

SYMPOSIUM Q
Flat-Panel Display Materials

April 25 – 27, 2000

Chairs

Paul H. Holloway

Dept of MS&E
Univ of Florida
202 Rhines Hall
Gainesville, FL 32611-6400
352-846-3330

Troy Trottier

Agilent Technologies Inc
MS IL-6
Palo Alto, CA 94304-1100
650-857-5454

James S. Im

Program in Matls Science
Columbia Univ
1106 SW Mudd MC 4711
New York, NY 10027-6623
212-854-8341

Sey-Shing Sun

Planar System, Inc
Beaverton, OR 97006
503-748-7286

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* Invited paper

SESSION Q1/R1: JOINT SESSION:
FIELD EMISSION AND DISPLAY APPLICATIONS

Chair: Dev Palmer
Tuesday Morning, April 25, 2000
Franciscan II/III (Argent)

8:30 AM *Q1.1/R1.1

FIELD EMISSION FROM CARBON SYSTEMS. John Robertson, Engineering Dept, Cambridge University, Cambridge, UNITED KINGDOM.

Nano-crystalline diamond, diamond-like carbon and carbon nanotubes can each show field emission at low applied electric fields. The initial work on diamond was motivated by its negative electron affinity and the expected low barrier for electron emission. However, electron energy distribution measurements show that the emission barrier is of order 4-5 eV, the work function, and the energy distribution width shows the presence of large local fields, of order 1000 V/um. In polycrystalline diamond, scanning tunneling microscopy measurements show that emission arises from grain boundary regions. These results suggest that the only common mechanism which can explain the facile emission from these systems involves field focusing and field enhancement to negative space accumulated at grain boundaries or conductive emission channels, or to the tubes in the case of nanotubes. Other mechanisms do not give sufficient barrier lowering. Consequences of this mechanism are discussed. The mechanism places requires the emission sites to be <10 nm in diameter, so the local emission current density is actually high.

9:00 AM *Q1.2/R1.2

APPLICATIONS OF ION TRACK LITHOGRAPHY IN VACUUM MICROELECTRONICS. R.G. Musket, Materials Science and Technology Division, Lawrence Livermore National Laboratory, Livermore, CA.

When a high-velocity (i.e., typically > 0.1 MeV/amu) ion passes through a material it can change the properties of the material within a cylindrical zone centered on the essentially straight trajectory of the ion. The electronic bonding, phase, and density are among the properties modified in the zone, which is called a latent nuclear, or ion, track. Because the diameters of latent ion tracks are typically less than 20 nm, selective chemical etching is generally employed to improve the detection and assessment of the tracks. Historically, etched nuclear tracks have been used mainly for nuclear particle identification, geochronology, measurement of extremely low-dose radiation levels, and creation of membrane filters. This presentation will provide an introduction to the basic concepts involved in the creation and etching of ion tracks to make masks for lithographic processes. Examples of documented applications in microtechnology and in vacuum microelectronics will be given. In particular, the role of ion track lithography in a novel process for producing cathode arrays with individual emitter structures having gates with < 300 nm diameters will be described. Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract #W-7405-Eng-48.

9:30 AM Q1.3/R1.3

SURFACE MODIFICATION OF Si FIELD EMITTER ARRAYS FOR VACUUM SEALING. M. Nagao, T. Matsukawa, S. Kanemaru, J. Itoh, Electrotechnical Laboratory, Ibaraki, JAPAN; H. Tanabe, Dai Nippon Printing Co., Ltd. Chiba, JAPAN; T. Kobayashi, Musashi Institute of Technology, Tokyo, JAPAN.

Vacuum sealing is one of the most important issues for vacuum microelectronics device. It is well known that emission characteristics are worse in vacuum package than that in ultra high vacuum (UHV) condition. This is due to poor vacuum in package and also due to heating treatment in vacuum packaging process. In the present study, the affect of the heating process on silicon field emitter arrays (FEAs) is investigated, and we tried surface modification to avoid the degradation of emission characteristics in heating process. Emission characteristics of Si FEAs in UHV condition were measured before and after heating process at the temperature of 300 degrees centigrade. Emission current dropped significantly by the heating process. The emission current recovered to the initial level by dipping the Si FEA in 1% hydrofluoric acid for 15 sec. This indicates that the deterioration of the emission characteristics by heating process is due to oxidation of the Si emitter surface. Therefore, it is essential to prevent the emitter surface from oxidation. We tried surface modification of coating the emitter surface with carbon by exposing the emitter to CHF₃ plasma in order to avoid the oxidation. Generally, CHF₃ plasma is used for etching SiO₂ and it is known that Si surface is covered with carbon polymer by exposing CHF₃ plasma. Si FEAs were exposed to CHF₃ plasma for 10 sec to be covered with carbon polymer thin film. Emission characteristics of the carbon coated emitters were measured before and after heating process. As

the result, no deterioration of emission characteristics by heating process was observed.

