field enhances the transmission of the barrier, by favoring the double exchange mechanism and the valence fluctuation of the manganese ions.

11:00 AM JJ1.6
MAGNETIC TUNNELING IN MOLECULAR BEAM EPITAXY GROWN $La_{0.67}Sr_{0.33}MnO_3/SrTiO_3/La_{0.67}Sr_{0.33}MnO_3$ JUNCTIONS. M.S. Rzchowski, X.W. Wu, Dept. of Physics, University of Wisconsin-Madison, WI; J. O'Donnell, J.N. Eckstein, Dept. of Physics, University of Illinois, Urbana, IL.

Magnetic tunneling junctions are fabricated from molecular beam epitaxy grown $La_{0.67}Sr_{0.33}MnO_3/SrTiO_3/La_{0.67}Sr_{0.33}MnO_3$ trilayers. Tunneling magnetoresistance as large as 500% has been observed. We have investigated the temperature and biasing dependent of conductance in both parallel and anti-parallel electrode configurations. We find a predominately linear behavior of conductance as a function of biasing voltage for biasing less than 100mV. We analyze this behavior quatitatively in term of inelastic magnon and phonon assisted tunneling.

11:15 AM JJ1.7
TUNNELING MAGNETORESISTANCE IN ORDERED DOUBLE PEROVSKITE $Sr_2FeMo_{1-x}W_xO_6$. Kei-Ichiro Kobayashi, Yasuhide Tomioka, Tsuyoshi Kimura, Joint Research Center for Atom Technology (JRCAT), Tsukuba, JAPAN; Yoshinori Tokura, Joint Research Center for Atom Technology (JRCAT), Tsukuba, JAPAN and University of Tokyo, Dept of Applied Physics, Tokyo, JAPAN.

Polycrystalline Sr_2FeMoO_6 has been reported to exhibit a spin-polarized giant tunneling magnetoresistance not only at 4.2K but also at room temperature. Sr_2FeMoO_6 is ferrimagnetic with half-metallic nature at the ground state. On the contrary, Sr_2FeWO_6 is an antiferromagnet and an insulator. W is thought to be W^{6+} without 5d electron in Sr_2FeWO_6. This implies that by the the substitution of W for Mo in Sr_2FeMoO_6, we can investigate the metal to insulator change and ferrimagnet to antiferromagnet change. The samples were prepared by solid state reaction. The ordering of Fe and Mo or W atoms was confirmed to be neary 100% at the x more than 0.4 by the Rietveld analysis of the X-ray powder pattern. We report this metal to insulator change precisely. Tunneling Magnetoresistance of these compounds ixhibits as large as around 80% at x=0.7 at 4.2K, which is

larger than that observed in Sr_2FeMoO_6. This work, supported in part by NEDO, was performed in JRCAT under the joint research agreement between NAIR and ATP.

11:30 AM JJ1.8
INFLUENCE ON THE LOW TEMPERATURE LOW FIELD MAGNETORESISTANCE OF THE ADDITION OF Y_2O_3 TO $La_{0.7}Ca_{0.3}MnO_3$. A. Arias, J. MacManus-Driscoll, Materials Dept, Imperial College of Science, Technology and Medicine, London, UNITED KINGDOM; F. Damay, L.F. Cohen, Blackett Laboratory, Imperial College of Science, Technology and Medicine, London, UNITED KINGDOM.

The low temperature low field magnetoresistance (LFMR) encountered in polycrystalline manganese pérovskites such as $La_{0.7}Ca_{0.3}MnO_3$, is attributed to the existence of grain boundaries. Decreasing the grains size in bulks materials has been found to increase the grain boundary material by volume and thus to enhance the LFMR. The increase of the magnetic disorder in a system such as $La_{0.7-x}Y_xCa_{0.3}MnO_3$ can also lead to an enhanced LFMR. Another possibility is to create nanoprecipitates of Y_2O_3 in a matrix of $La_{0.7}Ca_{0.3}MnO_3$. By adding 10% in mole of nano Y_2O_3 to $La_{0.7}Ca_{0.3}MnO_3$, the magnetoresistance, MR (defined as $1\text{-}\rho_H/\rho_0$), at 40K and under 0.1T, increases from 5% (pure matrix) to 19%, in contrast to $La_{0.6}Y_{0.1}Ca_{0.3}MnO_3$, for which MR(40K, 0.1T) reaches only 11%. Transport, as well as magnetisation measurements, confirm the presence of two phases in the sample with Y_2O_3 nanoprecipitates: the most important feature is that, in contrast to $La_{0.6}Y_{0.1}Ca_{0.3}$ MnO_3, which is spin glass at low temperature, the 10% Y_2O_3 sample clearly exhibits a collinear ferromagnetic state, confirming the fact that yttrium has not diffused in the structure.

11:45 AM JJ1.9
MEASUREMENT OF THE TRANSPORT SPIN POLARIZATION OF SRO AND OTHER MATERIALS USING PCAR. M.S. Osofsky, B. Nadgorny and R.J. Soulen, Jr., Naval Research Laboratory, Washington, DC; R.A. Rao and C.B. Eom, Dept. of Mechanical Engineering and Material Science, Duke University, Durham, NC.

The first high resolution (<1meV) transport measurements at low temperatures (< 4K) of the spin polarization of single crystal, epitaxial thin films of the ferromagnetic oxide, $SrRuO_3$, using point contact Andreev reflection (PCAR) will be presented. This technique utilizes point contact conductance measurements from a superconducting tip into a ferromagnetic material (FM) as a probe of the spin polarization of the FM. Quantitative information can be extracted from the data through a modified Blonder, Tinkham, Klapwijk (BTK) model of supercurrent conversion at a superconductor-metal interface (Andreev reflection) which includes the spin-polarization of the normal metal. The experimental results will be compared to predictions of electronic band structure calculations. These results will also be compared with those from measurements on several other oxides and metals.

SESSION JJ2: NOVEL MAGNETIC OXIDES
Chair: Mark Rzchowski
Monday Afternoon, November 29, 1999
Room 202 (H)

1:30 PM *JJ2.1
HALF METALLIC MAGNETIC OXIDE THIN FILMS AND HETEROSTRUCTURES. T. Venkatesan, NSF MRSEC on Oxide Thin Films, Surfaces and Probes, Center for Superconductivity Research, Department of Physics, University of Maryland, College Park, MD.

Half metallic oxides are very important both in terms of the fundamental physics of their magnetic interactions but also in terms of their technological relavence. This talk will cover progress in the synthesis and study of a variety of half metallic oxides such as the manganites, magnetites and molybdates in the form of thin films and heterostructures.

2:00 PM JJ2.2
TRANSPORT PROPERTIES AND MAGNETISM OF β-MnO_2. Hirohiko Sato, Toshiaki Enoki, Tokyo Institute of Technology, Dept of Chemistry, Tokyo, JAPAN.

Rutile type manganese oxides, β-MnO_2, has been known for its unique magnetism with helical structure. In addition, metallic electronic conduction has been reported, which drives us to seek interesting physical phenomena due to the coexistence of electric conduction and magnetism in this compound. Because of the difficulty of crystal growth, detailed information of transport properties and magnetism has been lacking for a long time. Recently, we have succeed to obtain good single crystals of β-MnO_2 by hydrothermal technique. In this talk, we will report their resistivity, thermoelectric power, Hall coefficient, magnetoresistance, and magnetic susceptibility. The resistivity shows a metallic behavior although the chemical composition suggests an insulating electronic state. The thermoelectric power and the Hall coefficient reveal that n-type carriers are responsible for the metallic conduction. This suggests that very small amount of oxygen defects causes electron-like carriers. The magnetic susceptibility shows a magnetic phase transition at T_N (96 K). Its temperature dependence and the anisotropy do not conflict with the existing model of helical magnetism although the Curie-Weiss analysis in the paramagnetic region gives a larger Curie constant than calculated value based on localized magnetic moments. The transport properties are accompanied by a large anomaly at T_N. In addition, magnetic short-range order in the temerature region far above T_N strongly enhances the scattering of conduction electrons. Magnetoresistance is not so large as that in perovskite manganates, but a remarkable anisotropy appears below T_N reflecting the anisotropic magnetic structure. These results clearly indicate a strong correlation between conduction and magnetism.

2:15 PM JJ2.3
PROPERTIES OF THE FERRIMAGNETIC DOUBLE-PEROVSKITES A_2FeReO_6 (A=Ba AND Ca). W. Prellier, V. Smolyaninova, A. Biswas, C. Galley and R.L. Greene, Center for Superconductivity Research, Department of Physics, University of Maryland, College Park, MD; K. Ramesha and J. Gopalakrishnan, Solid State and Structural Chemistry Unit, Indian Institute of Science, Bangalore, INDIA.

A significant feature of the electronic structure of the ferromagnetic colossal magnetoresistance manganites is that the charge carriers are almost completely spin polarized at the Fermi level E_F. These materials are half-metallic ferromagnets, where the majority spin states near E_F are delocalized and the minority spin channel is effectively localized. Since half-metallic ferromagnetism and magnetoresistance (MR) seem to be intimately related to each other there is an intense search for half-metallic magnets which could be candidate materials for the realization of MR applications. One such material, Sr_2FeMoO_6 has recently been shown to be a half-metallic ferrimagnet exhibiting a significant tunneling-type magnetoresistance at room temperature. [1]. Ceramics of A_2FeReO_6 double perovskites have been prepared and studied for A=Ba and Ca. Ba_2FeReO_6 has a cubic structure whereas Ca_2FeReO_6 has a distorted monoclinic symmetry. The barium compound is metallic from 5 K to 385 K and thc calcium compound is semiconducting from 5 K to 385 K. Magnetization measurements show a ferri-magnetic behavior for both materials, with T_c=315 K for Ba_2FeReO_6 and above 385 K for Ca_2FeReO_6. A specific heat measurement on the barium compound gave an electron density of states at the Fermi level, $N(E_F)$ equal to 5.9 x 10^{24} $eV^{-l}mole^{-l}$. At 5 K, we observed a negative magnetoresistance of 10% in a magnetic field of 5 T, but only for Ba_2Fe ReO_6. Electrical, thermal and magnetic properties are discussed and compared to those of the analogous compounds $Sr_2Fe(Mo,Re)O_6$. This work is supported by NSF-MRSEC at University of Maryland and the Department of Science and Technology, Goverment of India.
[1] K.I. Kobayashi *et al.*, Nature 395, 677 (1998)

2:30 PM *JJ2.4
EPITAXIAL CHROMIUM DIOXIDE THIN FILMS AND THEIR USE IN TUNNEL JUNCTIONS. Arunava Gupta, IBM T.J. Watson Research Center, Yorktown Heights, NY; Xinwei Li, Gang Xiao, Dept. of Physics, Brown University, Providence, RI.

Epitaxial chromium dioxide (CrO_2) thin films have been grown on TiO_2 (100) substrates at atmospheric pressure by chemical vapor deposition using CrO_3 as a precursor. The films have a Curie temperature around 390-395K and exhibit in-plane magnetocrystalline anisotropy, which favors the c-axis direction as the magnetic easy axis. They also display metallic characteristic, with room temperature resistivity of about 300 $\mu\Omega$cm, dropping by about two orders of magnitude upon cooling down to 5 K. A simple method, involving selective-area epitaxy on single crystal TiO_2 substrates pre-patterned with a SiO_2 thin film mask, has been developed for patterned deposition of CrO_2 films. Hall effect and magnetoresistance have been studied on these patterned samples. A positive ordinary Hall effect is found at low temperatures, indicating the conduction carriers are holes. Results on tunnel junction fabricated using CrO_2 as one of the electrode will also be presented.

3:30 PM *JJ2.5
SURFACES OF LAYERED TRANSITION METAL OXIDES. Rene Matzdorf, Ward Plummer, The University of Tennessee Knoxville, Dept of Physics and Astronomy, and Oak Ridge National Laboratory, Knoxville, TN.

Transition metal oxides (TMOs) exhibit complex behavior because the structural, electronic, and magnetic properties are strongly

coupled. A small change in one property (e.g., structure) can produce a large change in another property (e.g., the magnetic state). Many of these materials are layered or quasi two-dimensional (2D), and some of the most interesting physical phenomena such as phase transitions are associated with and controlled by symmetry-breaking perturbations. A surface (or an interface) breaks the inherent symmetry in a solid and can thus change the order parameters associated with various types of transitions. We have used variable temperature STM (T> 25 K) (microscopy) and STS (spectroscopy) to image spatial variations in the electronic and structural properties. LEED and ELS have been applied to determine surface structure and electronic and vibrational excitations, respectively. We find the surface of cleaved $Sr_2 2RuO_4$ exhibits a c(2x2) reconstruction and a defect stabilized (1x1) structure, yet the surface is metallic at all temperatures measured. Images and spectroscopy of $La_{0.5}Sr_{1.5}MnO_4$ clearly show electron inhomogenities on the ~50 Å scale. Finally recent STM measurements on $La_{1.2}Sr_{1.8}Mn_2O_7$ will be presented. * Funded by Joint Research Center for Atom Technology, Tsukuba, and the National Science Foundation

4:00 PM JJ2.6
NEW MAGNETIC AND FERROELECTRIC CUBIC PHASE OF THIN-FILM Fe-DOPED $BaTiO_3$. Roland Maier, Joshua L. Cohn, Department of Physics, University of Miami, Coral Gables, FL; Leonid A. Bendersky, Materials Science and Engineering Laboratory, National Institute of Standards and Technology, Gaithersburg, MD; John J. Neumeier, Department of Physics, Florida Atlantic University, Boca Raton, FL.

The growth, characterization, and physical properties of a new perovskite phase of thin-film $BaTi_{1-x}Fe_xO_3$ are reported. The films were grown by pulsed laser deposition from polycrystalline targets of hexagonal $BaTi_{1-x}Fe_xO_3$ ($0.5 \leq x \leq 0.75$) and $Ba_4Fe_4Ti_3O_{16}$ (BFTO-E). Epitaxial films, with stoichiometries close to those of the targets, have been grown on (100), (110), and (111) orientations of MgO and (100) $SrTiO_3$. The new phase is tetragonal with $c/a \simeq 1.002$, where c and a are the lattice constants normal and parallel to the substrate plane, respectively. The films are magnetic with $T_C > 125$ °C, the highest temperature measured thus far. The saturation magnetization (at $T = 5$ K) is approximately 0.5-0.6 μ_B/f.u. Measurements of electrical resistivity and lattice constants *vs* temperature suggest a ferroelectric transition in the range $T \sim 190 - 250$ °C.

4:15 PM JJ2.7
MICROWAVE DYNAMICS OF STRIPE TRANSITIONS IN $La_{5/3}Sr_{1/3}NiO_4$. N. Hakim, P.V. Patanjali, Z. Zhai and S. Sridhar, Physics Department, Northeastern University, Boston, MA; S. Cheong, Rutgers University, New Brunswick and Lucent Technologies, Murray Hill, NJ.

The importance of spin, charge and lattice degrees of freedom that result in numerous novel properties has recently been the focus in strongly correlated electronic materials. Charge and spin stripe phases have been demonstrated in the nickelates, $La_{2-x}Sr_xNiO_4$. We have carried out high precision microwave susceptibility measurements on single crystal $La_{5/3}Sr_{1/3}NiO_4$ in the frequency range 2-18 GHz as functions of temperature and crystal orientation. These precision susceptibility measurements reveal three different transitions: a high temperature transition at 240K associated with charge ordering, followed by spin freezing at around 220K and a low temperature (32K) feature attributed to stripe glass. The temperature dependence suggests that the spin ordering is driven by charge ordering. A hallmark of glassy systems is sensitivity of the transition temperature to the measurement time scales. The importance of time scales in stripe physics has become very clear by comparing neutron scattering (NS) and NMR measurements. Recent NMR results show that the magnetic ordering temperature is 30K less than that observed by NS. The peak temperature observed in the present microwave measurements is well above the NMR magnetic ordering temperature and is close to that of NS, whose time scales are close to the microwave time scales. The charge and spin ordering features observed in the nickelate bears strong similarities to those observed in the non-superconducting cuprates. Work at Northeastern supported by NSF-9623720.

4:30 PM JJ2.8
HIGH PRESSURE MEASUREMENTS ON $Tl_2Mn_{1-x}Ru_xO_7$. M. Nunez Regueiro, CRTBT/CNRS, Grenoble, FRANCE; R. Senis, W. Cheikh-Rouhou, P. Strobel, P. Bordet, M. Pernet, Lab. Cristallographie/CNRS, Grenoble, FRANCE; M. Hanfland, ESRF, Grenoble, FRANCE; B. Martinez and J. Fontcuberta, ICMAB, Barcelona, SPAIN.

Transport and structural properties of $Tl_2Mn_{1-x}Ru_xO_7$ pyrochlore are studied as a function of the Ru substitution rate x and applied pressure up to ~20GPa. the use of Ru substitution in the Mn network provides a convenient way of modifying the charge density in the Tl-O band without disrupting it with foreign cations. We find that the effect of pressure is similar to that of low Ru substitution on the pure material. However, we observe a non-monotonous pressure dependence of the magnitude of the resistivity and of the transition temperature. We correlate this unusual variation with the structural parameters that, according to electronic band calculations, are key in controlling the properties of these materials.

4:45 PM JJ2.9
MAGNETORESISTANCE IN THIN FILMS OF SILVER CHALCOGENIDES. Ilya S. Chuprakov, Klaus-H. Dahmen, Department of Chemistry and MARTECH, Florida State University, Tallahassee, FL; Peng Xiong, Department of Physics and MARTECH, Florida State University, Tallahassee, FL.

Thin films of silver telluride and selenide were deposited by different techniques including CVD, electron-beam evaporation and vapor transport methods at the different conditions. A variety of precursors were tested for the CVD of the materials. Highly oriented and polycrystalline films of these compounds were prepared on different substrates. Their chemical and phase composition, morphology and crystallography were investigated by XRD, SEM, XPS, profilometry, pole figures and other techniques. The interplay between these properties and magnetoresistive parameters of the films was studied. The magnetoresistance of the films was measured at different temperatures, magnetic fields and field-current orientations. New effect of negative magnetoresistance at transverse field-current orientation was confirmed and investigated in the films of different composition, morphology and orientation.

SESSION JJ3: POSTER SESSION I
Chair: M. Rajeswari
Monday Evening, November 29, 1999
8:00 P.M.
Exhibition Hall D (H)

JJ3.1
EPITAXIAL GROWTH AND MAGNETIC PROPERTIES OF METASTABLE PSEUDO-CUBIC AND 4-LAYERED HEXAGONAL $BaRuO_3$ THIN FILMS. M.K. Lee and C.B. Eom, Department of Mechanical Engineering and Materials Science, Duke University, Durham, NC; M. Smoak and F. Tsui, Department of Physics and Astronomy, University of North Carolina, Chapel Hill, NC; J.C. Jiang and X. Pan, Department of Materials Science and Engineering, University of Michigan, Ann Arbor, MI.