10:15 AM Q1.4/R1.4

SURFACE TREATMENT ON SILICON FIELD-EMISSION CATHODES. M. Hajra, N.N. Chubun, A.G. Chakhovskoi and C.E. Hunt, Electrical and Computer Engineering Dept. University of California, Davis, CA.

Arrays and single-tip n-type silicon and polysilicon micro-emitters have been formed using a subtractive tip fabrication technique. Following fabrication, several different surface treatments have been attempted for comparison. The objectives of these treatments include stabilization of the emission, lowering the effective workfunction, and reducing low-frequency noise. Treatments we have to consider include anodization of the Si tip, coating of the emitter tip with GaN or other nitrides, coating the tip with native or deposited HfC layer, or over-coating the tip with an amorphous or nanotube carbon layer. The tips were evaluated using I-V measurements in the diode configuration. A flat Si anode, spaced nominally 1um from the cathode, was used. The field emission characteristics are measured in a high vacuum chamber at a pressure of 10-8 Torr. The results suggest that the emitters benefit from seasoning or conditioning, for optimal performance, low noise, minimum work function and maximum reproducibility and reliability over the lifetime of the cathode.

10:30 AM Q1.5/R1.5

FABRICATION AND CHARACTERIZATION OF SINGLY-ADDRESSABLE ARRAYS OF POLYSILICON FIELD-EMISSION CATHODES. N.N. Chubun, A.G. Chakhovskoi and C.E. Hunt, Electrical and Computer Engineering Dept., University of California, Davis, CA.

Polysilicon is a candidate material for field-emission microelectronics devices. It can be competitive for large-size, cost-sensitive applications such as flat-panel displays and micro electro-mechanical systems. Singly-addressable arrays of field-emission cells were fabricated in a matrix configuration using a subtractive process on Polysilicon-On-Insulator substrates. Matrix rows were insulated polysilicon strips with emission tips; and matrix columns were thin-film, gold-gate electrodes. Ion implantation has been used to provide a required conductivity of the polysilicon layer. To reduce curvature radius of a tip, a sharpening oxidation was used. The final device had polysilicon emission tips with end radii smaller than 15 nm, surrounded by gate apertures of 0.4 um in diameter. Field emission properties of the cathodes were measured at a pressure of about 10-8 Torr, to emulate vacuum conditions available in sealed vacuum microelectronics devices. It was found that an emission current of 1 nA appears at a gate voltage of 30 V and can be increased up to 1uA at 70 V. Over this range of current, no semiconductor deviation from the Fowler-Nordheim equation is observed. I-V characteristics measured in cells of a 10x10 matrix, with a cell spacing of 50 um demonstrated good uniformity and reproducibility. Electron-optic properties of a single-cell emitted electron beam were investigated and will be discussed.

10:45 AM Q1.6/R1.6

NITROGEN CONTAINING HYDROGENATED AMORPHOUS CARBON PREPARED BY INTEGRATED DISTRIBUTED ELECTRON CYCLOTRON RESONANCE (IDECR) FOR LARGE AREA FIELD EMISSION DISPLAYS. N.M.J. Conway, C. Godet, Lab. PICM, Ecole Polytechnique, Palaiseau-Cedex, FRANCE.

Amorphous carbon (a-C) based films have shown considerable promise as potential cold cathode materials for flat panel display applications. We report results of the characterisation and field emission properties of nitrogen containing hydrogenated amorphous carbon (a-C:H:N). These were grown at high rates (3-12 Ås⁻¹) using acetylene gas in an integrated distributed electron cyclotron resonance (IDECR) reactor. Unlike the ion beam deposition techniques commonly used to produce a-C(:H) field emitters, the IDECR is easily scalable to the large areas required for many flat panel display applications. Furthermore, the addition of nitrogen, which has been shown to reduce the field required for emission in a-C(:H), can be achieved efficiently as the electron resonance condition results in high ionisation of the nitrogen gas. We have found that nitrogen incorporation increases with increasing flow of nitrogen gas up to atomic percentages of ~30%. Field emission measurements, using a parallel plate configuration, showed that the addition of nitrogen improved the emission properties of the films, resulting in low onset fields of ~8-10 Vµm⁻¹. To further understand this effect, UV-visible ellipsometry was used to study the optical properties. These could be modelled accurately without incorporating a roughness layer into the model, suggesting that all films are smooth in character. A decrease in the refractive index was observed with increasing nitrogen content, which correlates with the measured decrease in density from 1.7gcm⁻³ to 1.3gcm⁻³. The

optical (E_{04}) gap was also found decrease from 1.4eV to 1.0eV, whilst electrical measurements showed an increase in conductivity and a decrease in the activation energy. These results all point towards an increase in the number of sp^2 sites upon addition of nitrogen, which might be expected to lead to a higher electron affinity and poor emission, contrary to the improvement in emission observed. Possible reasons for this will be discussed.

SESSION Q2/R2: JOINT SESSION:
FIELD EMISSION
DISPLAY/CATHODOLUMINESCENCE

Chair: Troy A. Trottier
Tuesday Afternoon, April 25, 2000
Franciscan II/III (Argent)

1:30 PM *Q2.1/R2.1

CARBON NANO TUBE FEDS FOR LARGE AREA AND FULL COLOR APPLICATIONS. J.M. Kim, N.S. Lee, W.B. Choi, D.S. Jung, I.T. Han, J.H. Kang, H.Y. Kim, S.H. Park, S.S. Hong and H.R. Jang, Samsung Advanced Institute of Technology, The National Creative Research Initiatives, Suwon, KOREA.

Single wall nano tubes of about 2 μ m in length are refined and coated with lines of 240 on the 9 inch diagonal glass plate by squeeze and spray method as electron sources. On the other glasses, the R,G,B color phosphors are coated on the 576 lines. With the vacuum gap of 200 μ m, the FED panels are fully sealed and the color images on the 9 inch FED panel are first demonstrated. The electrical and optical properties are fully studied in diode mode and unique version of triode mode. The reliability of carbon nano tube based FEDs are fully with the correlated mechanism analysis with phosphors in the narrow vacuum gap.

2:00 PM Q2.2/R2.2

LOW TEMPERATURE CVD CARBON NANOTUBES ON GLASS PLATES FOR FLAT PANEL DISPLAY APPLICATION. Yonhua Tzeng, Chao Liu, Calvin Cutshaw, Department of Electrical and Computer Engineering, Auburn University, AL; Zheng Chen, Space Power Institute, Auburn University, AL.

The application of carbon nanotubes as the electron emitters for plasma displays requires that the carbon nanotubes be deposited on large-size and inexpensive substrates such as glass plates. Low-temperature chemical vapor deposition processes have been developed for coating of carbon nanotubes on glass plates. Substrates were heated by a heater at a chamber pressure between 10 and 760 Torr. Hydrocarbon mixtures were used as the carbon source for nanotube deposition. Carbon nanotubes deposited on glass plates were examined by a phase-contrast optical microscope, and SEM. An ultra high vacuum chamber was used to characterize the electron emission properties of these carbon nanotube coatings. A one millimeter diameter tungsten rod with a hemispherical tip and a glass plate coated with aluminum were used as the anode and placed at a distance between 50 and 300 micrometers from the nanotube coatings to measure the current-voltage characteristics of the carbon nanotubes. Electron emission from carbon nanotubes deposited on glass plates started from a turn-on electric field of about 4-6 volts per micrometer. Details of the deposition process and electron emission characteristics of the carbon nanotube coatings fabricated by the low-temperature CVD process will be presented.

2:15 PM Q2.3/R2.3

FABRICATION OF NANOCRYSTALLINE DIAMOND ARRAYS FOR FIELD EMISSION DEVICES. A.H. Jayatissa, A.R. Krauss, T. Corrigan, A. Sumant, D.M. Gruen, Materials Science and Chemistry Divisions, Argonne National Laboratory, Argonne, IL; O. Auciello, Materials Science Division Argonne National Laboratory, Argonne, IL; R.P.H. Chang, Materials Science and Engineering Dept, Northwestern University, Evanston, IL.