Epitaxial $BaRuO_3$ films with either metastable pseudo-cubic or 4-layered hexagonal structures were grown by 90* off-axis sputtering using (001) and (111) $SrTiO_3$ and MgO substrates. $BaRuO_3$ is generally known as having a 9-layered rhombohedral structure (9R structure: a=5.75Å, c=21.6 Å) with an antiferromagnetic transition at TN = 430 K. X-ray diffraction and transmission electron microscopy experiments reveal that the $BaRuO_3$ films grown on (001) $SrTiO_3$ have a pure pseudo-cubic structure with lattice parameters of 3.9±0.02 Å. The pseudo-cubic structure consists of 90* orthogonal domains. In contrast, the $BaRuO_3$ films grown on (111) MgO or (111) $SrTiO_3$ substrates are pure c-axis oriented, 4-layered hexagonal structures with lattice parameters a=5.73 Å and c=9.5 Å. The epitaxial orientation relationship for the 4-layered hexagonal is $BaRuO_3$ (0001) ∥ MgO or $SrTiO_3$ (111) and $BaRuO_3$ [01$\bar{1}$0] MgO or $SrTiO_3$ [$\bar{1}$10]. Scanning tunneling microscopy studies of the 4-layered hexagonal films indicate the presence of a smooth two-dimensional island growth with a half unit-cell hight. The correponding electrical transport and magnetic properties of both pseudo-cubic and 4-layered hexagonal $BaRuO_3$ films will be discussed. This work was supported by NSF Grant No. DMR-9802444, the NSF Young Investigator Award and the David and Lucile Packard Fellowship (CBE).

JJ3.2
EFFECT OF BIAXIAL STRESS ON MAGNETORESISTIVE TRANSITIONS IN LCMO FILMS. C. Curran, St. Senz, R. Pretorius, National Accelerator Centre, Van de Graaff Group, Faure, SOUTH AFRICA; I. Krylov, University of the Western Cape, Department of Physics, Bellville, SOUTH AFRICA.

The effect of biaxial stress in a thin film of $La_{1-x}Ca_xMnO_3$ (LCMO) grown on substrates with different thermal expansion coefficients like $LaAlO_3$ and Si on the magnetoresistive behavior are studied. Pulsed laser deposition (PLD) was used as deposition method. Epitaxial growth on Si requires the deposition of buffer layers (YSZ, CeO_2) prior to the LCMO growth. In order to prevent stress-induced cracking of the films, the total thickness of all oxide layers may not exceed a critical value. The presence of biaxial stress modifies the temperature of the metal-insulator transition. Biaxial stress at room temperature was determined by X-ray diffraction. TEM of cross-sections provides the opportunity to visualize different types of

structural defects in the LCMO films.

JJ3.3
THE ROLE OF STRAIN IN LOW-FIELD MAGNETOTRANSPORT PROPERTIES OF MANGANITE THIN FILMS. Y.F. Hu, H S. Wang, E. Wertz and Qi Li, Department of Physics, Pennsylvania State University, University Park, PA.

Strain-induced large low-field magnetoresistance has been observed in very thin $Pr_{0.67}Sr_{0.33}MnO_3$ films[1]. To better understand the role of strain in the low-field magnetotransport properties of manganite thin films, we have studied and compared very thin (3-20 nm) $Pr_{0.67}Sr_{0.33}MnO_3$(PSMO), $La_{0.67}Ba_{0.33}MnO_3$(LBMO), $La_{0.67}Sr_{0.33}MnO_3$(LSMO) and $La_{0.67}Ca_{0.33}MnO_3$(LCMO) films grown on different substrates, such as $LaAlO_3$(LAO)(001), $NdGaO_3$ (NGO)(110), and $SrTiO_3$(STO)(001), where different strains can be imposed to the films due to the lattice mismatch ranging from -2.4% to +1%. We have found that: (1) large low-field magnetoresistance(MR) is observed in PSMO and LCMO thin films on LAO substrates when a magnetic field is applied perpendicular to the film plane, but it has not been observed so far in LBMO and LSMO samples; (2) all films grown on LAO substrates show negative low-field MR while most of the films grown on STO substrates show positive MR when a magnetic field is applied perpendicular to the film plane, and when the field is parallel to the film plane all films show negative MR regardless of the substrates; (3) the large low-field MR is strongly dependent on the film thickness. The anomalous low-field MR effect will be discussed based on strain-induced magnetic anisotropy and domain rotation and movement. 1. H.S. Wang and Qi Li, Appl. Phys. Lett. 73, 2360 (1998).

JJ3.4
GROWTH AND CHARACTERIZATION OF EPITAXIAL THIN FILMS OF ANTIFERROMAGNETIC RUTHENATE, Sr_2YRuO_6. R. Price, M.K. Lee, C.B. Eom, Duke Univ, Dept of Mechanical Engineering and Material Science, Durham, NC; M.S. Rzchowski, Dept of Physics, Univ of Wisconsin-Madison, Madison, WI.

We have grown epitaxial thin films of antiferromagnetic ruthenate Sr_2YRuO_6 on miscut (001) $SrTiO_3$ substrate by 90° off-axis sputtering technique. Sr_2YRuO_6 is a unique material that would allow us to grow epitaxial ferromagnetic/antiferromagnetic heterostructures. The expected epitaxial nature of Sr_2YRuO_6 / $SrRuO_3$ bilayers permits detailed studies of magnetic exchange bias phenomena at these interfaces, including the role of uncompensated spins thought to arise from interface roughness. Such exchange-biased interfaces are important for electrode pinning in magnetic tunnel junctions. Antiferromagnetic Sr_2YRuO_6 has the same pseudo-cubic perovskite crystal structure as the ferromagnetic conductive oxide $SrRuO_3$. The Sr_2YRuO_6 perovskite crystal structure has Y and pentavalent Ru located on the octahedral sides and the pseudocubic lattice parameter of 4.08 A. The Neel temperature of Sr_2YRuO_6 is 26K. Four-circle X-ray diffraction analysis revealed the Sr_2YRuO_6 films are purely (110) normal to the substrate with two 90° domains in the plane. Electrical and magnetic properties of thin film Sr_2YRuO_6 and Sr_2YRuO_6 / $SrRuO_3$ heterostructures will be discussed.

JJ3.5
EVOLUTION OF THE Mn-O BOND ASYMMETRY WITH FILM THICKNESS IN La_xMnO_3 FILMS. T.A. Tyson, H. Woo, New Jersey Institute of Technology, C. Dubourdieu and J. P. Sènateur, Laboratoire des Matèriaux et Gènie Physique, St. Martin d'Hères, FRANCE.

X-ray absorption measurements have been performed on ferromagnetic La_xMnO_3 films (deposited on $SrTiO_3$) of thickness ranging from 10 to 500 nm. It is found, by polarized x-ray absorption and x-ray diffraction measurements, that an asymmetry exists between the in-plane and out of plane Mn-O bond distribution which varies with thickness. The details of the evolution of the bond asymmetry are explored and compared with the magnetic properties of the films. This work is supported by DOE grant DE-FG502-97ER45665

JJ3.6
EPITAXIAL GROWTH, STRUCTURE AND MAGNETIC PROPERTIES OF HIGH QUALITY $La_{0.65}Pb_{0.35}MnO_3$ FILMS. Q.L. Xu, C. Petersen, P.A. Dowben, S.H. Liou, University of Nebraska, Behlen Laboratory of Physics, Lincoln, NE.

Recently, $La_{1-x}A_xMnO_3$ (A=Ca, Sr, Ba, Pb) system have received much attractive interest, and these compounds show a paramagnetic to a ferromagnetic phase transition near the ferromagnetic Curie temperature T_c. These materials exhibit a wide range of interest imperfectly understood structure, magnetic and electronic properties. The electron-electron and electron-phonon coupling mediated by chemical composition, temperature and magnetic field so that control of structure and composition is essential for fundamental studies of electronic structure. We have successfully grown epitaxial $La_{0.65}Pb_{0.35}MnO_3$ thin films by a RF magnetron sputtering method. The targets were sintered by using high reaction activity, very homogeneous powers prepared by citric acid sol-gel process. X-ray diffraction measurements found that excellent (100) orientation films were grown on the (100) $LaAlO_3$ substrate. AFM measurements indicated that the surface of the films were smooth and no cracking or main defects were observed. Complex magnetic domain patterns were observed on the surface of the film, different from that of $La_{0.65}Ca_{0.35}MnO_3$ film. XPS and XAS showed that the defect density in the films was very low in the "bulk" single phase materials. The magnetic and magnetic transition measurements were carried out by using SQUID magnetometer and MCD. The magnetization of the film at 6K in 1T magnetic field reached 77 emu/g and the Curie temperature of these materials high at about 360 K. The curve of resistivity versus temperature showed a maximum at 365 K in zero field and the resistivity at this temperature was 7.5 mΩcm. The peak temperature of resistivity versus temperature curve shifted to 420 K at 5.5 T magnetic field and a negative magnetoresistance of 45% was observed at 340K in this field. These magnetic property parameters are similar to that of single crystal. All above results suggest that the films are high quality single crystal epitaxial film, and suitable for studies of the band structure.

JJ3.7
THE EPITAXIAL GROWTH OF COLOSSAL MAGNETO-RESSISTANCE THIN FILM LCMO BY A NOVEL AEROSOL-SPRAY DEPOSITION METHOD. Wei Bai, CellTech Power LLC, Pawtucket, RI.

The epitaxial thin film of $La_{0.67}Sr_{0.33}MnO_3$ (LSMO) has been successfully prepared on $LaAlO_3$ single crystal substrates by a novel aerosol-spray deposition method. The aerosol-spray deposition technique relies on transferring the aerosol from a liquid-state precursor solution into the gas phase using electrospray(ES) ionization sources. The precursor solution was prepared from the metal nitrate powders of La, Ca, and Mn in appropriate molar ratio (La:Ca:Mn=0.67:0.33:1). Deposition and heat treatment were conducted at a single step with an oxygen partial pressure of 3-5 mbar. The crystallographic, morphological properties of the epitaxial thin films were characterized by using XRD and AFM. The influence of deposition conditions and annealing process on the crystallinity and MR properties of the thin film were also discussed.

JJ3.8
EFFECT OF GROWTH CONDITIONS, LATTICE MISMATCH AND POST-ANNEALING ON THE PROPERTIES OF EPITAXIAL MANGANITE THIN FILMS. C. Sehman, A. Cavanaugh, M. Lewis, W. Prellier, M. Rajeswari, D.J. Kang, A. Biswas, R.C. Srivastava, Y.H. Li, R.L. Greene and T. Venkatesan, NSF MRSEC and Center for Superconductivity Research, University of Maryland, College Park, MD.

Our work on epitaxial manganite thin films grown by pulsed laser deposition has revealed the following key aspects: (i) The compositional phase diagram in thin film form can be distinctly different from that of the bulk - we will demonstrate this in the case of La-Ca system where the key differences are higher ferromagnetic transition temperatures and insulator-metal transition temperatures wrt bulk in the low doping ($x < 0.3$) regime. (ii) Substrate lattice mismatch strongly influences the film properties via the effect of bi-axial Jahn Teller type of strain fields. Our recent results reveal that the properties of films on lattice-mismatched substrates can be varied over a wide range (for a given thickness and composition) by subtle changes in the growth kinetics and the accompanying changes in strain relaxation. (iii) Post-annealing in different gaseous environments cause pronounced changes in the properties of thin films in the phase diagram. Such changes have contributions from changes in oxygen stoichiometry, creation of cation vacancies, strain relaxation and changes in film morphology. We will present results that highlight each of the above three aspects.
This work is supported by NSF MRSEC on Oxide Thin Films, Probes and Surfaces at the University of Maryland

JJ3.9
TEM INVESTIGATION OF $La_{1-x}Ca_xMnO_3$ FILMS. Y.H. Li, M. Rajeswari, A. Biswas, D.J. Lang, C. Sehman, L. Salamanca-Riba, R. Ramesh and T. Venkatesan; NSF MRSEC on Oxide Thin Films, Surfaces and Probes, and Center for Superconductivity Research, University of Maryland, College Park, MD.

We will present our Transmission Electron Microscopy studies of $La_{1-x}Ca_xMnO_3$ thin films (with x = 0.33 and x = 0.2). The studies in the x = 0.33 films on several substrates were carried out to study the effects of lattice mismatch strains on the microstructure. Interestingly, electron diffraction patterns reveal doubling of lattie-space over a range of thicknesses in the films on $LaAlO_3$. High resolution TEM pictures and image simulations indicate that these

cannot be explained by tilting of the oxygen octahedra but may be consistent with cation ordering at the rare earth site. Such evidence of cation ordering is also found in strain-relaxed films with x = 0.2 where anomalously high T_c values have been previously reported. The evidence for such cation ordering and its possible effects on the transport and magnetic properties will be discussed.

JJ3.10
LARGE MAGNETORESISTANCE ANISOTROPY IN STRAINED $Pr_{0.67}Sr0.33MnO_3$ THIN FILMS. H.S. Wang, Y.F. Hu, E. Wertz and Qi Li, Dept of Physics, Pennsylvania State Univ, University Park, PA.

We have studied the magnetoresistance(MR) anisotropy of differently strained $Pr_{0.67}Sr_{0.33}MnO_3$ (PSMO) thin films in magnetic field of 1-9 Teslas where the magnetization of the film is saturated.[1] The strains were introduced by epitaxially growing the PSMO thin films on $LaAlO_3$ (100), $SrTiO_3$ (100), and $NdGaO_3$ (110) crystals which induce compressive-, tensile-, and almost non-strain, respectively, due to different film-substrate lattice mismatches. The anisotropic MR was measured at given magnetic fields and temperatures by changing the angle between the field direction and the substrate normal. The compressive- and tensile-strained ultrathin (5-15 nm) films show unusually large anisotropic MR, but with opposite signs. The anisotropic MR defined as $(R_\perp - R_\parallel)/R_\parallel$ is as large as -70 % and 50 % for compressive- and tensile-strained films respectively. Furthermore, the field dependence of the anisotropic MR shows a crossover at the insulating to metallic transition temperatures (T_P) from decreasing with magnetic field below T_P to increasing with magnetic field above T_P. In contrast, the almost strain-free PSMO films show much lower (a few percent) anisotropic MR over all the temperature and field ranges measured. Similar measurements were also carried out on compressive- and tensile-strained $La_{0.67}Ba_{0.33}MnO_3$, $La_{0.67}Sr_{0.33}MnO_3$ and $La_{0.67}Ca_{0.33}MnO_3$ films, and the comparison between different manganites will be discussed. 1. H. S. Wang, Qi Li, Kai Liu, and C. L. Chien, Appl. Phys. Lett. 74, 2212(1999).

JJ3.11
MAGNETORESISTIVE PROPERTIES OF RARE-EARTH-DOPED Co-Ag THIN FILMS DEPOSITED BY RF-SPUTTERING. Kazuhiko Tonooka, Okio Nishimura, Hokkaido Natl Industrial Research Inst., Sapporo, JAPAN.

Magnetoresistance (MR) of RE(= Ce,Nd,Sm,Tb, Dy and Er) doped Co-Ag thin films have been investigated. RF-sputtered Co-Ag alloy films deposited onto Pyrex glasses at room temperature showed MR effect. To obtain a broad range of RE-doping into the Ag layer, an Ag target with small pieces of RE metal on it was used. MR measurements on as-deposited and annealed samples were made by the four-point prove method under a static magnetic field up to 300 Oe. Experimental results showed that the doping of Ce, Tb or Sm enhanced the MR response of Co-Ag alloy films, while Nd depressed the response. The optimal annealing temperature was increased by RE additions. A maximum MR ratio (=1.6%) was obtained for the annealed samples doped with about 0.8 at% of Ce or Sm.

JJ3.12
CHEMICAL COMPOSITION, MICROSTRUCTURE, AND ELECTRICAL CHARACTERISTICS OF $(La-1-xA-x)MnO-3$ (A=Sr,Ca,Ba) THIN FILMS. S.J. Lim, H. Heo, N.-H. Cho, Inha Univ., Dept. of Materials Sci. and Engineering, Inchon, KOREA; G.Y Sung, Electronics and Telecommunications Research Institute, Daejeon, KOREA.

Recently $(La_{1-x}A_x)MnO_3$ (A=Sr,Ca,Ba) thin films have attracted much attention mainly because they exhibit large magneto-resistance behaviors of more than thousand fold change in resistivity under certain magnetic fields. These materials can be used for highly sensitive magnetic sensors. In this study, pulsed laser deposition and rf magnetron sputter techniques were applied to grow the thin films at various conditions. The films exhibit a strong tendency of (100) preferential orientation. Microstructure, chemical ordering, and electrical properties of the thin films were investigated as a function of growing parameters such as substrate temperature, sputter power density, target composition, etc. The structural variation and chemical ordering features of the films were investigated by TEM and thin film XRD analysis. Chemical composition as well as electrical characteristics of the films were measured by RBS and four point probe techniques with VSM, respectively.

JJ3.13
MONTE CARLO SIMULATION STUDY OF THE BULK AND SURFACE MAGNETIZATION IN Sr_2FeMoO_6 : EFFECTS OF MIS-SITE DISORDER, OXYGEN VACANCIES AND SURFACE DEFECTS. Abhijit S. Ogale, S.B. Ogale, R. Ramesh and T. Venkatesan, NSF-MRSEC on Oxides, Surfaces and Probes, and Center for Superconductivity Research, Department of Physics, University of Maryland, College Park, MD.

Monte Carlo simulation studies are performed to compare the bulk and near-surface magnetization in the double perovskite Sr_2FeMoO_6 (SFMO), and to examine the dependence of these on mis-site disorder, oxygen vacancies and surface defects. A lattice configuration consisting of 52 x 52 x 52 lattice sites (with periodic boundary conditions for bulk simulation, and relaxed condition along one direction for surface simulation) has been used. A jiggle and relax scheme is employed to obtain the magnetic ground state. Correlations between the near-neighbor cation distributions and the spin distributions are also examined. It is shown that the decrease in the saturation magnetic moment (M_{sat}) and T_C are nearly linear with the increase in the mis-site defect concentration (x%) for the case of randomly created defects; the rates of decrease being $0.08m_B$/x for M_{sat} and -3 K/x for T_C. The quantitative values agree well with the recent experimental data of Kobayashi et al [Nature, 395, 677 (1998), x=13%)] with an oxygen vacancy concentration of ~12%. Two forms of surface defects, namely the surface steps and preferential cation surface seggragation, are also simulated. The depth scale of influence of such defects on the magnetic properties is examined in the context of its possible implications for realization of spin polarized transport devices based on these half metallic oxides.

JJ3.14
MAGNETOTRANSPORT IN EPITAXIAL TRILAYER JUNCTIONS FABRICATED FROM 90° OFF-AXIS SPUTTERED MANGANITE FILMS. J.S. Noh, T.K. Nath, J.Z. Sun* and C.B. Eom, Department of Mechanical Engineering and Materials Science, Duke University, Durham, NC; * IBM T.J. Watson Research Center, Yorktown Heights, NY.

We have grown $La_{1-x}Sr_xMnO_3$ (x=0.33) /$SrTiO_3$/ $La_{1-x}Sr_xMnO_3$ (x=0.33) trilayer junctions on both (110) $NdGaO_3$ and (001) $(LaAlO_3)_{0.3}$-$(Sr_2AlTaO_6)_{0.7}$ (LSAT) substrates by 90° off-axis sputtering. AFM study revealed surfaces of both bottom electrode and $SrTiO_3$ barrier to be smooth and free of particulates, with RMS surface roughness around 10 C. Current perpendicular spin-dependent transport was investigated both at room temperature and low temperature. We observed distinctive magnetoresistive behaviors reaching ~50% MR for junctions on LSAT substrate with 50 Å barrier at 13K. Resistance-area product of the junction was strongly dependent on the thickness of the barrier and it generally decreases with barrier thickness. Our results indicate that junction uniformity is improved by better interfaces prepared through 90° off-axis sputtering.

SESSION JJ4: TRANSPORT AND OPTICAL PROPERTIES
Chair: Stephan von Molnar
Tuesday Morning, November 30, 1999
Room 202 (H)

8:30 AM *JJ4.1
ELECTRON TUNNELING MEASUREMENTS ON THE CMR PERVOSKITES. F. Sharifi, H.D. Hudspeth, Univ of Florida, Dept of Physics, National High Magnetic Field Laboratory, Florida State Univ, FL; P. Xiong, S. von Molnar, Dept of Physics and MARTECH, Florida State Univ, National High Magnetic Field Laboratory, Florida State Univ., FL.

We present a series of tunneling and transport measurements on $La_{1-x}Ca_xMnO_3$ and $La_{1-x}Sr_xMnO_3$ pervoskite thin films. Tunnel junctions were fabricated using Pb as the counter-electrode, and we fully observe the gap and phonon structures associated with the Pb superconductivity. Our tunneling measurements show a zero bias conductance that follows the transport resistivity from 50 K to 300 K. We see evidence for a pseudo-gap below 50 K. Our data indicates that scattering may play a large role in determining the transport resistivity of the material. We will discuss the implications of this data.

9:00 AM JJ4.2
OPTICAL STUDIES OF MANGANESE DOPED LANTHANUM GALLIUM OXIDE, A CRYSTAL RELEVANT TO COLOSSAL MAGNETORESISTANCE MATERIALS. M.A. Noginov, N. Noginova, G.B. Loutts, Center for Materials Research, Norfolk State University, Norfolk, VA.

We have grown and characterized bulk single crystals of Mn:$LaGaO_3$. In Mn(0.5%):$LaGaO_3$ the 0.48 μm absorption band and 0.715 μm emission band of Mn^{4+} are almost identical to those in Mn:$YAlO_3$ [1,2]. In Mn(2%):$LaGaO_3$ the intense visible and near IR absorption peaking around 0.55 μm has a complex structure and apparently is multicomponent. A related absorption attributed to Mn^{5+} was observed in annealed Mn:$YAlO_3$ grown in reducing atmosphere [3].

The emission band in Mn(2%):$LaGaO_3$ (=1.15 μm) closely resembles that of Mn^{5+} in $YAlO_3$ [4]. The long-wavelength shoulder in Mn(2%): $LaGaO_3$ absorption reduces at increased temperature (200°C). Such a behavior can be expected from charge transfer (CT) bands. However, an electrical conductivity in Mn:$LaGaO_3$ increases with the increase of temperature, demonstrating a controversy with the behavior of the near-IR absorption. In Mn(10%):$LaGO_3$ the absorption is much stronger than that in Mn(2%): $LaGaO_3$ and the shape of the absorption spectrum is different form that in Mn(2%):$LaGaO_3$. A very high absorption intensity ($\gg$2000 cm^{-1}) is an evidence of a CT transition occurring in the crystal. The nature of this CT may be different from that in Mn(2%):$LaGaO_3$. The absorption in 50% Mn doped $LaGaO_3$ is much stronger than that in Mn(10%):$LaGO_3$. The increase of absorption intensity with the increase of Mn concentration in Mn:$LaGaO_3$ is in a good agreement with the increase of electrical conductivity. $LaGaO_3$ crystals have a sharp phase transition that can be observed in optical transmission. The critical temperature equal to =140°C in low Mn doped crystals increases with the increase of Mn concentration. More experimental results and discussion will be presented at the conference.

9:15 AM JJ4.3
TERAHERTZ TIME-DOMAIN OBSERVATION OF SCATTERING-RATE RENORMALIZATION IN $SrRuO_3$. J.S. Dodge, E.O. Lawrence Berkeley National Laboratory, J. Corson, R. Mallozzi and J. Orenstein, University of California at Berkeley, Berkley, CA; J. Reiner and M.R. Beasley, Stanford University, Stanford, CA.

We have used time-domain terahertz spectroscopy to measure the microwave conductivity of the itinerant ferromagnetic oxide $SrRuO_3$. In the frequency range of our measurements, 100-800 GHz, we are in the *elastic* scattering limit, in contrast to previous infrared measurements on this and similar materials. From the frequency dependence of the imaginary part of the conductivity, we are able to obtain a direct measure of the renormalized scattering time, τ^*, as a function of temperature. By comparing this time to the unre-normalized scattering time measured by resistivity, we find a dramatic increase in renormalization effects near the Curie point. The strength and temperature dependence of this effect suggest a magnetic origin, similar to that observed previously in heavy fermion compounds. However, the ruthenates generally possess only one set of roughly degenerate bands which cross the Fermi level, so existing two-band models for heavy fermion behavior are inappropriate.

9:30 AM *JJ4.4
ELECTRONIC STRUCTURE OF THE CMR MANGANITES. H.D. Drew, J. Simpson, V. Smolyaninova, R. Greene, M. Rajeswari, A. Biswas, T. Venkatesan, University of Maryland, Physics Department, College Park, MD; M. Quijada, NASA, Goddard, Greenbelt, MD; A.J. Millis, Rutgers Univ, Department of Physics and Astronomy, Piscataway, NJ.

The optical properties of the pseudocubic manganite perovskites $La_{0.7}Sr_{0.3}MnO_3$, $La_{0.7}Ca_{0.3}MnO_3$3 and $Nd_{0.7}Sr_{0.3}MnO_3$ will be reviewed. These materials exhibit large shifts in optical spectral weight from the infrared to the visible as they go from the low temperature ferromagnetic metal state to the high temperature paramagnetic insulator state. This spectral shift is a signature of large changes of the electronic structure on the scale of several eV's. The metallic state is found to be a conventional Fermi liquid with a relatively large mass enhancement. The electronic mass measured optically and by specific heat are enhanced relative to band calculations $m^*/m_b \approx 2-3$ and are in good agreement with each other. The carrier relaxation rate is of the form $\gamma = \gamma_0 + T^2/W$, with $W = 100\ K$. No evidence is found for charge ordering instabilities in the metallic state. The insulating state is characterized by Jahn-Teller small polarons. The transport is by thermal hopping of small polarons and the optical response by the photoionization of the polarons. Near but below T_C the system appears to support both metallic and polaron pictures which is suggestive of a mixed phase. The optical properties are consistent with theoretical treatments in which both double exchange and the coupling to the lattice are included.

10:30 AM *JJ4.5
GIANT 1/f NOISE IN LOW-T_c CMR MANGANITES: EVIDENCE FOR THE PERCOLATION THRESHOLD. M.E. Gershenson, Serin Physics Laboratory, Rutgers University, Piscataway, NJ.

The ferromagnetic transition in the manganites is often acompanied by the metal-insulator transition. The intriguing property of these materials, the colossal magnetoresistance (CMR), is usually associated with the magnetic-field-induced shift of this transition. The nature of the transition changes drastically when the transition temperature T_c is varied with the chemical pressure. While the transition in the high-T_c materials is of the second order, the low-T_c manganites demonstrate many properties which are intrinsic to the first order transitions, including a strong thermal hysteresis of the resistivity and magnetization. To clarify the nature of the transition in the low-T_c manganites, we have done extensive measurements of the resistivity, magnetization, and 1/f noise in poly- and single-crystal samples of $La_{5/8-x}Pr_xCa_{3/8}MnO_3$. All our data, especially a dramatic peak of the 1/f noise observed at the transition, provide a strong evidence that the transition occurs when the concentration of the metallic ferromagnetic (FM) domains, which appear progressively with decreasing the temperature in the insulating charge-ordered (CO) phase, exceeds the percolation threshold. The scaling analysis of the 1/f noise and the resistivity in the polycrystalline samples is consistent with the percolation model of conducting FM domains randomly placed in the insulating CO matrix. The normalized magnitude of the 1/f noise, observed in the low-T_c manganites at the transition, is one of the largest for the solid-state systems. For high-quality single crystals, a well-pronounced step-like temperature dependence of the the resistivity and 1/f noise has been observed. This suggests that the scale of the phase separation depends on the size of crystallites.
In collaboration with V. Podzorov, M. Uehara, K. H. Kim, T. Y. Koo, and S-W. Cheong

11:00 AM JJ4.6
EVIDENCE OF ANISOTROPIC THERMOELECTRIC PROPERTIES IN DOPED $LaMnO_3$ THIN FILMS. Hanns-Ulrich Habermeier, X.H. Li, P.X. Zhang, Max-Planck-Institut für Festkörperforschung, Stuttgart, GERMANY.

Electrically anisotropic materials deposited epitaxially onto vicinal cut substrates show large thermoelectric signals due the off-diagonal elements in the Seebeck tensor. This has been studied extensively in the caase of HTS materials. Novel experiments performed in doped $LaMnO_3$ thin films show effects in remarkable analogy to those of intrinsically anisotropic YBCO thin films. Systematic measurements of laser induced thermoelectric voltages in LCMO and LSMO thin films deposited on $SrTiO_3$ substrates with vicinal angles ranging from 1° to 10° reveal the existence of a thermoelectric signal compatible with all predictions derived from the Seebeck equation. The results demonstrate the existence of anisotropy in the quasicubic material. The data are analysed in a model describing the origin of this anisotropy as a combination of Jahn-Teller based cooperative lattice distortions and effects due to epitaxial strain.

11:15 AM JJ4.7
INVESTIGATION OF THE TRANSPORT MACHANISM IN DOPED La-BASED MANGANITE THIN FILMS BY TRAVELING WAVE METHOD. Li Wang, Shaoyun Huang, Jiang Yin, Jun Xu, Xinfan Huang, Zhiguo Liu, Kunji Chen, National Laboratory of Solid State Microstructures and Department of Physics, Nanjing University, Nanjing, P.R.CHINA.

Lanthum-based manganites have received wide attention since these materials exhibit a large negative magnetroresistance called colossal magnetroresistance (CMR) effect. These materials also are suitable to act as the semiconductor lay of the ferroelectric field effect transistor (FET). However, the mechanism of CMR and the detailed transport properties of these materials in paramagnetic-insulator state are unknown until now. Recently, Hall measurements have been employed to investigate the transport processes in these materials. But since the anomalous Hall coefficient is not understood, the further information such as the drift mobility and the carrier concentration on the transport can not be got by Hall measurement. In this paper, we adopt the traveling wave (TW) method to investigate the transport mechanism in doped lanthum-based manganite films above the Curie temperature. Since it was introduced by Adler et al., TW method has been utilized to investigate the transport in amorphous semiconductor for several years.
$La_{0.75}Sr_{0.11}Ca_{0.14}MnO_3$ thin films were fabricated by pulse laser deposition (PLD) on fused silica substrate with a thickness of 500 nm at 800°C. Then the films were annealed at 850°C for an hour in oxygen. To meet the need of the TW measurements, co-planar aluminum electrodes were deposited by evaporation. The measurements were carried out in the vacuum.
The conductivity and the drift mobility in the films were measured by TW method at different temperatures. It is for the first time that the thermal activation of the drift mobility in La-based manganite films has been observed. The drift mobility of the films increases from $2.2 \times 10^{-2}\ cm^2/Vs$ at 300 K to about $9.2 \times 10^{-2}\ cm^2/Vs$ at 410 K. And the conductivity also increased with increasing temperature and extends from $1.6 \times 10^{-2}\ cm^2/Vs$ at 300 K to $9.6 \times 10^{-2}\ cm^2/Vs$ at 400 K. The Arrhenius behaviors of the conductivity and drift mobility are consistence with a small polaron model, which indicate that the transport mechanism in manganites above the Curie temperature is dominated by the thermally assisted hopping of small polarons.

11:30 AM JJ4.8
RAMAN STUDIES OF THE TWO LAYERED MANGANITE $Nd_{2-2X}Sr_{1+2X}Mn_2O_7$ (X = 0.25 AND 0.40). N. Malde, L.F. Cohen, Imperial College of Science, Technology and Medicine, Blackett Laboratory, Lon don, UNITED KINGDOM; H.J. Trodhal, O. Pantoja, Victoria University of Wellington, NEW ZEALAND; R.G. Buckley, Industrial Research Limited, NEW ZEALAND; G. Balakrishnam, University of Warwick, Dept of Physics, Coventry, UNITED KINGDOM.

The two layered perovskite system ($Nd_{2-2x}Sr_{1+2x}Mn_2O_7$) is interesting to study using Raman spectroscopy because unlike the cubic perovskite system, the tetragonal (I4/mmm, D_{4h} space group) two-layer system has well defined Raman active peaks. As anomalous lattice changes are known to occur in this system at the magnetic transition, it is interesting to see whether observations of local phonon modes can shed further light on the role of polarons in this system. To understand the relationship between structural and magnetic changes in the two layered system, spectroscopic Raman measurements as a function of hole doping and temperature were performed in (XX) polarisation. For both compositions studied here, x = 0.25 and x = 0.40, striking anomalous behaviour is observed with temperature for the high frequency modes at 530 cm^{-1} and 650 cm^{-1}. These modes are associated with oxygen vibrations. In both cases the anomalous behaviour is coincident with the magnetic ordering transition T_c. Interestingly, the x = 0.25 composition which undergoes a ferro-magnetic metallic (FMM) transition, shows far greater phonon mode frequency shifts at the magnetic ordering transition than the x = 0.4 compound which only undergoes a weak ferromagnetic insulating transition. This suggests that the itinerant carriers present in the x = 0.25 compound influence the structural distortion which is known to take place at Tc_c, indicative of polaronic behaviour in this case.

11:45 AM JJ4.9
rf MAGNETOIMPEDANCE OF $La_xSr_{1-x}MnO_3$ and $La_{2-2x}Sr_{1+2x}Mn_2O_7$. P.V. Patanjali, H. Srikanth, S. Gasser, C. Kusko, Z. Zhai, J. B. Sokoloff and S.Sridhar, Physics Department, Northeastern University, Boston MA; L. Pinsard, G. Dhalenne, R.Suryanarayanan and A.Revcolevschi, Laboratoire de Chimie des Solides, Universite Paris- Sud, Orsay, FRANCE.

The mechanism of CMR is still an unsolved issue. While Zener double exchange is not adequate to explain CMR the effect of Jahn-Teller distortions contributing to various first order transitions besides metal insulator transition is being currently investigated. In this paper we present results of radio frequency dynamic response of single crystals of $La_xSr_{1-x}MnO_3$ and $La_{2-2x}Sr_{1+2x}Mn_2O_7$ as functions of temperature and magnetic field. In $La_{2-2x}Sr_{1+2x}Mn_2O_7$ for x = 0.5 a charge ordering transition is observed at around 200K. The high sensitivity of the rf technique enables us to observe additional transitions above this temperature. In $La_xSr_{1-x}MnO_3$ for x = 0.125 a metal insulator transition at T_c = 180K and two first order transitions at T_s = 270K and T_{co} = 150K are observed. The hump observed at T_{co} is very clear and strong unlike the CO transition observed in resisitivity and magnetization measurements. For x = 0.175 clear signatures of a metal insulator transition at 300K, an orthorhombic to tetragonal transition at 220K and a broad O0xb4 to O0xb40xb4 transition have been observed. Strong dependence of rf reactance on magnetic field suggests magnetoelastic poloron contribution to CO besides coulomb repulsion. Magnetic field dependent study reveals very important features at low fields in the rf susceptibility of $La_xSr_{1-x}MnO_3$ with compositions x = 0.125, 0.175, 0.28, and 0.33, and of $La_{2-2x}Sr_{1+2x}Mn_2O_7$ with x = 0.4. The consistent variation in these features with different doping levels suggests micro-domain formation due to magnetic inhomogenieties (phase separation into ferromagnetic and antiferromagnetic domains) in the samples. Supported by NSF-DMR-9623720 and NSF-INT-9726801.

SESSION JJ5: CHARGE AND ORBITAL ORDERING EFFECTS
Chair: E. Ward Plummer
Tuesday Afternoon, November 30, 1999
Room 202 (H)

1:30 PM *JJ5.1
CHARGE AND ORBITAL ORDERING OBSERVED BY RESONANT X-RAY SCATTERING. Youichi Murakami, Photon Factory, Institute of Materials Structure Science, High Energy Accelerator Research Organization, Tsukuba, JAPAN.

It is widely recognized that the charge, spin and orbital degrees of freedom play important roles in the electric and magnetic properties of magnetoresistive oxides, especially, manganites. Recently, in order to observe the charge and orbital ordering directly we developed synchrotron x-ray diffraction techniques, that is, resonant x-ray scattering. Using the techniques, the development of charge and orbital order parameters is observed as a function of temperature. The stability of these ordered states will be discussed in some perovskite-type manganites; a single layered compound $La_{0.5}Sr_{1.5}$ MnO_4, a bi-layered compound $LaSr_2Mn_2O_7$ and three-dimensional compounds $LaMnO_3$, $La_{0.88}Sr_{0.12}MnO_3$, $Nd_{0.5}Sr_{0.5}MnO_3$, $Pr_{1-x}Ca_xMnO_3$ (x = 0.4, 0.5).

2:00 PM JJ5.2
MAPPING THE VALENCE STATES OF Co AND Mn USING ENERGY- FILTERED TRANSMISSION ELECTRON MICRO-SCOPY. Z.L. Wang, J. Bentley[a] and N.D. Evans[a] School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta GA; [a]Metals and Ceramics Division, Oak Ridge National Laboratory, Oak Ridge TN.

The properties of transition metal oxides are related to the presence of elements with mixed valences. Spatial mapping of valence state distribution of transition metal elements is a challenge to existing microscopy techniques. In electron energy-loss spectroscopy (EELS), the L ionization edges of transition-metal, rare-earth and actinide compounds usually display sharp peaks at the near edge region. These threshold peaks are known as white lines. The unoccupied 3d states form a narrow energy band, the transition of a 2p state electron to the 3d levels leading to the formation of white lines observed experimentally. EELS experiments have shown that a change in valence states of cations introduces significant change in the intensity ratio of the white lines. With the use of valence state information provided by the white lines, an experimental approach is demonstrated here to map the valence state distributions of Mn using the energy-filtered transmission electron microscope (TEM). A spatial resolution of $\sim$2 nm has been achieved. This provides a new technique for quantifying the valence states of cations in magnetic oxides [1]. [1] Z.L. Wang, J. Bentley and N.D. Evans J. Phys. Chem. B, 103 (1999) 751-753 Plus Cover. [2] Research sponsored by US NSF grant DMR-9733160, the Outstanding Oversea Young Scientist Award of China NSF (59825503), and by the Division of Materials Sciences, U.S. Department of Energy, under contract DE-AC05-96OR22464 with Lockheed Martin Energy Research Corp., and through the SHaRE Program under contract DE-AC05-76OR00033 with Oak Ridge Associated Universities.