It has been shown that nanocrystalline diamond (NCD) has attractive properties as an electron field emission material because of its low emission threshold voltage (2-5 V/micron), and chemical and thermodynamic stability, although the electron emission mechanism is not fully understood. In order to use NCD in electron emission displays, it will be necessary to deposit the electron-emissive coating on a conductive layer on a glass substrate. The deposition area must be patterned to provide row and column addressing of individual pixels. We have deposited patterned NCD coatings on Ti and Mo patterned films using stripe and island geometries for both the metallization layer and the NCD coatings. Feature resolution of ~100 nm has been demonstrated for the NCD patterning, and NCD islands ranging in diameter from 2 to 100 microns have been fabricated. The electron emission uniformity has been studied using a phosphor screen tester, photoelectron emission microscopy (PEEM), and field electron

emission microscopy (FEEM), to determine the emission current density and emission site location as a function of NCD feature size and separation.

Work supported by the U.S. Department of Energy, BES-Materials Science under contract W-31-109-ENG-38 and USIC CRADA C9501500, and the Office of Naval Research under contract #N00014-97-F-0905. The submitted manuscript has been created by the University of Chicago as Operator of Argonne National Laboratory (Argonne) under Contract No. W-31-109-ENG-38 with the U.S. Department of Energy. The U.S. Government retains for itself, and others acting on its behalf, a paid-up, nonexclusive, irrevocable worldwide license in said article to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the Government.

2:30 PM Q2.4/R2.4

EPITAXIAL OXIDE THIN-FILM PHOSPHORS FOR LOW VOLTAGE FED APPLICATIONS. Yong Eui Lee, David P. Norton, J.D. Budai, Miyoung Kim and S.J. Pennycook, Solid State Division, Oak Ridge National Laboratory, Oak Ridge, TN; Philip D. Rack and Michael D. Potter, Advanced Vision Technology, Inc., W. Henrietta, NY.

Oxide thin-film phosphors are attractive for low voltage field emission display applications due to their thermal stability and excellent luminescent properties. Nevertheless, improvements in luminescent efficiency and brightness are needed. For cathodoluminescence (CL), the utility of the phosphor depends upon multiple interrelated properties such as spectra response, charge carrier transport and chemical stability. Current research in luminescent thin-film displays is focused on use of polycrystalline phosphors that do not adequately satisfy the required criteria and limit performance of these devices. It has recently been reported that epitaxial thin-film phosphors can exhibit superior PL and CL luminescent intensity as compared to randomly-oriented polycrystalline deposits. We have investigated the epitaxial growth and properties of Li-doped $ZnGa_2O_4$ and Sr_2CeO_4 phosphors on (100) MgO and (100) YSZ single crystal substrates, respectively. Those films exhibit blue CL efficiencies of up to 0.28 lm/W at 1kV, 4.5 micro-A/cm². The photoluminescent properties of epitaxial Li-doped $ZnGa_2O_4$ and Sr_2CeO_4 will also be discussed, including the role of Li in $ZnGa_2O_4$. These results are useful not only for developing high performance phosphors, but also in understanding the fundamental properties of crystalline phosphor films. This research was sponsored by the Office of Science, U.S. Department of Energy under contract No. DE-AC05-96OR22464 with Lockheed Martin Energy Research Corp..

3:15 PM *Q2.5/R2.5

MECHANISMS AFFECTING EMISSION IN RARE-EARTH-ACTIVATED PHOSPHORS. David R. Tallant, Carleton H. Seager and Regina L. Simpson, Sandia National Laboratories, Albuquerque, NM.

The relatively poor efficiency of phosphor materials in cathodoluminescence with low accelerating voltages is a major concern in the design of field emission flat panel displays operated below 5 kV. Our research on rare-earth-activated phosphors indicates that mechanisms involving interactions of excited activators have a significant impact on phosphor efficiency. Persistence measurements in photoluminescence (PL) and cathodoluminescence (CL) show significant deviations from the sequential relaxation model. This model assumes that higher excited manifolds in an activator de-excite primarily by phonon-mediated sequential relaxation to lower energy, emitting manifolds in the same activator ion. In addition to sequential relaxation, there appears to be strong coupling between activators, which results in energy transfer interactions. In terms of phosphor efficiency, some of these interactions appear to be benign, resulting in direct transfer of excitation to emitting manifolds from remote higher manifolds. Because they accelerate the rate of population of emitting manifolds, these effects are observable in the persistence curves of these manifolds. Other interactions negatively impact phosphor efficiency by nonradiatively de-exciting activators. Increasing activator concentration and excitation by CL, as compared to PL, enhances these interactions. The net effect is a significant degradation in phosphor efficiency at low accelerating voltages and useful activator concentrations. I will present phosphor efficiency and persistence data primarily from PL, but with comparisons to CL, which indicate the presence and suggest the nature of these interactions. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000