2:15 PM JJ5.3
NONEXPONENTIAL RELAXATION IN CHARGE-ORDERED $La_{0.5}Ca_{0.5}MnO_3$. V.N. Smolyaninova, C.R. Gally, R.L. Greene, Center for Superconductivity Research, Dept of Physics, University of Maryland, College Park, MD.

An unusual charge-ordering transition[1] with strong sensitivity to external magnetic field has been observed in the manganese oxides, the nature of which is not well understood $La_{0.5}Ca_{0.5}MnO_3$ exhibits a commensurate charge ordering (Mn^{3+} - Mn^{4+}) at $T_{CO} \approx$ 150 K, which is accompanied by antiferromagnetic ordering and a large increase in resistivity. The insulating charge ordered state can be destroyed by an external magnetic field resulting in a ferromagnetic metallic state. In a magnetic field of 8.5 T the low temperature resistivity of $La_{0.5}Ca_{0.5}MnO_3$ decreases ten orders of magnitude and has a metallic temperature dependence. Temperature and magnetic field dependencies of the resistivity are highly hysteretic showing a phase separation (coexistence of ferromagnetic metallic state and antiferromagnetic CO insulating state). Moreover, the metallic state is metastable, i. e. once driven into metallic state, material tends to stay metallic even if the magnetic field is switched off, only slowly relaxing towards insulating state. We studied relaxation behavior of resistivity and magnetization in $La_{0.5}Ca_{0.5}MnO_3$ for different magnetic and thermal condtions. We have observed that resistivity and magnetization have a stretched exponential time dependence. A possible model of this relaxation in $La_{0.5}Ca_{0.5}MnO_3$ will be discussed This work was supported in part by NSF-MRSEC.
1. Y. Tomioka et al., Phys Rev. Lett 74, 5108 (1995), C.H. Chen and S.-W. Cheong, Phys Rev. Lett. 76, 4042 (1996).

2:30 PM *JJ5.4
MAGNETISM AND CMR IN ELECTRON DOPED PEROVSKITE MANGANITES. A. Maignan, C. Martin, M. Hervieu, B. Raveau, Laboratoire Crismat, Caen, FRANCE.

One remarkable feature of the $Ln_{1-x}A_xMnO_3$ manganites is the absence of symmetry of their colossal magnetoresistance properties (CMR) between the hole doped region (x<0.5) and the electron doped counterpart (x>0.5). For instance, the C-type antiferromagnet (AFM) $Sm_{0.15}Ca_{0.85}MnO_3$, which is an electron doped compound, is a CMR oxide although all the hole doped compositions $Sm_{1-x}Ca_xMnO_3$ (x<0.5) do not show any CMR properties. On the opposite, the C-type AFM $Pr_{0.15}Sr_{0.85}MnO_3$ is not a CMR material whereas the $Pr_{1-x}Sr_xMnO_3$ manganites with x<0.55 exhibit CMR properties. These different behaviors are ascribed to the role of the Mn-O-Mn

angle which controls the competition between double-exchange and charge ordering. In this respect, the metastable structural and physical properties of $Ln_{0.15}Ca_{0.85}MnO_3$ manganites are related to the vicinity of the charge ordered insulating compositions ($0.30 \leq x \leq 0.80$) and of the metallic cluster glass phases showing G-type AFM structures ($x \sim 0.90$). The peculiarities of the electron doped manganites will be illustrated by comparing the magnetic phase diagrams of four series with Ln=Pr,Sm and A=Ca,Sr.

3:30 PM *JJ5.5
ORBITAL-STATE-MEDIATED PHASE-CONTROL OF MANGANITES AS DEMONSTRATED BY FIRST-PRINCIPLES CALCULATIONS. Zhong Fang, Kiyoyuki Terakura, Joint Research Center for Atom Technology (JRCAT), Angstrom Technology Partnership (ATP), Tsukuba, Ibaraki, JAPAN.

Orbital degrees of freedom in perovskite manganites, cooperating with the competition between double-exchange and super-exchange, give us an opportunity to control the system ground state phases simply by changing c/a ratio or doping x [1]. This kind of phase control can be properly predicted by our first-principles calculations. I will present a general phase diagram of $La_{1-x}Sr_xMnO_3$ in the plane of c/a and doping x. This phase diagram consists of half-metallic ferromagnetic (FM) state, nearly half-metallic A-type, C-type and G-type antiferromagnetic (AF) states. The orbital polarization in each phase can be seen clearly from the plots of charge distribution near the Fermi level. The phase boundary between A-type and C-type AF states is not parallel to the $c/a = 1.0$ line. This results a general trend of FM→A→C→G state with increasing hole doping. I will also discuss the volume effects, which could be used as another factor to shift the phase boundaries. Finally, the present work gives an example where first-principles calculations based on density function theory can work well even in the difficult field of transition-metal oxides. [1] Y. Konishi, Z. Fang, M. Izumi, T. Manako, M. Kasai, H. Kuwahara, M. Kawasaki, K. Terakura and Y. Tokura, submitted to SCIENCE (1999).

4:00 PM JJ5.6
ELECTRON-PHONON COUPLING IN THE $A_3MN_2O_7$: CAN CHARGE-DENSITY WAVES PLAY A ROLE? Geoffrey F. Strouse, Heloisa N. Bordallo, University of California at Santa Barbara, Santa Barbara, CA.

Physical properties in materials can be modulated by the competition of electron-electron (el-el), electron-phonon (el-ph), and magnetic interactions. The evolution of these interactions in electronic materials is fundamental to describing the properties of a wide class of materials, including mixed-stack charge transfer salts, high-temperature superconductors, conducting polymers, and the halogen-bridged transition-metal (MX) chains. Subtle changes in structure or electronic terms can significantly modulate the electronic and magnetic interactions in these materials. While the importance of dynamic Jahn-Teller mechanisms are important to the understanding of magnetoresistive behavior in the layered CMR material $La_xSr_{1-x}Mn_2O_7$, the importance of el-ph coupling and broken symmetry ground states have largely been ignored. We present a correlation of single crystal neutron diffraction, and zone-center phonon analysis of a series of layered mangnaese oxides suggeting the importance of a competition of electron-phonon interactions in these materials near Tc.

4:15 PM JJ5.7
PRESSURE AND DOING DEPENDENCE OF THE METAL-INSULATOR (MI) TRANSITION IN $La_{1-x}Ca_xMnO_3$ near x=0.16. Kara Beauchamp, E.G. Van-Dyck, Wesleyan Univ., Department of Physics, Middletown, CT.

The structure and transport properties of $La_{1-x}Ca_xMnO_3$ ($0.16 \leq x \leq 0.20$) have been investigated by means of XRD, resistivity and susceptibility measurements to locate the metal-insulator (MI) transition in doping very precisely. This MI transition can be well interpreted in the context of the Mott's theory of electron-induced localization. In addition, we present evidence for the variable range hopping (VRH) in resistivity measurement for all samples and in particular for sample with x=0.16, which does not undergo MI transition. The resistivity exhibits a $T^{-1/2}$ dependence when $T<T_c$ and a $T^{-1/4}$ dependence above T_c. This behavior is discussed as the observation of the crossover from the Efros-Shklovski law to the Mott law in the variable range hopping conductivity. We will report on the effect of pressure on the transport properties near the metal-insulator transition.

4:30 PM JJ5.8
MnO_6 ROTATION AND JOHN-TELLER POLARIZATION IN THE PEROVSKITE MANGANITES. J.Q. Li, Z.X. Zhao, National Laboratory for Superconductivity, Institute of Physics & Center for Condensed Mater Physics, Chinese Academy of Sciences, Beijing, CHINA; Y. Matsui, National Institute for Research in Inorganic Materials, Tsukuba, Ibaraki, JAPAN.

The structural distortions arising from the condensation of two typical kinds of phonon modes: the triply degenerated rotational modes (Θ_x, Θ_y Θ_z) of MnO_6 and the doubly degenerated Jahn-Teller (JT) active modes (Q_1, Q_2), have been systematically investigated in the perovskite manganites. As a result of the strong coupling among the carrier, lattice, and eg -orbitals, the rotation of MnO_6 octahedron evidently impacts behaviors of the low-temperature cooperative JT polarization. In the A-type antiferromagnetic materials, $Pr_{0.5}Sr_{0.5}MnO_3$ and $Nd_{0.45}Sr_{0.55}MnO_3$ a dx2-y2 (Mn^{3+}) orbital (JT degree) order and its resultant structural transition was directly observed. Some essential structural features in the perovskite manganites have been presented diagrammatically.

4:45 PM JJ5.9
ELECTRONIC STRUCTURES IN $La_{1/2}Sr_{1/2}MnO_3$ THIN FILMS GROWN ON MISMATCHED SUBSTRATES AS INVESTIGATED BY OPTICAL SPECTROSCOPY. Yoichi Okimoto, Yoshinori Konishi, Makoto Izumi, Takashi Manako, Joint Research Center for Atom Technology (JRCAT), Tsukuba, JAPAN; Masashi Kawasaki, JRCAT, Tsukuba, JAPAN and Department of Innovative and Engineered Materials, Tokyo Institute of Technology, Yokohama JAPAN; Yoshinori Tokura, JRCAT, Tsukuba, JAPAN and Department of Applied Physics, Univ. of Tokyo, Tokyo, JAPAN.

Studies of thin films of Perovskite-type manganese oxides have been of current interest during past several years. Very recently, Konishi *et al.* showed that a distortion of Mn-O_6 octahedron (c/a) can be artificially controlled by using various kinds of lattice-mismatched substrates in perfect epitaxial thin films, and demonstrated a novel phase-diagram of $La_{1-x}Sr_xMnO_3$ [1]. According to the phase diagram, we can prepare three different types of $La_{1/2}Sr_{1/2}MnO_3$ (x=0.5) thin films with ferromagnetic metallic (FM), C-type antiferromagnetic (AF) insulating, and A-type AF state with x^2-y^2 orbital ordering at the lowest temperature. We investigated variation of electronic structures of those three $La_{1/2}Sr_{1/2}MnO_3$ thin films with different ground states in the light of optical absorption spectroscopy.
With decreasing temperature, a mid-infrared part of absorption coefficient spectra [$\alpha(\omega)$] of a C-type film is suppressed, indicating a charge-gap formation similar to the case of a typical charge ordered compound, $Pr_{0.6}Ca_{0.4}MnO_3$ [2]. $\alpha(\omega)$ of a FM film is largely changed from gap-like to Drude-like incoherent spectrum with decrease in temperature, which is consistent with the case a relaxed FM thin film [3]. A noteworthy phenomenon is temperature dependence of $\alpha(\omega)$ in an A-type film, where a peak structure around 0.2 eV persists down to the lowest temperature 10 K. This signals a pseudo-gap due to eg intraband excitation (x^2-y^2band→$3z^2 - r^2$ band) in the x^2-y^2 orbital ordered state [4].
This work was partly supported by NEDO.
[1] Y. Konishi *et al.*, to be published.
[2] Y. Okimoto *et al.*, PRB 59, 7401 (1999).
[3] M. Quijada *et al.*, PRB 58, 16093 (1998).
[4] F. Mack and P. Horsh, PRL 82, 3160 (1999).

SESSION JJ6: TWO-PHASE COEXISTENCE IN THE MANGANITES
Chair: Andrew J. Millis
Wednesday Morning, December 1, 1999
Room 202 (H)

8:30 AM *JJ6.1
INTERLACING OF PERCOLATION, POLARONIC AND BAND FEATURES IN DOPED MANGANITES. Lev P. Gorkov, Florida State Univ, NHMFL, Tallahassee, FL; Vladimir Z. Kresin, Lawrence Berkeley National Laboratory, Berkeley, CA.

We address mainly the low temperature properties and the nature of the ground state of doped pseudocubic manganites, and their evolution with the concentration increase of divalent atoms. First, we discuss the percolative scenario for the conduction threshold concentration, x=.16-.17. Difference in the effective interaction radii for the percolative onset of conductivity and ferromagnetism is addressed. It is shown that the collossal magnetoresistance phenomenon itself may bear percolative features. The range of concentrations where percolation behavior takes place is limited by the Coulomb forces. Next, the band approach is applied to the discussion of manganites' properties at x=.3-.4. It turns out that while for LaSrMnO the applicability of the band description seems to be limited only by the samples quality, for some others the residual resistance may be an intrinsic proprty related to polaronic formation mechanisms. Short discussion of various self-trapped states is given together with a suggestion that, at least for a few cases, low temperature phase transitions may be regarded as some order-disorder

transitions.An attempt is made to account for unusual features of the A-phase (such as in PrSrMnO at x=.5).

9:00 AM JJ6.2
INVESTIGATION OF THE LOCAL MAGNETIZATION IN SINGLE CRYSTAL $La_{0.8}Sr_{0.2}MnO_3$. Andrew Schwartz, M. Scheffler, C.P. Vlahacos, S. Chatraphorn, F.C. Wellstood and Steven M. Anlage, Maryland/NSF MRSEC, Department of Physics, University of Maryland, College Park, MD.

We have studied the magnetization of single crystal $La_{0.8}Sr_{0.2}MnO_3$ using three novel techniques: broadband microwave surface impedance measurements, near-field scanning microwave microscopy, and scanning SQUID microscopy. Each method yields information about the local magnetization of this manganite perovskite. The broadband technique, which measures the frequency dependent microwave permeability through the frequency (45MHz–45GHz) and field (0–0.19T) dependence of the ferromagnetic resonance, provides a unique opportunity to measure the magnitude of the local spontaneous magnetization in zero applied field, and thereby to study the critical behavior of the magnetization just below the Curie temperature ($T_C \approx 305$K). We find that the magnetization obeys a scaling law with an exponent which is consistent with mean-field theory, suggesting long-range ferromagnetic interactions. While this technique is sensitive only to the average magentization of the sample, the two scanning techniques allow us to examine the magnetization in a spatially resolved manner. Both operate at room temperature, just below the Curie temperature of $La_{0.8}Sr_{0.2}MnO_3$. With the microwave microscope we have measured the ferromagnetic resonance field and linewidth as functions of location on the sample. From this we can extract information about the local magnetization and internal fields within the sample. The SQUID microscope also provides spatially resolved images of the magnetization. These are obtained by measuring the magnetic field above the sample as a function of position, and then converting these data to magnetic charge density and magnetization by Fourier transformation. We find significant variations of the magnetization even in these high-quality single crystal samples, and compare these spatial variations to the line-widths we observe in the broadband permeability measurements, which depend in part on spatial inhomogeneities.
We acknowledge the support of the Maryland/NSF Materials Research Science and Engineering Center on Oxide Thin Films (NSF DMR-9632521) and of the National Science Foundation (ECS-9632811 and DMR-9624021).

9:15 AM JJ6.3
INHOMOGENEOUS MAGNETIC STRUCTURES OF $La_{0.7}Ca_{0.3}MnO_3$ INVESTIGATED BY ESR AND MAGNETIZATION MEASUREMENTS. Keon Woo Joh, Chang Hoon Lee, Cheol Eui Lee, Korea Univ, Dept of Physics, Seoul, KOREA; Yoon Hee Jeong, Pohang Univ of Science and Technology, Pohang, KOREA.

Comprehensive measurements of electron spin resonance and magnetization of $La_{0.7}Ca_{0.3}MnO_3$ in the ferromagnetic as well as paramagnetic phases were carried out. From the quantitative analysis of the ESR signal, attributed to itinerant spins and localized spins in bottleneck regime, evidences for the inhomogeneous nature of both phases, consisting of clusters of one phase embedded in the other, were found. It is suggested that the microscopic local magnetic structures above and below T_c are qualitatively similar except that the phase below T_c carries long range order.

9:30 AM *JJ6.4
OPTICAL STUDIES OF ELECTRONIC PHASE SEPARATION BEHAVIOR IN THE MANGANESE PEROVSKITES. S.L. Cooper, Dept. of Physics and Frederick Seitz Materials Research Laboratory, University of Illinois at Urbana-Champaign, Urbana, IL.

The manganese perovskite system $A_{1-x}B_xMnO_3$ (A = rare earth; B = Ba, Sr, Ca) is characterized by a diversity of remarkable phases and phenomena, including a paramagnetic insulator phase associated with colossal magnetoresistance behavior, a ferromagnetic metal phase, and an antiferromagnetic insulator phase associated with charge ordering behavior. Perhaps most interesting is recent evidence that many phases of this manganese perovskite system defy simple categorization as either metallic or insulating, exhibiting instead various forms of electronic phase separation into coexisting metallic- and insulating-like meso-scale regions. In this talk, I will describe optical studies of electronic phase separation in the colossal magneto- resistance (CMR) and charge-ordering (CO) phases of the manganese perovskite system, and will discuss what these studies tell us about the nature and origin of electronic phase separation behavior, and about the impact of this behavior on CMR and CO phenomena.

10:30 AM *JJ6.5
X-RAY INDUCED TRANSITIONS AND PHASE SEPARATION IN MAGNETORESISTIVE MANGANITES. V. Kiryukhin, Physics Dept, MIT, Cambridge, MA; D. Casa, O.A. Saleh, B. Keimer, Physics Dept, Princeton Univ, Princeton, NJ; J.P. Hill, A. Vigliante, Physics Dept, Brookhaven Natl. Laboratory, Upton, NY; Y.J. Wang, R.J. Birgeneau, Physics Dept, MIT, Cambridge, MA; Y. Tomioka, Y. Tokura, JRCAT, Tsukuba, JAPAN, and Univ of Tokyo, Tokyo, JAPAN.

Charge-ordered (CO) manganites often exhibit persistent changes upon exposure to x-rays. X-ray irradiation results in the changes of the lattice structure, and dramatic changes in transport properties are observed in many cases. X-ray induced change can be annealed by heating above the CO transition temperature, and therefore it is distinctly different from a common radiation damage. Here we consider materials of two different compositions: Pr_{1-x} $(Ca_{1-y}$ $Sr_y)_xMnO_3$, and $La_{0.875}Sr_{0.125}MnO_3$. In the former case, x-ray irradiation induces a dramatic insulator-metal transition, similar to the transition observed in magnetic field. As the material is being irradiated, the transport mechanism changes from tunneling between isolated clusters to ohmic transport along an indefinite cluster. Thus, the x-ray induced transition proceeds through the percolation mechanism. In $La_{0.875}Sr_{0.125}MnO_3$, x-rays destroy the CO state and induce substantial changes in the lattice structure. The CO correlation length is finite at all temperatures. In the both cases, our measurements provide evidence for the inhomogeneity (phase separation) of the low-temperature state in these materials.

11:00 AM JJ6.6
Abstract Withdrawn.