3:45 PM Q2.6/R2.6

MODELING OF INTERFACIAL SCATTERING EFFECTS DURING LIGHT EMISSION FROM PHOSPHOR THIN FILMS FOR FIELD EMISSION DISPLAYS. Rajiv Singh, Kyu-Gong Cho,

Zhan Chen and Dhananjay Kumar, Department of Materials Science and Engineering, University of Florida, Gainesville, FL.

It has been experimentally shown that the light trapping due to internal reflection effects from a smooth surface is reduced as the surface becomes progressively rougher. Although this phenomenon is qualitatively understood, there has been a lack of detailed analysis of the scattering phenomenon which affects the light emission from thin film phosphors. Factors which affect the brightness of thin film phosphors such as thickness, microstructure, wavelength, and dimensions of the surface roughness, type of substrate used (and thus the interface formed), in many cases, cannot be independently varied, thus making it difficult to quantitatively interpret the solutions. Furthermore, as the wavelength of the surface roughness is smaller or has the same dimensions of the wavelength of the emitted radiation, classical theories based on rectilinear propagation of the light cannot be used without gross simplifications. Some simplified models have been suggested to predict the brightness of the thin film phosphors as a function the effect of bulk and surface structure, however they do not take into account complex surface scattering-based effects. To overcome the deficiencies of the earlier work, we have developed a new model which incorporates diffraction related surface scattering effects. The results have been obtained experimentally from deposition of $Y_2O_3:Eu$ thin film phosphors with different thickness (and surface roughness) values on various substrates. Indeed, the model supplies an integrated solution for predicting the cathodoluminescent properties of thin film phosphors considering the most primary parameters affecting brightness of the thin film phosphors.

4:00 PM Q2.7/R2.7

CATHODOLUMINESCENCE DECAY MEASUREMENTS OF EMISSION FROM Eu AND Tb RARE-EARTH IONS AT LOW ELECTRON BEAM ENERGIES. C.H. Seager and D.R. Tallant, Sandia National Laboratories, Albuquerque, NM.

Most conventional phosphors used in cathode ray tubes have efficiencies which decrease almost linearly as function of beam energy for E less than 5 keV. It is commonly thought that this is due to the non-radiative recombination of beam-created electrons and holes in a near-surface dead layer or at the free phosphor surface itself. In this work we have measured the cathodoluminescence (CL) decay of excited Eu and Tb rare earth ions in commercial and experimental powders of Y_2O_3 and Y_2SiO_5 over a range of beam energies from 0.8 to 4 keV. CL measurements were directly compared to photoluminescence (PL) persistence data obtained from the same emitting states. We find that, in general, the initial CL decay process is faster than that seen in PL, and that the decay rate depends significantly on beam energy. These effects are most noticeable for the higher excited states of these ions and for activator concentrations > 2 at%. Accompanying measurements over the same beam energy and activator concentration range show that the beam energy dependence of the CL efficiency is noticeably stronger at higher activator concentrations. Several explanations for these data are examined, and we introduce a model which assumes that: 1. Low energy electrons, because of their large stopping power, have a high probability of producing densely spaced excited activators, particularly at high activator concentrations, and 2. Activator-activator (non-radiative) quenching is enhanced when nearby rare-earths are both excited. This model attributes much of the decay rate dependences on E , and at least some of the beam energy dependence of CL efficiency on interaction effects, rather than energy losses which occur before activators are excited. *Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-ACO4-94AL85000.

4:15 PM Q2.8/R2.8

EFFECTS OF VACUUM PARTIAL PRESSURES ON ELECTRON STIMULATED SURFACE CHEMICAL REACTIONS ON COATED AND UNCOATED CATHODOLUMINESCENT PHOSPHORS. Paul H. Holloway, Wiets Roos, Billie Abrams and Joe Thomes, University of Florida, Gainesville, FL.

Electron beam stimulated surface chemical reactions (ESSCRs) have been shown to lead to degradation of cathodoluminescent (CL) phosphors. We have studied in detail the effects of various gaseous partial pressures on the processes leading to degradation. We have demonstrated that either high partial pressures of H_2 or H_2O will cause degradation of ZnS P22 phosphors, but the ESSCR is very different. Degradation is much more severe and occurs at lower coulombic loadings when partial pressures of $\sim 10^{-8}$ Torr of H_2O are present. This partial pressure was controlled over a wide range by back filling the vacuum chamber from a stainless steel vessel containing H_2O isolated from the vacuum by a leak valve. Hydrogen partial pressures of $\sim 10^{-7}$ Torr were sufficient to result in degradation by an ESSCR in which H_2S was speculated to be formed. It was shown that the presence of SiO_2 coatings could accelerate this process, and a mechanism involving the formation of hydroxyl radicals will be

discussed. The implications of ESSCRs for FEDs will be discussed. This work supported by DARPA through the Phosphor Technology Center of Excellence.

4:30 PM Q2.9/R2.9

NANOFUNCTIONALIZED SULFIDE BASED POWDERS FOR FLAT PANEL DISPLAY APPLICATIONS. Michael Ollinger, Valentin Craciun, Rajiv K. Singh, Dept of Materials Science and Engineering, University of Florida, Gainesville, FL.

Sulfide based phosphor materials have been routinely utilized in cathode ray tube displays (CRT), electroluminescent (EL) displays, and have been explored for field emission display (FED) applications due to their high luminescent efficiencies in comparison to oxide based phosphors. However, the sulfide-based phosphors are prone to degradation of the cathodoluminescent properties caused by the interaction of the e-beam with the adsorbed residual gases on the particle surface of the phosphors. To overcome this critical issue we have synthesized nanofunctionalized phosphor powders, which are formed by coating a very thin film onto the surfaces of the phosphor powders using a novel atomic flux coating technique. This technique uses a 248 nm wavelength excimer laser, with a pulse duration of 25 ns operated from 5-15 Hz at energies between 2-5 J/cm², which strikes a solid target under a high vacuum (10^{-5} Torr) and creates a plume of atomic species. These species or nanoclusters are then deposited onto the host particles that are being mechanically agitated during deposition for coating uniformity. The coating material should be a low Z material, electrically conducting, transparent, and chemically stable. Characterization of the brightness and degradation was performed using cathodoluminescence (CL), the stoichiometry and chemical composition of the particle surface was studied using x-ray photoelectron spectroscopy (XPS), and the presence of the coating was seen using Auger Electron Microscopy (AES). The effect of different coatings on the brightness and degradation characteristics of $Y_2O_2S:Eu$ has been investigated and a degradation mechanism has been proposed.

4:45 PM Q2.10/R2.10

THE EFFECT OF MICROSTRUCTURE ON THE BRIGHTNESS OF PULSED LASER DEPOSITED $Y_2O_3:Eu$ THIN FILM PHOSPHORS. Kyu-Gong Cho, Dhananjay Kumar, Zhan Chen, Rajiv Singh, Department of Materials Science and Engineering, University of Florida, Gainesville, FL; Gary Russel and Brent K. Wagner, PTCOE, Georgia Institute of Technology, Atlanta, GA.

In order to investigate the effect of microstructure on the brightness of thin film phosphors, $Y_2O_3:Eu$ thin film phosphors were prepared using pulsed laser deposition. To experimentally deconvolute the effects, the $Y_2O_3:Eu$ films of controlled thickness and microstructure were prepared on the various substrate materials such as amorphous quartz, (0001) sapphire, (100) lanthanum aluminate ($LaAlO_3$), and (100) silicon wafers. Cathodoluminescent brightness and efficiency of the films were obtained in both transmission and reflection mode. The $Y_2O_3:Eu$ films deposited on the quartz substrates showed the maximum brightness followed by the films on (0001) sapphire, (100) lanthanum aluminate ($LaAlO_3$), and (100) silicon substrates. The role of interface scattering of the emitted light on the film brightness will be discussed together with changing surface roughness and film thickness.