11:15 AM JJ6.7
CHARGE INHOMOGENEITIES IN COLOSSAL MAGNETO-RESISTANT MANGANITES FROM THE LOCAL ATOMIC STRUCTURE. S.J.L. Billinge, V. Petkov, Th. Proffen, Dept. of Physics and Astronomy, Michigan State University; G.H. Kwei and J. Sarrao, Los Alamos National Laboratory; S. Kycia, Cornell High Energy Synchrotron Source, Cornell University.

We have measured the atomic pair distribution function (PDF) of $La_{1-x}Ca_xMnO_3$ using high energy X-ray diffraction. This yields accurate PDFs with very high real-space resolution [1]. It also avoids potential pitfalls from more usual neutron measurements that magnetic scattering is present in the measurements, that the neutron scattering length of manganese is negative leading to partial cancellation of PDF peaks, and that inelasticity effects may distort the resulting PDF. We have used this to address the following questions which do not have a satisfactory answer: (i) What are the amplitudes and natures of the local Jahn-Teller and polaronic distortions in the CMR region? (ii) Is the ground state of the ferromagnetic metallic phase delocalized or polaronic? (iii) As one moves away from the ground state, by rising temperature or decreasing doping, towards the metal transition, how does the state of the material evolve? The X-ray PDFs reveal important information about each of these questions which will be dicussed.
[1] V. Petkov, I-K Jeong, J.S. Chung, M.F. Thorpe, S. Kycia and S.J.L. Billinge, Phys. Rev. Lett., submitted.

11:30 AM JJ6.8
COMPLEMENTARY X-RAY EMISSION AND X-RAY ABSORPTION MESUREMENTS OF $R_{1-x}Ca_xMnO_3$ (R=La, Bi, Pr). Q. Qian, T.A. Tyson, Department of Physics, New Jersey Institute of Technology, Newark, NJ; C.-C. Kao, NSLS, Brookhaven National Laboratory,Upton, NY; M. Croft, Department of Physics and Astronomy, Rutgers University, Piscataway, NJ; S.-W. Cheong, Department of Physics and Astronomy, Rutgers University, Piscataway, NJ and Laboratories, Lucent Technologies, Murray Hill, NJ; M. Greenblatt, Department of Chemistry, Rutgers University, Piscataway, NJ.

Comparison studies of perovskite compounds systems $R_{1-x}Ca_xMnO_3$ (R= La, Bi, Pr) by both Mn K_β emission and x-ray near edge measurements (XANES) are presented. The insensitivity of x-ray emission measurements to structural distortions coupled with the sensitivity of x-ray absorption near edge measurements to changes in both structure and valence enable one to detect the presence of structural distortions. Theoretical XANES computations for ordered and disordered endmembers are used to show the effects of disorder in XANES as well as to comment of the nature of the pre-edge features in the spectra. The Bi containing system is found to have significantly higher levels of distortions than both the Pr and La systems. All compounds are shown to be Mn^{3+}/Mn^{4+} mixtures. Temperature dependent x-ray absorption and emission measurements yield not change in the $La_{0.5}Ca_{0.5}MnO_3$ spectra. However, the emission main line profile of $La_{0.7}Ca_{0.3}MnO_3$ is found to narrow and shifting to low energy at low temperature- suggesting a Mn convalency decrease on going below T_c. This is consistent with the low temper-
ature metallic state of x=0.3 compared with the insulating x=0.5 state.

11:45 AM JJ6.9
MAGNETIC AND LOCAL STRUCTURAL PROPERTIES OF CHARGE ORDERED $Bi_{1-x}Ca_xMnO_3$ (BCMO). Hyungje Woo, Trevor A. Tyson, New Jersey Institute of Technology, Dept. of Physics, Newark, NJ; Mark Croft, Rutgers University, Dept. of Physics, Piscataway, NJ; Sang-Wook Cheong, Rutgers University, Dept. of Physics, Piscataway, NJ, Bell Lab Lucent Tech, Murray Hill, NJ; J. C. Woicik, National Institute of Standards and Technology, Gaithersburg, MD; B.L. Brandt, National High Magnetic Field Laboratory, Tallahassee, FL.

$Bi_{1-x}Ca_xMnO_3$ (BCMO) is known to exhibit charge ordering near x $\sim$ 0.8. However, the properties of BCMO over the entire doping range are not well understood. We have performed x-ray absorption (XAFS), x-ray diffraction, magnetization and resistivity measurements on BCMO to correlate transport and structural properties with the magnetic properties. For the low calcium concentration x $<$ 0.4 of BCMO the first detailed XAFS, resistivity, and magnetization have been made. The BCMO system is charge ordered, insulating and antiferomagnetic for a broad range except near x $\sim$ 0.875 where we find a strong canted spin arrangement with maximum moment on the Mn site. Transport and magnetic properties have been studied in magnetic fields up to 30T. X-ray absorption measurements reveal a significant structural distortion of the Mn-O bond distributions with increasing Bi content which correlates directly with increasing charge ordering temperature. The x-ray diffraction data reveal splittings consistent with lower symmetry cell (distortions) as Bi content increases. This Research is funded by DOE Grant DE-FG02-97ER45665.

SESSION JJ7: STRAIN EFFECTS IN MANGANITE THIN FILMS
Chair: Andrew J. Millis
Wednesday Afternoon, December 1, 1999
Room 202 (H)

1:30 PM *JJ7.1
ANOMALOUS MAGNETORESISTANCE EFFECTS IN STRAINED MANGANITE ULTRATHIN FILMS. Qi Li, Department of Physics, Pennsylvania State University, University Park, PA.

It is known that in the colossal magnetoresistive manganites, spin, charge, and lattice are strongly coupled and the magnetotransport properties are expected to be very sensitive to the lattice distortion. We have studied the magnetoresistance (MR) in strained ultrathin (3 to 20 nm) manganite films epitaxially grown on different substrates in which different types of uniaxial lattice distortion are introduced due to the lattice mismatch between the films and substrates. We have observed many anomalous behaviors in these thin films including (a) large low field magnetoresistance (for example, MR ratio of $\sim$ 400% at about 2 KOe and 40 K) and MR hysteresis in compressively strained $Pr_{0.67}Sr_{0.33}MnO_3$ thin films when a magentic field is applied perpendicular to the film surface. In comparison, only less than 1% of MR and a small positive MR was observed in non-strained and tensile-strained films respectively; (b) strong film thickness dependence of the low-field MR effect; (c) large MR anisotropy both at low magnetic fields and at high magnetic fields. The temperature and magnetic field dependence of these effects will be presented. We have also compared the strained thin films of different manganites, such as $La_{0.67}Sr_{0.33}MnO_3$, $La_{0.67}Ca_{0.33}MnO_3$, and $Pr_{0.67}Sr_{0.33}MnO_3$, and the differences in the low-field MR behaviors and the MR anisotropy at high magnetic fields among the different manganites will be discussed.
*Work done in collaboration with H.S. Wang, Y.F. Hu, E. Wertz, X.W. Wu, M. Rzchowski, K. Liu, C L. Chien, P. Lubitz, and M. Rubinstein.

2:00 PM JJ7.2
STRAIN ANALYSIS IN THIN $La_{1-x}Ca_xMnO_3$ FILMS BY GRAZING INCIDENCE X-RAY SCATTERING. M. Petit, L.J. Martinez-Miranda, University of Maryland, Dept. of Materials and Nuclear Eng. and NSF-MRSEC, College Park, MD; M.Rajeswari, A. Biswas, D.J. Kang, T. Venkatesan, University of Maryland, NSF MRSEC on Oxides, Probes and Surfaces & Center for Superconductivity Research, College Park, MD.

We have performed depth profile analysis of the lattice parameters in epitaxial thin films of $La_{1-x}Ca_xMnO_3$, where x=0.33 or 0.3, to understand the evolution of strain relaxation processes in these materials. This was done using Grazing Incidence X-ray Scattering (GIXS)on films of different thicknesses on two different substrates, (100)oriented $LaAlO_3$ with a lattice-mismatch of $\sim$ 2% and (110) oriented $NdGaO_3$ with a lattice mismatch $<$ 0.1%, were studied to analyze the effect of in-plane compression on the evolution of the film structure. Films grown on $LaAlO_3$ can exhibit up to three in-plane lattice constants corresponding to an orthorhombic distortion of the crystal, as well as near-surface lattice relaxation. The in-plane compressive strain has a range of 0.2 - 1%, depending on the film thickness. Films grown on $NdGaO_3$ are more uniform, and exhibit in-plane strains of less than 0.2%. The correlation of the thickness profile of structure with the film microstructure and properties will be discussed. This work is supported by a NSF-MRSEC Grant No. DMR-9632521. Work at the National Synchrotron Light Source is partially supported by the US Department of Energy.

2:15 PM JJ7.3
SUBSTRATE-INDUCED TRANSPORT AND MAGNETIC TRANSITIONS OF EPITAXIAL $La_{0.66}Sr_{0.33}MnO_3$ FILMS GROWN ON {100} $BaTiO_3$ SUBSTRATES. T.K. Nath, M.K. Lee, C.B. Eom, Department of Mechanical Engineering and Materials Science, Duke University, Durham, NC; M. Smoak, P.A. Ryan, F. Tsui, Department of Physics and Astronomy, University of North Carolina, Chapel Hill, NC.

Effects of substrate structural transformations on the transport and magnetic properties of epitaxial $La_{0.66}Sr_{0.33}MnO_3$ (LSMO) thin films were studied using (001) and (100) $BaTiO_3$ as the templates. The LSMO epitaxial films exhibit dramatic jumps in electrical resistance and magnetization at the structural transition temperatures of the substrates. Application of a high magnetic field (5T) suppresses both the electrical transport and magnetization jumps. The observed low-field transitions correspond sudden changes in magnetic anisotropy, caused by the structural transformation of the substrate. Normal and grazing incidence X-ray diffraction have been carried out to probe the origin of the observed behavior. The understanding of underlying physics involved would be a critical issue to control strain dependent CMR device issues. This work was supported by the NSF Grant No. DMR-9802444, the NSF Young Investigator Award (CBE) and the David and Lucile Packard Fellowship (CBE).

2:30 PM JJ7.4
STRAIN EFFECTS IN $La_{1-x}Sr_xMnO_3$ FILMS STUDIED BY MAGNETIC FORCE MICROSCOPY. Yeong-Ah Soh and G. Aeppli, NEC, Princeton, NJ; N.D. Mathur and M.G. Blamire, University of Cambridge, Materials Science, Cambridge, UNITED KINGDOM.

Variation of T_c due to strain in epitaxial $La_{1-x}Sr_xMnO_3$ films was studied using Magnetic Force Microscopy and compared to classical magnetometry data. The results obtained by the two independent methods agree remarkably well. Depending on the strain on the film, T_c can vary by 20 K for the same film composition. The effect of film microstructure and disorder on the magnetic properties of the film, including magnetic domains and T_c, will be presented.

2:45 PM JJ7.5
EFFECTS OF BI-AXIAL STRAIN IN ULTRA-THIN MANGANITE THIN FILMS. Amlan Biswas, M. Rajeswari, R.C. Srivastava, Y.H. Li, R.L. Greene and T. Venkatesan, NSF-MRSEC on Oxide Thin Films, Surfaces and Probes, and Center for Superconductivity Research, University of Maryland, College Park, MD; A. J. Millis, Rutgers University, Dept. of Physics, Piscataway, NJ; Q. Lu, A.L. de Lozanne, Department of Physics, University of Texas, Austin, TX.

Hole-doped manganites showing colossal magnetoresistance (CMR) are materials whose transport properties are extremely sensitive to Hole-doped manganites showing colossal magnetoresistance (CMR) are materials whose transport properties are extremely sensitive to strain, structure and oxygen content.We present here a study of the growth morphology of ultra thin manganite films and its effect on the electrical and magnetic properties, on being subjected to different amounts of biaxial strain related to substrate lattice mismatch. Thin film growth under biaxial strain has been studied extensively mainly for semiconductor heterostructures. Studies on the kinetics of the growth of these strained, epitaxial films have shown that the minimum energy configuration is a non-uniform strain distribution in the film resulting from a formation of islands i.e. there are regions which are relatively strain-free while some regions have strains which are much higher than that due to the lattice mismatch. These factors can lead to structural transitions in the highly strained regions of the film. We observe that the manganite films grown under bi-axial compressive strain exhibit a similar island -like growth morphology as revealed by Atomic Force Microscopy. Transport and magnetic properties of such ultra thin films suggest evidence for the coexistence of two different states, Transport and magnetic properties of such ultra thin films suggest evidence for the coexistence of two different states, presumably related to the effects of such non-uniform strain distribution and resultant structural changes or even possible compositional variations. The properties are very sensitive to magnetic fields. While the zero field transport is insulating, magnetic fields of several tesla can drive the low temperature state to be metallic. Thermal annealing which causes strain relaxation destroys this mixed phase behavior, resulting in properties close to that of the bulk material.

3:30 PM *JJ7.6
LATTICE DISTORTIONS AND DOMAIN STRUCTURE IN EPITAXIAL MANGANITE THIN FILMS. Yuri Suzuki, Yan Wu, Dept. of Materials Science and Engineering, Cornell University, Ithaca, NY; U. Ruediger, J. Yu, A.D. Kent, Dept. of Physics, NYU, New York, NY.

The magnetism and magnetotransport of colossal magnetoresistance (CMR) materials has been shown to be highly sensitive to lattice distortions both in bulk and in thin films. Magnetic domain structure may also to lead to distinctive magnetotransport effects in thin films. Several groups have shown that properties such as Curie temperature, resistivity and magnetoresistance effect are extremely sensitive to chemical as well as hydrostatic pressure. Others have identified domain wall scattering as an additional source of magnetoresistance. In epitaxial manganite films, the substrate imposes a strain on the film which affects the magnetic anisotropy, magnetic domain formation and anisotropy of magnetoresistance. We have conducted a detailed investigation of the evolution of structure, magnetic anisotropy, magnetic domain configurations and magnetoresistance (MR) of smooth epitaxial $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) thin films. Films grown on (100) and (110) $SrTiO_3$ substrates are tensilely strained while (100) oriented films grown on $LaAlO_3$ substrates are compressively strained and exhibit a strong perpendicular anisotropy. In films grown on $SrTiO_3$, the magnetic anisotropy and the anisotropic magnetoresistance are dominated by tensile strain effects. In thin films on $LaAlO_3$, the magnetic anisotropy is more than sufficient to overcome the film demagnetization factors and results in perpendicularly magnetized domains with fine scale 200 nm domain subdivision, which we image directly at room temperature using magnetic force microscopy. The main MR effects can be understood in terms of bulk colossal MR and anisotropic MR. We also find evidence for a small but measurable domain wall contribution to the MR, which is significantly larger than that expected based purely on a double exchange picture.

4:00 PM JJ7.7
STRAIN-INDUCED MAGNETIC PROPERTIES OF $Pr_{0.67}Sr_{0.33}MnO_3$ THIN FILMS. X.W. Wu, M.S. Rzchowski, Physics Department, University of Wisconsin-Madison, Madison, WI; H.S. Wang, Qi Li, Physics Department, Pennsylvania State University, University Park, PA.

We reported the temperature dependence of the magnetic anisotropy in both compressive and tensile strained films of $Pr_{0.67}Sr_{0.33}MnO_3$ (PSMO). Compressive strain induced by growth on $LaAlO_3$ (LAO) substrates results in a spontaneous out-of-plane magnetization, while tensile strain (grown on $SrTiO_3$) results in in-plane magnetization. The coefficient of linear proportionality between the magnetic anisotropy energy and the tetragonal strain for both compressive and tensile strained PSMO films is larger than that found previously in stained $La_{0.67}Ca_{0.33}MnO_3$ films. From the data, we estimate a 20 unit cell magnetic domain wall width for PSMO/LAO. Scattering from such a narrow domain wall could produce a potentially significant contribution to the resistivity.

4:15 PM JJ7.8
MAGNETIC MEASUREMENTS ON STRESSED AND STRESS-RELIEVED $La_{0.67}Ca_{0.33}MnO_3$ THIN FILMS. H.-U. Habermeier[1], R.B. Praus[1], G.M. Gross[1] and F.S. Razavi[1,2]; [1]Max-Planck-Institut für Festkörperforschung, Stuttgart, GERMANY, [2]Brock University, Department of Physics, St. Catharines, Ontario, CANADA.

The systematic control of epitaxial strain in thin films of doped manganites, due to the lattice mismatch of film and substrate material, can be used as an easy way to tailor the film's magnetic and magetotransport properties. This reveals insight in the interrelation of microscopic order and macroscopic behaviour. In our first experiment $La_{0.67}Ca_{0.33}MnO_3$ thin films with varying thickness (40nm to 475nm) were grown on $SrTiO_3$ (100) substrates using the pulsed laser deposition technique. The thickness dependent epitaxial strain causes a systematic modification of the characteristic parameters of the magnetization curve and the temperature dependence of resistivity. We analyse the magnetic data of as grown films and compare them to results of measurements performed on identical films subjected to a postdeposition annealing process (1h @ 900°C in 10^5 Pa oxygen). For the second experiment $La_{0.67}Ca_{0.33}MnO_3$ thin films were deposited on vicinal cut $SrTiO_3$ (100) substrates. We find a strong anisotropy of the magnetic properties depending on the in plane direction of the field relative to the substrate steps.

4:30 PM JJ7.9
THE EFFECTS OF SUBSTRATE-INDUCED STRAINS ON THE CHARGE-ORDERING TRANSITION IN $Nd_{0.5}Sr_{0.5}MnO_3$ THIN FILMS. W. Prellier, A. Biswas, M. Rajeswari, T. Venkatesan and R. Greene, Center for Superconductivity Research, Department of Physics, University of Maryland, College Park, MD.

Hole-doped manganites, with the general formula $RE_{1-x}A_xMnO_3$ (RE=rare earth and A=alkaline earth) exhibit a rich phase diagram as a function of the doping concentration. For certain values of χ and the average A-site cation radius, the metallic state below T_c becomes unstable and the material goes to an insulating state. This is due to the real space ordering of the Mn^{3+} and Mn^{4+} ions in different sublattices [1]. Such a charge ordering transition is associated with large lattice distortions. This phenomenon has been observed in $Nd_{0.5}Sr_{0.5}MnO_3$ [2]. However, most of the work published up to now has been on single crystals or ceramic samples. Epitaxial thin films have properties similar to those of single crystals and are also important for potential device applications. We report the synthesis and characterization of $Nd_{0.5}Sr_{0.5}MnO_3$ thin films grown by the Pulsed Laser deposition technique on [l00]-oriented $LaAlO_3$ substrates. X-ray diffraction (XRD) studies show that the films are [101]-oriented, with a strained and quasi-relaxed component, the latter increasing with film thickness. We observe that transport properties are strongly dependent on the thickness of the films and significantly different from those observed in single crystals. Variable temperature XRD down to 100 K suggests that this is caused by substrate-induced strain on the films.
This work is supported by NSF-MRSEC at University of Maryland.
[1]. C.N.R. Rao, et al., Chem. Mater. 10, 2714 (1998).
[2]. H. Kuwahara, et al., Science 270, 961 (1995)

4:45 PM JJ7.10
THE STUDY OF MAGNETIC PROPERTIES ON MAGNETO-RESISTIVE OXIDES USING MAGNETO-OPTICAL KERR EFFECT. J.F. Zhang, X.W. Wu, M.S. Rzchowski, Dept. of Physics, University of Wisconsin-Madison, Madison, WI.