SESSION Q3/S4: JOINT SESSION: ORGANIC LIGHT EMITTER DEVICES

Chair: Paul H. Holloway
Wednesday Morning, April 26, 2000
Metropolitan II (Argent)

8:30 AM *Q3.1/S4.1

FUNDAMENTAL AND PRACTICAL ISSUES IN LARGE-AREA POLYMER PATTERNING FOR POLYMER LED DISPLAYS. J.C. Sturm, F. Pschenitzka, T.R. Hebner, M.H. Lu, B. Diamond and S. Troian.

To achieve a polymer OLED display capable of high efficiency and full color, some patterning of the organic materials is generally required. This talk will discuss both fundamental and practical issues, and how they may be resolved, four different approaches for achieving such patterning over large area: ink jet printing of red, green, and blue-emitting polymers, ink-jet printing of dyes into polymer films, masked thermal diffusion of dyes into polymers, and the patterned dry etching of organic films. The ink-jet printing approaches have the advantage of conceptual simplicity, but their practice is complicated by the fact that one is printing onto an essentially non-absorbing surface (in contrast to paper, e.g.). Thus in both ink-jet printing approaches one must face very fundamental issues associated with the mass transport dynamics within liquid drops during drying due to

edge pinning, Marangoni-driven flows, and other related effects. Dry etching has perhaps the highest potential resolution, but one must address issues of pattern formation on top of the organic film for masking and lateral propagation of etching species under masked regions, as well as the sensitivity of devices to ambients once metal contacts have been formed. Patterned thermal diffusion of dyes in practice turns out to be very straightforward and simple in practice, but high quality results are dependent on soft masking technology which still has good dimensional control.

9:00 AM Q3.2/S4.2

ORGANIC LIGHT EMITTING DIODES BASED ON CARBON NANOTUBES DISPERSED IN A CONJUGATED CO-POLYMER MATRIX. R. Czerw, H.S. Woo, S. Webster, A. Date, D.L. Carroll, Clemson Univ, Dept of Physics and Astronomy, Clemson, SC; B. McCarthy, W. Blau, Polymer Research Ctr, Dept of Physics, Trinity College, Dublin, IRELAND.

We present the characteristics of organic light emitting diodes (OLEDs) based on a polymer composite of single wall carbon nanotubes (SWNT) dispersed in a copolymer matrix, poly (m-phenylene vinylene-co-2,5-dioctoxy-p-phenylene) (PmPV). Polyethylene dioxythiophene (PEDOT) was used as a buffer between the anode and the polymer composite. We observed that the turn-on voltage of a device fabricated using this polymer composite with a concentration of 0.1 weight % of SWNT's was significantly lowered with enhanced electroluminescence (EL) as compared to the pure PmPV device, suggesting that the carbon nanotubes act as a minor charge carrier. Our device shows light emission in the range of green with a peak wavelength near 510 nm. However, photoluminescence (PL) of the polymer composite decreased as we increased the SWNT concentration due to increased photon scattering with the SWNT. The device characteristics including the current-voltage relation and efficiency, as well as the PL and EL, will be discussed as a function of the SWNT concentration in the polymer composite.

9:15 AM Q3.3/S4.3

ELECTRON INJECTION IN HOLE DOMINATED POLYMER LIGHT EMITTING DIODES. Luisa D. Bozano, Sue A. Carter, University of California, Santa Cruz, Dept of Physics, Santa Cruz, CA; Phillip J. Brock, Campbell J. Scott, IBM Almaden Research Center, San Jose, CA.

We use MEH-PPV single-layered device sandwiched between polyaniline and aluminum electrodes to obtain Ohmic injection of holes with minimal electron current. The current and light emission are measured as a function of temperature in a range between 200K and 300K. The low electron injection allows treatment of the sample as a hole-only device and hence determination of the relationship between the measured current and applied bias potential in terms of space-charge limited behavior. Because of the Ohmic-hole-injecting contact, the electric field vanishes at the anode while it reaches its maximum value at the cathode. Similarly, the hole density is large near the anode, and therefore, the small number of electrons injected recombine completely. With these approximations, the radiance is proportional to the electron current. We analyze the experimental data to derive the electric field at the cathode for a Poole-Frenkel-like mobility at the different temperatures. The measured radiance then gives the electric field and temperature dependences of the cathode injection current.

10:00 AM *Q3.4/S4.4

ORGANIC LIGHT-EMITTING DIODES USING TRIPHENYL-AMINE BASED HOLE TRANSPORTING MATERIALS. Hisayoshi Fujikawa, Masahiko Ishii, Shizuo Tokito, and Yasunori Taga, TOYOTA Central Research & Development Labs., Inc., Nagakute, Aichi, JAPAN.