Magnetic anisotropy magnetoresistive oxides thin films has attacted much attention because of its potential impact on magnetics devices. The qualitative study of the magnetic anisotropy in $Pr_{0.67}Sr_{0.33}MnO_3$ (PSMO) thin films with 10 nm thickness (t) has been previously reported using the magentic hysteresis loops. The 10nm PSMO / LAO films grown by pulsed laser deposition (PLD) has already shown a significant strain relaxation. For thinner films (t<10nm), the small magnetic signal will challeng the sensitivity of the magnetometry. We have developed a magneto-optic Kerr effect measurement system for studies of ultrathin magnetic-oxide films. We report our initial results of magneto-optic properties for oxides.

SESSION JJ8: POSTER SESSION II
Chair: Masashi Kawasaki
Wednesday Evening, December 1, 1999
8:00 P.M.
Exhibition Hall D (H)

JJ8.1
THERMAL TREATMENT EFFECTS ON $La_{0.5}Ca_{0.5}MnO_3$. P. Levy, F. Parisi, D. Vega, G. Polla, CNEA, CAC, Dept of Physics, Buenos Aires, ARGENTINA.

Doping level, average cation size and cation disorder control physical properties in magnetoresistive perovskite manganese oxides $L_{1-x}A_xMnO_3$ (L is a lanthanide, A is a divalent alkaline earth). Grain boundary properties and grain size determine low field magnetotransport response in polycrystalline samples. We have studied the effect of different thermal treatment processes on polycrystalline $La_{0.5}Ca_{0.5}MnO_3$. We show that grain size, magnetization an resistivity values are highly influenced by these treatments. Possible explanations of these results will be discussed.

JJ8.2
CONDUCTIVITY AND NMR STUDY OF $LaGa_{1-x}\ Mn_xO_3$ SINGLE CRYSTALS. N. Noginova, G.B. Loutts, L. Mattix, Center for Material Research, Norfolk State University, Norfolk, VA.

For better understanding of electron exchange mechanism and magnetic interactions in Colossal Magnetoresistance (CMR) materials, we study the similar structures with decreasing concentration of Mn ions. Conductivity, NMR spectra and nuclear spin-relaxation relaxation times has been studied in Mn doped $LaGaO_3$ single crystals, with different relative concentration of Mn ions, varying from 0% to 50%. It was found, that the temperature dependence of the resistance can be described adequately by the hopping model with a value of the activation energy, E_g, depending on the Mn doping concentration. For materials with 50% concentration of Mn ions, E_g, is close to that in CMR materials. The samples with lower concentration of Mn ions demonstrate substantially higher values of E_g. Nuclear magnetic resonance spectrum of ^{71}Ga in the materials consists of

triplets corresponding to quadrupolar splitting, different for the different crystals. Spin-spin relaxation time, T_2, changes slightly from 0.7 ms for undoped sample to 0. 5 ms in 10% Mn sample. In contrast, the spin-lattice relaxation time T_1 in the same samples strongly depends on the Mn concentration, decreasing from 1.8 s in the undoped sample to 5 ms in the 10% doped sample. A model accounting for electron exchange in Mn^{3+} - Mn^{4+} pairs and electron spin dephasing time is suggested.

JJ8.3
CRITICAL PHENOMENA AT THE ANTIFERROMAGNETIC TRANSITION IN MnO. Brian F. Woodfield, Jennifer L. Shapiro, Rebecca Stevens, Juliana Boerio-Goates, Brigham Young University, Department of Chemistry and Biochemistry, Provo, UT; Michael L. Wilson, University of Tulsa, Department of Physics, Tulsa, OK.

The specific heat of a polycrystalline sample of MnO was measured from T $\approx$ 1 K to T $\approx$ 400 K using two different experimental apparatuses at zero applied pressure. Features revealed by the data include a hyperfine contribution due to the Mn nuclei, a T^2 temperature dependence at low temperatures due to the type-II antiferromagnetic magnon contribution, and a sharp but well defined antiferromagnetic transition (T_N = 117.7095 K) that is clearly second order in nature. The critical exponent, α, deduced from the transition is consistent with a two dimensional Ising model. The specific heat of MnO is also compared with recent results on the type-A antiferromagnet $LaMnO_3$.

JJ8.4
TUNNEL TYPE MAGNETORESISTANCE IN ELECTRON BEAM DEPOSITED FILMS OF COMPOSITIONS $(Co_{0.5}\ Fe_{0.5})_x(Al_2O_3)_{(1-x)}$ ($7 \leq x \leq 72$). H.R. Khan, FEM, Materials Physics Department, Schwaebisch Gmuend, GERMANY and Department of Physics, University of Tennessee, Knoxville, TN; A. Ya Vovk, A.F. Kravets, O.V. Shipil and A.N. Pogoriliy, Institute of Magnetism, Kiev, UKRAINE.

Tunnel type magnetoresistance (TMR) has attracted much attention due to its potential applications as magnetic sensors and memory devices. A series of 400 nm thick films of compositions $(Co_{0.5}\ Fe_{0.5})_x(Al_2O_3)_{(1-x)}$ ($7 \leq \times \leq 72$) were deposited on glass substrates by dual electron beam evaporation techniques. X-ray diffraction study shows that nanoparticles of $Co_{0.5}Fe_{0.5}$ are embedded in the Al_2O_3 matrix. The temperature (25 - 300 K) dependent resistivity ρ decreases with increasing $Co_{0.5}Fe_{0.5}$ concentration and below the critical volume fraction 17.4 vol% of $Co_{0.5}Fe_{0.5}$ ρ follows the exponential relation $\rho = \rho_o$ exp. [2 * $(E/kT)^{0.5}$]. The activation energy E determined from the ρ vs. T curves shows that it decreases with increasing $Co_{0.5}Fe_{0.5}$ concentration in the films e.g. from 4.27 $\times$ 10^{-2}(x = 7) to 1.8 x 10^{-3}(x = 12). The magnetoresistance of the films is GMR type caused by the scattering of spin polarized electrons which tunnel through the Al_2O_3. The film of composition $(Co_{0.5}\ Fe_{0.5})_{16}(Al_2O_3)_{84}$ shows a maximum ρ value of 1.4 $\times$ $10^6 \mu\Omega$cm and a maximum TMR ratio of 7.3% (300 K; 8.2 kOe) The magnetic hysteresis loops of the films show an easy plane anisotropy. The TMR-behaviour of the films in relation to structural, electrical and magnetic properties will be discussed.

JJ8.5
COMPARISON OF DC AND MICROWAVE RESISTIVITY IN POLYCRYSTALLINE $La_{0.7-x}Y_xCa_{0.3}MnO_3$ SAMPLES - INFLUENCE OF Y AT THE GRAIN BOUNDARIES. Karen Yates, C. Watine, T.-N. Tay, Francoise Damay, Blackett Laboratory, Imperial College of Science, Technology and Medicine, London, UNITED KINGDOM; J. MacManus-Driscoll, Materials Department, Imperial College of Science, Technology and Medicine, London, UNITED KINGDOM; L. Ghivelder, Instituto de Física, Universidade Federal do Rio de Janeiro, Rio de Janeiro, BRAZIL; Lesley Cohen, Blackett Laboratory, Imperial College of Science, Technology and Medicine, London, UNITED KINGDOM.

A series of $La_{0.7-x}Y_xCa_{0.3}MnO_3$ samples were studied where x = 0, 0.07, 0.1, 0.15, 0.2 using magnetisation, dc resistivity and a cavity perturbation technique with a dielectric resonator at 9GHz. The comparison of magnetisation and dc resistivity across the series allows us to comment on the influence of Y on the spin ordering in the system and the compound influence this has on the low temperature grain boundary MR. Additionally the activation energies above Tc were determined from the dc and microwave resistivities quantitatively. It is found that whilst the dc activation energy, defined as $\rho = \rho_0 \exp\{Ea/kT\}$ is roughly constant across the series, the activation energy measured at 9GHz increases with increasing x. This indicates that the 9GHz data reflects intragranular properties which are modified by the Y doping above Tc even though the system is in a spin disordered state. Quantitative information on grain and grain boundary behaviour as a function of doping above Tc will also be discussed. Work Supported by the EPSRC, NPL and the Royal Society.

JJ8.6
COLOSSAL MAGNETORESISTANCE IN NEW MANGANITES. Chih-Hung Shen, Ru-Shi Liu, National Taiwan Univ, Dept of Chemistry, Taipei, TAIWAN, R.O.C.; Su-Fen Hu, National Nano Devie Laboratory, Hsinchu, Taiwan, R.O.C.; Jauyn Grace Lin, National Taiwan Univ, Center for Condensed Matter Sciences, Taipei, TAIWAN, R.O.C.; Chao-Yuan Huang, Center for Condensed Matter Sciences and National Taiwan Univ, Dept of Physics, Taipei, TAIWAN, R.O.C.

The effects of structural, electrical and magnetic properties with the isovalent chemical substitution of Ca^{2+} into the Sr^{2+} sites in new series of two-dimensional $La_{1.2}(Sr_{1.8-x}Ca_x)Mn_2O_7$ compounds (x = $0 \sim 0.8$) and three-dimensional $La_{0.6}(Sr_{0.4-x}Ca_x)MnO_3$ compounds (x = $0 \sim 0.4$) are investigated. The highest magnetoresistance (MR) ratios [$\rho(0)/\rho$(H)] of 208 % (H = 1.5 T) at the temperature of 102 K and 115 % (H = 1.5 T) at the temperature of 210 K were observed for the x = 0.4 samples in $La_{1.2}(Sr_{1.8-x}Ca_x)Mn_2O_7$ and $La_{0.6}(Sr_{0.4-x}Ca_x)MnO_3$, respectively. The Curie temperatures decreased from 135 K to 102 K and 300 K to 210 K for x = 0 to 0.4 in $La_{1.2}(Sr_{1.8-x}Ca_x)Mn_2O_7$ and $La_{0.6}(Sr_{0.4-x}Ca_x)MnO_3$, respectively. The antiferromagnetic behavior with Néel temperature around 30 K was found in the x = 0.8 sample in $La_{1.2}(Sr_{1.8-x}Ca_x)Mn_2O_7$. The superstructure of $La_{1.2}(Sr_{1.8-x}Ca_x)Mn_2O_7$ within the compounds has also been found by electron diffraction and high resolution transmission electron microscopic techniques. The composition induced structural variation has been discovered in $La_{0.6}(Sr_{0.4-x}Ca_x)MnO_3$. All the results confirm that the dimensionality and chemical size play the important role in controlling the colossal magnetoresistance in manganites.

JJ8.7
ATOMIC CONTROL OF INTERFACIAL LAYERS AND RELATED GROWTH BEHAVIORS OF $SrTiO_3/LaAlO_3$ FILMS. Dong-Wook Kim, Dae Ho Kim, Ki-Deung Lim, Crystal Choi, and T.W. Noh, Dept of Physics, Seoul National University, Seoul, KOREA; D.R. Lee and K.-B. Lee, Dept of Physics, Pohang University of Science and Technology, Pohang, KOREA.

Roles of chemical stability of interfacial layers in the growth behaviors of oxide heterostructures were investigated. $SrTiO_3$(STO)/$LaAlO_3$ (LAO) films with two kinds of interfacial layers were grown by laser molecular beam epitaxy.[1] In-situ reflection high energy electron diffraction (RHEED) measurements enabled us to characterize and control the top-most atomic layers. After a proper heat treatment, LAO substrates were found out to be dominantly terminated by AlO_2 layers, and hence LaO-terminated LAO substrates were prepared by growth of LaO atomic layers on the annealed LAO substrates. As a result, LAO substrates with two kinds of terminations could be obtained. STO films were grown on top of the LaO-LAO substrates (Film I) and the AlO_2-LAO substrates (Film II). In the case of Film I, clear RHEED intensity oscillation was observed from the first layer, but the oscillation amplitude damped out after growth of 10 monolayers. This showed that a transition from layer-by-layer growth to island growth occurred. In the case of Film II, initial a few RHEED oscillations were missed, which indicated that the first atomic layer in the interface had lots of defects. The strain states of Film I and Film II were revealed by making x-ray reciprocal space mappings around (101) reflections. Film I had fully strained layers only, however Film II had both of strained and partly relaxed layers. These interesting growth behaviors and strain relief could not be explained solely in terms of the stress effects. We suggested that interfacial charge compensation should influence the structural properties of oxide heterostructures significantly. [1] D.-W. Kim, et. al., Appl. Phys. Lett. **74**, 2176 (1999).

JJ8.8
B-SITE DOPED LANTHANUM STRONTIUM MANGANITES BY THE DAAS TECHNIQUE. S. Yang, M.R. Kolody, C.T. Lin, Northern Illinois University, Department of Chemistry, DeKalb, IL; P.M. Adams, and D.M. Speckman, The Aerospace Corporation, Los Angeles, CA.

A series of iron-doped and chromium-doped lanthanum strontium manganite (LSMO) perovskite powders of the general form $La_{0.7}Sr_{0.3}Mn_{1-x}M_xO_3$ (M = Fe, Cr; x = 0 - 0.15), have been successfully synthesized using an aqueous acetate solution deposition method (DAAS). The influence of increasing the B-site dopant content of these LSMO materials on their structural, electrical, and magnetic properties was determined using X-ray diffraction, Auger and EDX spectroscopies, resistivity measurements, and magnetoresistance measurements. LSMO powders without B-site doping were found to crystallize with a monoclinic unit cell structure, which is consistent with a distorted perovskite lattice. Increasing the percentage of the

B-site dopant in the LSMO powders did not appear to reduce the distortion in the crystal lattice structure. The lattice parameters did not show a shift towards a pseudo-cubic phase as the percentage of B-site dopant increased, as is typically seen in LSMO powders as the percentage of A-site dopant increases. For the iron-doped LSMO powders, the lattice parameters a, b, c, and β all increased with increasing iron concentration. As the percentage of iron in the LSMO powders increased, the metal-insulator transition temperature was found to decrease; however this decrease could be offset slightly by increasing the annealing temperature of these materials. Using an iron doping level of x = 0.07 and an anneal temperature of 1300°C, B-site doped LSMO powders with a transition temperature of approximately 310 K were prepared. The magnetoresistive effect for these powders ($\Delta\rho/\rho_0$) was measured to be 40% at an applied field of 5 Tesla. The influence of iron and chromium doping on Mn^{3+}/Mn^{4+} ratios and perovskite local structure will be discussed.

JJ8.9
THE CORRELATION BETWEEN OXYGEN CONTENTS AND MAGNETIC PROPERTIES OF $LaMnO_3$ FILMS. J.H. Song, S.H. Park, C.H. Yang, K.-B. Lee, Y.H. Jeong, Dept. of Physics, Pohang Univ. of Science and Technology, Pohang, S KOREA.

Bulk $LaMnO_3$ is an A-type antiferromagnetic insulator with T_N,~ 140 K. We have deposited $LaMnO_3$ on MgO and $SrTiO_3$ substrates using the pulsed laser deposition method under various oxygen pressure conditions (up to 200 mTorr). High resolution X-ray diffraction analysis revealed that high quality epitaxial films were obtained in the wide range of oxygen pressure values. Despite these similar structural qualities, the magnetic properties varied significantly. The magnetic properties of the films were investigated in detail with the conventional VSM and the x-ray magnetic resonant scattering using synchrotron radiation. The transition temperature reaches as high a temperature as room temperature in samples synthesized under high oxygen pressure. This peculiar behavior probably has to do with cation vacancies arising from the deposition condition of high oxygen pressure.

JJ8.10
ELECTRICAL PROPERTIES OF $SrVO_3/SrTiO_3$ SUPERLATTICES GROWN BY LASER MOLECULAR BEAM EPITAXY. Dae Ho Kim, Dong-Wook Kim, B.S. Kang, Ki-Deung Lim, Crystal Choi, T.W. Noh, Dept of Physics, Seoul National Univ, Seoul, KOREA; D.R. Lee, K.-B. Lee, Dept of Physics, Pohang Univ of Science and Technology, Pohang, KOREA; S.J. Lee, Basic Research Lab, Electronic and Telecommunications Research Institute, Daejeon, KOREA.

There are a couple of important issues in metal/insulator superlattices. First, what kind of electrical properties will the superlattices have when it's metallic sublayers are thinner than the "dead layer", the minimum thickness needed for metallic behaviors in a monolayer film? Second, how strong is the interlayer coupling in determining the electrical properties? We investigated above mentioned issues in $SrVO_3/SrTiO_3$ superlattices, where $SrVO_3$ has a metallic behavior and $SrTiO_3$ is a d^0 insulator. $SrVO_3$ monolayer films and the $SrVO_3/SrTiO_3$ superlattices were grown on atomically flat $SrTiO_3$(001) substrates by laser molecular beam epitaxy. Under a proper growth condition metallic $SrVO_3$ layers and insulating $SrTiO_3$ layers could be obtained simultaneously. The structures of the superlattices were confirmed by *in situ* reflection high-energy electron diffraction and *ex situ* x-ray reflectivity. By varying the thickness of each sublayer, we could observe an interesting metal-insulator transition. The resistivities of superlattices with 2 unit cells of $SrTiO_3$ sublayers exhibited three dimensional behaviors in strong and weak localization regime. The three dimensional rather than two dimensional behaviors suggest that there should be interlayer coupling between $SrVO_3$ sublayers. Some superlattices whose $SrVO_3$ sublayers were thicker than 3 unit cells showed metallic behaviors at room temperature. This means that the minimum metallic thickness of the $SrVO_3$ sublayers in the superlattices could be much smaller than the dead layer of $SrVO_3$ monolayer films estimated to be about 10 unit cells. There are several factors which might be related to this intriguing behavior: strain, interface disorder, and interlayer coupling. In our $SrVO_3/SrTiO_3$ superlattices, the interlayer coupling seems to play the most important role. More detailed explanations on the effects of interlayer coupling and other factors will be presented.

JJ8.11
TWO PEAK EFFECT IN GMR: A CHEMICAL EFFECT? R. Cloots, B. Vertruyen, A. Rulmont, S. Dorbolo, H. Bougrine, Ph. Vanderbemden, M. Ausloos, SUPRAS, Université de Liège, Liège, BELGIUM.

Several $La_{0.7}Ca_{0.31-x}Na_xMnO_3$ have been synthesized under various conditions. The electrical and magnetic properties have been measured. The peaks appearing in the electrical resistance at ca. 260 and 240 K are discussed from the kinetic growth conditions. Their appearance is thought to be due to a hybrid sturcture of the grains with different crystallographic properties in the core and in a surface shell.

JJ8.12
TIME-RESOLVED OPTICAL OBSERVATION OF SPIN-WAVE RENORMALIZATION. J.S. Dodge, A.B. Schumacher, J.-Y. Bigot and D.S. Chemla, Materials Sciences Division, E.O. Lawrence Berkeley National Laboratory; N. Ingle and M.R. Beasley, Department of Applied Physics, Stanford University, Stanford, CA.

We have performed spectral- and time-resolved pump-probe spectroscopy of the exciton-magnon transition in Cr_2O_3. We observe a time-dependent pump-probe lineshape which we attribute to excitation induced renormalization of the spin-wave band structure. At its peak, the strength of this renormalization implies a spin-wave energy density which is consistent with the known laser absorption. In the initial stages after photoexcitation, however, the renormalization induced nonlinearity is less than an order of magnitude smaller than this expected value. The lineshape grows exponentially to its maximum value on a 40 ps timescale before decaying on a time scale of nanoseconds. We present a simple model that reproduces the basic characteristics of the data, in which we postulate the optical nonlinearity to be dominated by interactions among long wavelength spin-waves. The time scale for the signal growth is then associated with the thermalization of the initial, strongly nonequilibrium population of short wavelength spin-waves.

SESSION JJ9: MAGNETIC OXIDE THIN FILMS AND HETEROSTRUCTURES
Chair: M. Rajeswari
Thursday Morning, December 2, 1999
Room 202 (H)

8:30 AM *JJ9.1
MICROSTRUCTURE AND PROPERTIES OF $La_{0.7}Ca_{0.3}MnO_3$ FILMS AND CRYSTALS. J. Aarts, Kamerlingh Onnes Laboratory, University Leiden, THE NETHERLANDS; H.W. Zandbergen, Material Science Department, Delft University of Technology, THE NETHERLANDS.

Given the current discussion on intrinsic electronic inhomogeneities in CMR manganites, the issue of structure and structural homogeneity should be given equal attention. In this respect, the ferromagnetic metal (FM) regime of $La_{1-x}Ca_xMnO_3$ (LCMO) with x ~0.3 is of special interest. Although the FM regime should be least prone to inhomogeneous charge distributions, indications for this have been found in a number of experiments. Moreover, in the case of films, strain as an additional variable may enhance such tendencies or even lead to a different crystal and electronic structure. Here we show that ultrathin (6 nm) films of LCMO sputter-deposited on $SrTiO_3$ (with a 1% larger lattice parameter) are ferromagnetic insulating, although with still large magnetoresistance effects. From High Resolution Electron Microscopy we find that the structure is different from the bulk material, with as important features a distortion of the MnO6 octahedra, probably responsible for the insulating state, and a strong tendency to twinning. Very thin films prepared by laser ablation show similar structure and properties, which makes the finding general. Furthermore, deposition on $LaAlO_3$ (2% smaller lattice parameter) cannot and does not give rise to the same structural changes, as will be discussed. However, structural inhomogeneities may also be present in LCMO (single) crystals. Again by Electron Microscopy, it is shown that even high quality crystals are strongly twinned on length scales of not more than 50 nm. Furthermore, scanning tunneling microscopy and spectroscopy at different fields and temperatures performed on both crystals and films show a percolative-like transition to the metallic state, with (small) regions of more insulating character persisting to far below the transition temperature. The electronic structure therefore appears inhomogeneous, but this may be a consequence of the morphology.

9:00 AM JJ9.2
GROWTH AND PROPERTIES OF Fe DOPED $La_{0.7}Ca_{0.3}MnO_3$ FILMS. T. Fujishima, S.B. Ogale, Y.H. Li, R.C. Srivastava, A. Cavanaugh, R. Ramesh and T. Venkatesan, NSF-MRSEC on Oxides, Surfaces and Probes, and Center for Superconductivity Research, Department of Physics, University of Maryland, College Park, MD; K.M. Gupchup, Department of Physics, University of Pune, Pune, INDIA.

Epitaxial thin films of $La_{0.7}Ca_{0.3}Mn_{1-x}Fe_xO_3$ (x = 0, 0.05, 0.10) are grown on (001) $LaAlO_3$ substrates by pulsed laser deposition. The resistivity(r), the peak resistivity temperature(Tp), the Curie temperature (TC), the Magnetization (M), and the temperature coefficient of resistance (TCR=1/RdR/dT) at the metal-insulator

transition are examined and compared for the undoped and Fe-doped cases. X-ray diffraction is used to obtain the changes in unit cell volume due to doping. Transmission electron microscopy (TEM) and electron diffraction is employed to examine clustering and ordering effects, if any. In the as-deposited state Fe doping depresses the TC and Tp values significantly; from 266K for the undoped film to 227K for x=0.05 film, and 181K for x=0.10 film. The unit cell volume shows a progressive increase with doping, while the magnetization shows a progressive decrease. The TCR shows a dramatic increase from ~11%/K for the undoped film to ~16%/K in the doped films. Electron diffraction for the x=0.10 film shows extra family of spots corresponding to ordering, as well as additional spots possibly due to a small and finely distributed impurity phase, which couldn't be seen by XRD. The pattern for x=0.05 film showed extremely weak ordering spots and no impurity phase. Annealing of the films in oxygen at 850°C for 10 Hrs leads to significant changes in the film properties. These data will be presented and analyzed.

9:15 AM JJ9.3
ATOMIC SCALE CONTROLLED GROWTH OF $SrRuO_3$-$SrTiO_3$-$SrRuO_3$ TRILAYERS USING IN-SITU HIGH PRESSURE RHEED FOR SPIN-POLARIZED PERPENDICULAR TRANSPORT. J.H. Choi, J.S. Noh, C.B. Eom, Duke University, Department of Mechanical Engineering and Materials Science, Durham, NC; A.J.H.M. Rijnders, F.J.G. Roesthuis, D.H.A. Blank, Department of Applied Physics, University of Twente, Enschede, THE NETHERLANDS; J.Z. Sun, IBM T.J. Watson Reserch Center, Yorktown Heights, NY.

Atomic scale control of the interfaces and barrier layers in ferromagnetic oxide (FM-I-FM) trilayer junctions are very important for the fabrication of reliable spin polarized tunnel junctions and the understanding of magnetotransport in ferromagnetic oxides. We have grown $SrRuO_3$-$SrTiO_3$-$SrRuO_3$ trilayers on well-defined TiO_2 terminated (001) $SrTiO_3$ substrates using pulsed laser deposition including in-situ high pressure RHEED. $SrRuO_3$ is a 4-d itinerant ferromagnet with a Curie temperature (T_C) of 160K. It is a distorted perovskite similar to the $LaMnO_3$-based colossal magnetoresistive (CMR) materials with a lattice parameter of 3.93ÅWe have already demonstrated the growth of single crystal epitaxial thin films of $SrRuO_3$ on miscut (001) $SrTiO_3$ substrates. The single domain $SrRuO_3$ thin films have been found to exhibit a strong anisotropic magnetoresistance. We have used the metallic oxide $SrRuO_3$ as the ferromagnetic top and bottom electrodes for such a model system since $SrRuO_3$ is chemically very stable and forms excellent interfaces with other perovskites. Furthermore, the electronic structure of $SrRuO_3$ is interesting in its own way and much can be learned if its spin-dependent tunneling spectrum is obtained. AFM images of the surface of each separate layer in the trilayer structure show well-defined single unit-cell high steps, as perfect as the TiO_2 terminated (001) $SrTiO_3$ substrates. Furthermore, sharp 0th-order Bragg reflections in the RHEED pattern and very low diffuse background intensity confirm the perfect crystalline surface. Our RHEED intensity data show that the $SrRuO_3$ films grow in the step-flow mode. Such controlled structure allows for quantitative studies of spin-polarized transport across the trilayer junction interface, which will also be discussed.

9:30 AM JJ9.4
A-SITE ORDERED, PEROVSKITE-LIKE MANGANITES GROWN BY PLD LASER-MBE: THEIR GROWTH AND STRUCTURAL AND PHYSICAL CHARACTERIZATION. B. Mercey, A.M. Haghiri-Gosnet, Ph. Lecoeur, B. Raveau, Laboratoire CRISMAT-ISMRA, Caen, FRANCE; P.A. Salvador, Carnegie Mellon University, Department of Materials Science and Engineering, Pittsburgh, PA.

As the magnetic and electronic properties of manganites are strongly dependent on the size of the perovskite A-site cations, it is interesting to grow perovskite-like manganites in which an artificial ordering is promoted. Our initial studies were realized with a "classical" setup on the $LaMnO_3 - SrMnO_3$ system. Artificially ordered films were grown from a two-target set-up and the physical properties were shown to be strongly dependent on the stacking sequence. The main difficulty was controlling the number of deposited layers of each composition. To overcome this problem, a RHEED controlled, laser-MBE deposition system was used. Intensity oscillations (corresponding to the deposition of single unit-cell-thick layers) of the specular beam are clearly observed when depositing perovskite-like manganites in an oxygen-ozone mixture ($94\%\ O_2 - 6\%\ O_3$). Thus, the number of deposited layers can be precisely controlled. Furthermore, the growth of each layer can be interrupted either at the top or bottom of an oscillation, leading to controlled single-or mixed-cationic layers, respectively. Using such a controlled growth method, various novel stacking sequences have been grown. Results on the growth and physical characterization will be presented on the $PrMnO_3 - SrMnO_3$ and $LaMnO_3 - SrMnO_3$ systems. As for the bulk compounds, the physical properties of such artificial stacking sequences are strongly dependent on the cation size and on the size ratio between the alkaline earth and lanthanide cation. Moreover, the physical properties of the ordered materials are strongly affected by the sub-layer thickness, and are distinctly different from those of the purposefully-disordered films, the latter of which have bulk-like properties.

9:45 AM JJ9.5
STRUCTURE AND MAGNETISM OF NANOCRYSTALLINE $K_\delta MnO_2$. R.M. Stroud, V.M. Browning, J.W. Long, K.E. Swider and D.R. Rolison, Surface Modification, Materials Physics and Surface Chemistry Branches, Naval Research Laboratory, Washington, DC.

Similarly to the perovskite-type manganites, MnO_2-based materials exhibit a complex interplay of structure, magnetism and transport. A century of research into these materials, as naturally occurring minerals, and for battery applications, has documented the extreme polymorphism of MnO_2 and related oxyhydroxides. The polymorphs are built up from MnO_6 octahedra with different long-range order that depends on the balance of charge between the oxygen anions and mixed valent manganese cations, dopant cations, and incorporated OH^- and H_20. We have used sol-gel synthesis methods to produce nanocrystalline $K_\delta MnO_2$. The synthesis conditions were controlled to vary both the phase and overall morphology. For one set of samples, the gel drying conditions were varied for a fixed precursor solution, yielding a nanocrystalline cryptomelane phase with a "rice-grain morphology. The grains were single crystal rods, approximately 5 nm in diameter x 30 nm long. The surface area of the grains and the distribution of pores between grains changed as function of the drying conditions. High resolution transmission electron microscopy revealed ~ 0.45 nm tunnels along the axis of the rods, which is characteristic of the cryptomelane phase. The temperature-dependent magnetization of these samples showed two transitions, one field-dependent and one field-independent. The field-dependent transition indicates spin glass behavior arising from competing ferromagnetic and antiferromagnetic interactions of the mixed valence Mn. The field-independent transition likely results from intergranular coupling. The dependence of these transitions and the transport on the morphology of the nanocrystalline grains will be discussed.

10:30 AM *JJ9.6
SPIN/ORBITAL MODULATION IN PEROVSKITE MANGANITE SUPERLATTICES. Makoto Izumi and Takashi Manako, Joint Research Center for Atom Technology (JRCAT), Tsukuba, JAPAN; Masashi Kawasaki, JRCAT, Tsukuba, JAPAN; and Dept. of Innovative and Engineered Materials, Tokyo Institute of Technology, Yokohama, JAPAN; Yoshinori Tokura, JRCAT, Tsukuba, JAPAN; and Dept. of Applied Physics, Univ. of Tokyo, Tokyo, JAPAN.

We have grown and characterized the artificially constructed superlattices based on perovskite transition metal oxides. Our interests are focused on the interface properties when two of the strongly correlated materials having different ground states are face each other. Here, $La_{0.6}Sr_{0.4}MnO_3$ as a ferromagnetic metal is combined with antiferromagnetic materials (F), for example, $La_{0.6}Sr_{0.4}FeO_3$ or $La_{0.45}Sr_{0.55}MnO_3$. $La_{0.6}Sr_{0.4}FeO_3$ shows G-type antiferromagnetic ordering in which spins line up as NaCl type structure. In this superlattice grown along (001) direction, spin structure has to be modulated along the growth direction, with the magnetic frustration at the interface. We found the magnetic frustration suppresses the ferromagnetism of $La_{0.6}Sr_{0.4}MnO_3$ layer and magnetoresistance is enhanced significantly because of the recovery of ferromagnetic ordering at the interface otherwise spin canting dominates the property. The results are explained as competition between spin ordered structures, ferromagnetism *vs.* antiferromagnetism in this spin modulated superlattices. When the layered type (A-type) antiferromagnetic $La_{0.45}Sr_{0.55}MnO_3$ is combined, we expected the absence of magnetic frustration at the interface. Indeed, the constituting layers can keep their magnetic properties with orbital ordering in $La_{0.45}Sr_{0.55}MnO_3$ as $d_{x^2-y^2}$ in the superlattices. Therefore, these superlattices are considered to be superlattices modulated in terms of spin and orbital structure. Magnetic field induces spin canting in A layer and enhances the inter-F layer coupling, resulting in low temperature magnetoresistance. This work, supported in part by NEDO, was performed in JRCAT under the joint research agreement between NAIR and ATP.

11:00 AM JJ9.7
LOCAL BONDING AND SHORT RANGE ORDER OF $La_{0.65}Pb_{0.35}MnO_3$ THIN FILMS. Z.C. Zhong, C. Borca, Q.L. Xu, S.H. Liou and P.A. Dowben, Center for Materials Research and Analysis and Dept of Physics and Astronomy, Univ of Nebraska, Lincoln, NE.

CMR materials such as $La_{0.65}Pb_{0.35}MnO_3$ are potential candidates for spin-dependent tunnel junction electronic devices. In this paper, we will present our most recent results in structure and magnetic properties of $La_{0.65}Pb_{0.35}MnO_3$ perovskite. X-ray diffraction shows

that the Pb-films with (100) orientation are very well grown on the (100) $LaAlO_3$ substrate. The structure is confirmed and clarified further by neutron diffraction. The magnetization and magnetic transition are measured by SQUID magnetometer and magnetic circular dichoism (MCD). XPS, UPS and inverse photoemission are used to characterize the electronic structure and surface properties of the Pb-sample. We have found that there is a surface segregation and a novel surface phase transition, which is distinct from that of the bulk. High-resolution transmission electron microscopy gives a direct view of surface structure (image) of this Pb-sample, which is consistent with other measurements.

11:15 AM JJ9.8
AMORPHOUS MANGANITE FILMS GROWN BY MOCVD: STUDY OF CRYSTALLIZATION AND RELATED MAGNETO-TRANSPORT PROPERTIES. C. Dubourdieu, M. Audier, J.P. Sénateur, Laboratoire des Matériaux et du Génie Physique, UMR CNRS, ENSPG, St. Martin d'Hères, FRANCE; J. Pierre, Laboratoire L. Néel, CNRS, Grenoble, FRANCE.

Low processing temperatures are often required for hybrid integration of several materials on a same chip. We have studied the possibility of growing manganite $La_{1-x}Sr_xMnO_3$ films at low temperature (450°C) by metal organic chemical vapor deposition (MOCVD). The films were grown on silicon substrates since it has been shown[1] that at higher substrate temperatures (550°C and above) the films are polycrystalline and can exhibit up to 20% of low-field magneto-resistance (20 K - 0.2 Tesla) on such a substrate. At a substrate temperature of 450°C, the films are amorphous. They exhibit a high resistivity (> 1 Ω ·m) and are useless for applications. Different kinds of in situ annealing (450°C for 1h, 3h, 6h, 10h, 800°C for 15 mn, 900°C for 5 mn) were investigated in order to achieve crystallization. X-ray diffraction and transmission electron microscopy were used to characterize the films (phase, orientation, grain size...). We will discuss the effect of annealing on the crystallization process and on the related magneto-transport properties. At 450°C, crystallization starts after more than one hour of annealing but is still incomplete after 10 hours of annealing. A composition change of the intergranular amorphous phase as the annealing time increases is most probable. At 900°C, the crystallization is completed after 5 mn and the corresponding resistivity (over the whole temperature range 4 K - 300 K) is about 2 orders of magnitude lower than at 450°C. A low-field magneto-resistance of 20 to 25% (22 K-0.2T) is achieved for all types of annealings. 1. C. Dubourdieu, M. Audier, J.P. Sénateur, J. Pierre, submitted to Journal of Applied Physique

11:30 AM JJ9.9
PARALLEL SYNTHESIS OF (RESr)MnO_3 SUPERLATTICES BY COMBINATORIAL LASER MBE. Takashi Koida, Daisuke Komiyama, Mikk Lippmaa, Yuji Matsumoto, Masashi Kawasaki and Hideomi Koinuma, Materials and Structures Laboratory, Tokyo Institute of Technology, Yokohama, JAPAN.

We have developed a novel way to integrate several superlattices on a single substrate by combining laser molecular beam epitaxy, physical masking techniques, and a scanning reflection high-energy electron diffraction(RHEED). With observing RHEED oscillation at the individual pixels, which are defined by a mask, we can arbitrarily accumulate molecular layers of perovskite materials at the each pixel. Here we present superlattices of manganese perovskite oxide ($RE_{1-x}A_xMnO_3$, RE:rare-earth ion, A:alkaline-earth ion) to investigate charge ordering behavior. The alloy materials, which has random and homogeneous distribution of RE and A, show versatile ground states such as ferromagnetic metal, charge ordered insulator and antiferromagnetic insulator having orbital ordering depending on the doping level(x), that is Mn^{3+}/Mn^{4+} ratio. Our question is that if Mn^{3+} and Mn^{4+} are artificially located in superlattices, how the ground state is modified. The superlattices composed alternatively of $RE_{1-x}Sr_xMnO_3$ (0<x<0.5) and $RE_xSr_{1-x}MnO_3$ are fabricated on $SrTiO_3$ substrates. Averaged x in superlattices is fixed at 0.5 and the periodicity is changed from one to several unit cells. The electric and magnetic properties of the superlattices are characterized and compared with those of $RE_{0.5}Sr_{0.5}MnO_3$ alloy films. The end members of the films, $REMnO_3$ and $SrMnO_3$, could be grown with observing RHEED oscillation to result in antiferromagnetic insulators. Superlattices composed of these molecular layers are fabricated to show very smooth surfaces represented by unit cell high steps and atomically flat terraces. These superlattices show insulative behaviors presumably due to charge ordering.

11:45 AM JJ9.10
DISCOVERY OF A HIGH FREEZING TEMPERATURE AND CONTROL OF A SPIN-GLASS STATE IN MG−1.5FETI−0.5O−4 SPINEL FILMS. Yuji Muraoka, Kenji Ueda, Hitoshi Tabata and Tomoji Kawai ISIR-Sanken, Osaka University, Osaka, JAPAN.

Thin films of (111)-oriented $MG_{1.5}FETI_{0.5}O-4$ spinel have been prepared by pulsed laser deposition technique on sapphire (0001) substrates and their magnetic properties have been investigated. The optimum growth condition of the films was found to be the substrate temperature of 500°C and the oxygen pressure of 1.5×10^{-5} Torr, which agrees well with the simple thermodynamic consideration. A single-phase spinel film showed ferrimagnetism with the Neel temperature of 270 K. The magnetic measurement also indicated that the spinel film exhibited a spin-glass behavior: in an applied filed of H=1000 Oe, the cusp of zero-field-cooled curves was observed at 100 K, but no cusp of field-cool curves was observed. This cusp shape became sharper and its temperature increased with decreasing the applied field. The cusp temperature (spin freezing temperature T_f) rose up even to 200 K in H=100 Oe, which is 180 K higher than that of bulk material (T_f =22 K). This is the first example for the material with a spinel structure to exhibit a spin freezing temperature as high as 200 K. We have successfully controlled the spin-glass state of this spinel film by shining the light. The magnetic moment in ZFC operation dramatically increased by Xe lamp irradiation and approached to the moment in FC operation. This indicates that the melt of spin-glass state was accelerated due to both the photo excite and thermal effect accommodated with the irradiation.

SESSION JJ10: MAGNETIC OXIDE HETEROSTRUCTURES AND DEVICES
Chair: Masashi Kawasaki
Thursday Afternoon, December 2, 1999
Room 202 (H)

1:30 PM *JJ10.1
STRUCTURAL AND MAGNETIC STATES IN LAYERED MANGANITES: AN EXPANDING VIEW OF THE PHASE DIAGRAM. J.F. Mitchell, M. Medarde, D.N. Argyriou, S. Rosenkranz, R. Osborn, A. Berger, Materials Science Division, Argonne National Laboratory, Argonne, IL; S. Sinha, O. Seeck, Advanced Photon Source, Argonne National Laboratory, Argonne, IL; L. Vasiliu-Doloc, J. Lynn, National Institute for Standards and Technology, Gaithersburg, MD.

Colossal magnetoresistive (CMR) manganites display a fantastic range of structural, magnetic, and electronic phases as a function of hole concentration, temperature, magnetic field, etc. Although the bulk of research has concentrated on the 3-D perovskite manganites, the ability to study anisotropic magnetic and electronic interactions made available in reduced dimensions has accelerated interest in the layered Ruddlesden-Popper (R-P) phases of the manganite class. The quest for understanding the coupling among lattice, spin, and electronic degrees of freedom (and dimensionality) is driven by the availability of high quality materials. In this talk, we will present recent results on synthesis and magnetic properties of layered manganites in the $La_{2-2x}Sr_{1+2x}Mn_2O_7$ series in three regimes of the phase diagram: (1) the x=0.40 material illustrates how lattice polarons can order on short-range length scales in the paramagnetic phase and "melt" in the metallic regime; (2) compounds in the range $0.32 \leq x \leq 0.40$ demonstrate how T_C is strongly related to the coherent (i.e. as measured by the average structure) and incoherent (i.e., as measured by Debye-Waller factors) components of the structure; and (3) compounds $0.5 \leq x \leq 1.0$ illustrate the importance of strategic synthesis techniques for opening up a new range of compounds that greatly expand the range of magnetic structures heretofore unidentified in the layered manganite phase space.

2:00 PM JJ10.2
PHASE DIAGRAM STUDIES IN THE PSEUDO BINARY SYSTEMS $LaMnO_3$ - $SrMnO_3$ and $LaMnO_3$ - $CaMnO_3$.
Peter J. Majewski, Lars Epple, Fritz Aldinger, Max-Planck-Institut fuer Metallforschung, Stuttgart, GERMANY.

Sr or Ca doped LaMnO3 (LM) is of great technological importance for magnetic information storage systems due to its significant magneto resistive properties. Phase equilibria within the pseudo binary systems LM - SrMnO3 (SM) and LM - CaMnO3 (CM) have been examined with special regard to the extension of the Sr and Ca solubility of LM at different temperatures, respectively. Our results indicate that the Sr and Ca solubility is temperature dependent, respectively. This behavior causes a miscibility gap between LM and SM as well as CM at lower temperatures. The phase transformation of LM from orthorhombic to rombohedral with increasing Sr or Ca content has not been observed at high temperatures indicating that the orthorhombic modification of LM represents the stable high temperature modification. The opening of the miscibility gap between LM and SM as well as CM is assumed to depend on the phase transformation of Sr or Ca doped LM from orthorhombic to rombohedral with decreasing temperatures. Material aspects regarding the processing and magnetic properties of Sr and Ca doped LM due to temperature dependent Sr and Ca solubilities will be discussed.

2:15 PM JJ10.3

ENHANCEMENT OF THE CMR EFFECT NEAR ROOM TEMPERATURE BY DEFECTS AND STRUCTURAL TRANSITIONS IN $La_{1-x}Sr_xMnO_3$. S. Kolesnik, B. Dabrowski, Z. Bukowski, J. Mais, and C.W. Kimball, Department of Physics, Northern Illinois University, DeKalb, IL.

The Curie temperature (TC) of stoichiometric $La_{1-x}Sr_xMnO_3$ increases with increasing the Sr content and is near 300 K for x = 0.185. Simultaneously, $La_{1-x}Sr_xMnO_3$ undergoes several structural phase transformations at different temperatures. The structure of this compound changes from an orthorombic structure (O') to another orthorombic structure (O*) and, subsequently, to a rhombohedral (R) structure. For this work, we selected $La_{1-x}Sr_xMnO_3$ samples within the Sr content range $0.14 < x < 0.19$, for which the Curie temperature coincides with the O'-O* and O*-R transformation temperatures, respectively. Oxygen stoichiometry was controlled by quenching samples from high temperatures in air or high oxygen pressure annealing. Magnetoresistance and magnetization measurements were performed using a Physical Properties Measurement System (Quantum Design) in the magnetic field up to 7 T. On cooling in zero magnetic field, we observe a rapid increase of resistivity just above TC for x 0.1425 and x 0.1725 due to the O*-O' and R-O* structural phase transformations, respectively. This increase is followed by a rapid decrease due to the ferromagnetic transition. The applied magnetic field significantly shifts the ferromagnetic transition to higher temperatures and suppresses the structure related resistivity increase. We show that a combination of structural and ferromagnetic transitions gives rise to an enhancement of the negative magnetoresistance due to strong spin-lattice coupling. By choosing the proper composition, the enhancement can be optimized to appear at relatively low magnetic fields. By changing oxygen stoichiometry for samples with x 0.185, we have tuned TC to appear near 300 K while the CMR effect was further enhanced by increased resistivity due to scattering on defects.
* Work supported by the ARPA/ONR and the State of Illinois under HECA.

2:30 PM *JJ10.4
ARTIFICIAL CONTROL OF MAGNETIC AND MAGNETO-RESISTIVE PROPERTIES IN THE PEROVSKITE MANGANITES SUPERLATTICES AND THEIR MULTILAYERS WITH ORGANICS. Hitoshi Tabata, Kenji Ueda, Yuji Muraoka, Tomoji Kawai, ISIR-Sanken, Osaka Univ., Osaka, JAPAN.

Artificial superlattice of $LaFeO_3$-$LaMnO_3$ have been formed on $SrTiO_3$(111), (110) and (100) substrates with various stacking periodicity using pulsed laser deposition. Their magnetic properties have been controlled by altering the ordering of magnetic ions (Fe or Mn). Charge disproportionate behaviors are also observed in these superlattices. For the superlattices on (111) plane, all the samples showed ferromagnetic (or ferrimagnetic) behaviors and the same Curie temperature of 230K. In the case of other superlattices formed on (110) and (100), oh the other hand, the increase of the spin frustration effect between LFO-LMO interface with decrease of the stacking periodicity causes reduction of Tc and magnetization. Specially, spin glass like behaviors observed in the superlattices of less than 3/3 stacking periodicity Furthermore, we have constructed heterostructures of Organic/Inorganic multilayers with a sequence of Copper phthalocyanine(CuPc), $BaTiO_3$ and (La,Sr)MnO_3. In this system, magnetoresistive properties have been controlled by the photo irradiation through the lattice strain and/or induced charges caused by the piezo effect and electric field effect. That is magnetoresistance in the (La,Sr)MnO_3 layer can be controlled by the shining the light.

3:30 PM JJ10.5
CMR MANGANITE THIN FILMS ON Si FOR UNCOOLED IR IMAGING. D.J. Kang, M. Rajeswari, M. Lewis, C. Sehman, M. Downes, R. Ramesh and T. Venkatesan; NSF MRSEC on Oxide Thin Films, Surfaces, and Probes and Center for Superconductivity Research, Department of Physics, University of Maryland, College Park, MD.

The study of manganese based perovskites $A_{1-x}B_xMnO_3$ (where A is a trivalent rare earth ion such as La, Nd, Pr ... and B is a divalent alkali ion such as Ca, Sr, Ba ...) has recently attracted great interest because of their vast range of unusual electrical, magnetic, and optical properties and their associated potential device applications such as magnetic sensors and infrared detectors. Growth and optimization of these films on technologically viable substrates such as Si and GaAs are an essential step towards integration with semiconductor devices. This task is particularly challenging owing to a very large difference in the thermal expansion coefficient and also chemical incompatibility between Si and oxide films at high growth temperatures. We report on the growth of high quality epitaxial CMR oxide thin films on Si (001) substrates. Our goal is to obtain maximum Temperature Coefficient of Resistance (TCR) properties at close to room temperature, allowing them to be used for room temperature uncooled IR imaging applications. We show that a suitable choice of the buffer and template heterostructure allows one to obtain CMR thin films of high crystalline quality with excellent TCR, electrical transport and ferromagnetic properties. We also report on the beneficial effects of adding silver as a non-substitutional dopant, which includes the growth of high quality films at relatively lower substrate temperatures. The influence of deposition conditions including cooling rate and oxygen in-situ annealing as well as the correlation between the strain state and the properties of the CMR films will be discussed in detail.

3:45 PM JJ10.6
EPITAXIAL $La_{0.7}(Pb_{1-x}Sr_x)_{0.3}MnO_3$ THIN CMR FILM ROOM TEMPERATURE BOLOMETER. S.I. Khartsev, Alvydas Lisauskas and Alex Grishin, Condensed Matter Physics, Royal Institute of Technology, Stockholm, SWEDEN.

We explore the application of epitaxial colossal magnetoresistive films of continuous solid solution $La_{0.7}(Pb_{1-x}Sr_x)_{0.3}MnO_3$ (LPSMO) as a bolometer for uncooled infrared detection. Submicron thick LPSMO films have been grown onto $SrTiO_3$ (001) single crystal by KrF pulsed laser deposition. Changing film composition the paramagnetic-ferromagnetic phase transition temperature T_c has been tailored close to the operation room temperature without significant loosing of Temperature Coefficient of Resistivity (TCR). The series of fabricated $La_{0.7}(Pb_{1-x}Sr_x)_{0.3}MnO_3$ films offers the continuously variable TCR ranged $10.3\%K^{-1}$ to $3.3\%K^{-1}$ within 266K - 327K temperature interval of Tcs. Using the film with TCR = $7.3\%K^{-1}$, T_c = 298 K, low noise voltage of 3.15 $nV/Hz^{1/2}$ without presence of 1/f excess noise at frequencies above 30 Hz and bias current densities up to 70 A/cm^2 we built simple uncooled bolometer demonstrator with voltage response about 1 V/W and Noise Equivalent Power (NEP) of 200 nW at modulation frequency of 2 Hz. From TCR and noise measurements, we estimated LPSMO film bolometer would have the responsivity as high as $2.8*10^4$ V/W and the detectivity as high as $2.8*10^{10}$ cm $Hz^{1/2}/W$ for 25 μA bias current and frame frequency of 30 Hz if integrated with a typical air-gap thermal isolation structure with an effective area of 10-5 cm^2.

4:00 PM JJ10.7
PROSPECTS OF ROOM-TEMPERATURE MICROBOLOMETERS BASED ON CMR THIN FILMS. A.A. Verevkin, Yale University, New Haven, CT; N. Noginova, E.S. Gillman, Norfolk State University, Norfolk, VA.

Due to the strong temperature dependence of the CMR films resistance in the ferromagnetic transition temperature range, it is possible to get much higher photoresponce values for this type of materials in comparison to traditional metals used before. The maximum of responsivity for CMR based films is reached just below the transition temperature at the range corresponding to domination of single-magnon scattering processes. The experimental data on photoresponse of the CMR films to low-intensity laser illumination confirms generaly our speculations. We consider characteristics of potential CMR-based microbolometers at single-magnon scattering range in frames of Wiedemann-Franz law.

4:15 PM JJ10.8
PULSED LASER DEPOSITION AND ELECTRONIC PROPERTIES OF DIELECTRIC/FERROMAGNETIC HETEREOSTRUCTURES. T. Wu, Z. Chen, E. Li, S. Ogale, R. Ramesh, T. Venkatesan, Center for Superconductivity Research, Department of Physics, University of Maryland, College Park, MD.

Ferromagnetic ($La_xSr_{1-x}MnO_3$)/Dielectric ($SrTiO_3$ or $PbZr_{0.2}Ti_{0.8})O_3$) hetereostructures have been constructed using pulsed laser deposition. High quality STO or PZT film with high dielectric constant was firstly deposited on Nb doped STO substrate. Then (001) orientated LSMO film was deposited on the top of it. Both layers were calibrated using x-ray diffraction, RBS, AFM. Epitaxy wa achieved successfully due to the similar crystal structures of perovskite type oxides and small lattice mismatch. Smooth interface was also achieved by optimizing the deposition conditions including the laser energy density, the deposition temperature and the oxygen pressure. A FET-like device with manganite as the channel was fabricated using photolithography and chemical etching. Channel resistance was monitored with different gate voltages. A large modulation more than 30% of channel resistance was realized with electrical field of 0.5 MV/cm at the Dielectric/Ferromagnetic interface. This value is much lager than calculated from the modulation of areal carrier of field-induced charge density. It is shown that channel carrier mobility can be controlled by the external field. A signature of metal-insulator transition is indicated in the device operation. This device offers a potential for applications of magnetoresistive oxides in electronics.

4:30 PM JJ10.9
EPITAXIAL $Pb(Zr_{0.52}Ti_{0.48})O_3/La_{0.7}(Pb,Sr)_{0.3}MnO_3$ FERRO-ELECTRIC/CMR MEMORY OPTIMIZED FOR ROOM

TEMPERATURE OPERATION. Daniel Lundstroem, Jan Yilbar, S.I. Khartsev and Alex Grishin, Condensed Matter Physics, Royal Institute of Technology, Stockholm, SWEDEN; Masanori Okuyama, Dept of Physical Science, Graduate School of Engineering Science, Osaka University, JAPAN.

Recently we have demonstrated *magnetosensitive nonvolatile memory* (MSM) based on epitaxial ferroelectric/colossal magnetoresistive heterostructures made by pulsed laser deposition. [1] Here we report on high performance MSM with the maximum of magnetoresistivity tailored to room temperature. Epitaxial ferroelectric/colossal magnetoresistive $Pb(Zr_{0.52}Ti_{0.48})$ $O_3/La_{0.7}(Pb,Sr)_{0.3}MnO_3$ (PZT/LPSMO) heterostructures have been grown onto $LaAlO_3$ (001) and $SrTiO_3$ (001) single-crystal substrates by KrF pulsed laser deposition. Different *in situ* heat treatments have been used to control oxygen content in manganite bottom electrode. Hysteresis $P-E$ loop for ferroelectric capacitors made from PZT and fully oxygenated LPSMO magnetoresistive layer exhibited large offset which indicates strong built-in electric field. On the contrary, capacitors made on oxygen deficient CMR template layer show symmetrical $P-E$ loops with saturated polarization of 40 $\mu C/cm^2$, remnant polarization of 25 $\mu C/cm^2$, and loss tan $\delta = 0.05$ at 1 kHz. It appears the oxygenation of LPSMO results in increase of the paramagnetic/ferromagnetic phase transition temperature T_c from 280K to 313K (fully oxygenated LPSMO film) accompanied with three time loss in the peak value of resistivity. Optimized LPSMO film has the maximum of temperature coefficient of resistivity TCR = $5.4\%K^{-1}$ at 297K and magneto- resistivity R(0)-R(7 kOe)/R(0) = 27% at 300K. Different top contact materials deposited at room temperature have been examined. As compared with Ag and Ta, Au top contacts show superior performance regarding to combined properties: high remnant and saturated polarization, low loss and no fatigue while top Ta contacts have been found to be more efficient to reduce leakage in ferroelectric. [1] Alex Grishin, S.I. Khartsev, Peter Johnsson, Appl. Phys. Lett. 74, 1015 (1999).

4:45 PM JJ10.10
THE OXYGEN MOBILITY AND CATALYTIC ACTIVITY OF $La_{1-x}Sr_xMO_3$ (M=Cr,Mn,Co) PHASES. Ivan A. Koudriashov, Ludmila V. Borovskikh, Galina N. Mazo, Moscow State Univ, Dept of Chemistry, Moscow, RUSSIA; Sven Scheurell, Erhard Kemnitz, Humboldt Univ, Inst of Inorganic Chemistry, Berlin, GERMANY.

Highly - defective nonstoichiometric perovskite-like complex oxides of 3-d transition elements are promising objects for elaboration of multi-functional materials. The compounds of general formula $La(Sr)MO_3$ (M=Mn, Co, Cr) are interesting due to their unusial physical properties (e.g. CMR-effect for manganites). Moreover, the information on catalytic activity of these materials in oxidation - reduction processes is available. The purpose of this work was the investigation of oxygen mobility in the $La_{1-x}Sr_xMO_3$ phases and its correlations with catalytic activity of these phases in the oxidation catalysis. Single-phase samples of the compositions $La_{1-x}Sr_xMO_3$, (M=Mn, Co, x=0; 0,3) and $LaCrO_3$ were synthesized using freeze-drying and ceramic techniques. The Mn^{4+}/Mn^{3+} and Co^{4+}/Co^{3+} ratio was determined by iodometric titration. The surface of prepared samples were characterized by electron microscopy and low temperature adsorption of nitrogen (BET). The oxygen mobility in these compounds was investigated using a dynamic - thermal isotope exchange technique. The temperature intervals of passing of surface reaction 'oxygen-solid' and out-diffusion of oxygen were determined from the variation of the isotopic composition of the gas phase. The surface reactions oxygen-solid were occured for manganites and cobaltates at lower temperatures than for chromite. The catalitic activity of manganites and cobaltates in the reaction of the CH_4 and CO oxidation was similar to but higher than activity of $LaCrO_3$. The correlations between activity of these compounds in the isotope exchange reaction and oxidation catalysis was revealed. This work was supported by Ministry of Science and Technical Politics of RF, project No 139/97 RUS.