Light-emitting diodes (LEDs) based on organic materials are attracting much attention as candidates for flat-panel displays and backlights for liquid crystal displays. Recently, a practical multi-color display has been commercialized in small molecular organic materials. However, further research and development are required to improve the lifetime and the color tunability, especially materials developments are significantly important. In this paper, we briefly review the developments of hole transporting materials and the EL properties of the organic LEDs operated at a high temperature^[1,2]. The durability of the tris(8-quinolinolato) aluminum based device is related to the thermal stability of the hole transport layer. Several triphenylamine oligomers were synthesized and used for the hole transport layer. The thermal stability was clearly seen to depend on a glass transition temperature (T_g) of the hole transporting material, and a linear relationship between the T_g and the thermal stability was found. A lowering of "turn-on voltage" for light emission and an increase of luminous efficiency with increasing temperature were also observed. Excellent durability of the organic LED with a tetramer of triphenylamine was achieved at a high temperature of 105°C. Our results indicate that the linear linkage of triphenylamine leads to a

high T_g and high device performance at high temperatures.

References

- [1] S. Tokito, et al., IEEE Trans. Electron Devices, 44, 1239 (1997).
- [2] S. Tokito, et al, Thin Solid Films 363, 290 (2000)

10:30 AM Q3.5/S4.5

OPTICAL PROPERTIES OF MICROCAVITY STRUCTURES USING THE ORGANIC LIGHT EMITTING MATERIALS. Boo Young Jung, Nam Young Kim, Chang Hee Lee, Chang Kwon Hwangbo, Inha Univ, Dept of Physics, Incheon, KOREA; Chang Seoul, Inha Univ, Dept of Textile Engineering, Incheon, KOREA.

We investigated the optical properties of Fabry-Perot microcavity with a tris(8-hydroxyquinoline)aluminum Alq₃ organic film by measuring the photoluminescence (PL) and transmittance. An Alq₃ layer as an active layer was sandwiched between two mirrors, which were metal or (TiO₂/SiO₂) dielectric multilayer reflectors. A resonant wavelength of [mirror|Alq₃|mirror] cavity was designed to be coincided with a peak of PL intensity of [air|Alq₃|glass]. We have used two methods to control the resonant wavelength of the cavity; one is to adjust a cavity length and the other is to control the phase change on reflection of mirrors. An Alq₃ layer on glass, [air|Alq₃|glass], showed a PL peak around 513 nm and its full width half maximum (FWHM) was about 80 nm. Three types of microcavity, such as [air|metal|Alq₃|metal|glass], [air|dielectric|Alq₃|dielectric|glass], and [air|metal|Alq₃|dielectric|glass], were designed and fabricated by a physical vapor deposition method. The result shows that the FWHM of three Fabry-Perot microcavities for s- or p-polarized waves was reduced to 16~27, 7~11 and 15~16 nm, respectively, and the microcavity structure is expected to improve the efficiency and tunability of emission spectrum in display. Also the reduction on emission spectrum was described in terms of cavity length, incident angle, and phase change on mirror reflection in this paper.

10:45 AM Q3.6/S4.6

NEW EXPERIMENTAL TECHNIQUES PROBING POLYMER LEDs. Dickon Pinner, Richard Friend, Cavendish Laboratory, Cambridge, UNITED KINGDOM; Nir Tessler, EE Department, Technion, Haifa, ISRAEL.

We present a comprehensive and self-consistent analysis of polymer LEDs that combines experimental and theoretical studies. We show that previously illusive properties such as the temporal and spatial evolution of charges and excitons, as well as the internal electric field can be made accessible. Using pulsed excitation we present, for a wide variety of different polymers, results of: i) the mobility of both electrons and holes (from a single device); ii) the temporal evolution of the internal electric field at the recombination zone during the voltage pulse; iii) the temporal and spatial evolution of the recombination zone itself, and; iv) the motion of charges both during and after the application of a pulse. These processes have been investigated on time scales from ns to s. The implications of these results for device applications will be discussed.

11:00 AM Q3.7/S4.7

EXPERIMENT AND MODELING OF CONVERSION OF SUBSTRATE WAVEGUIDED MODES TO SURFACE-EMITTED LIGHT BY SUB-STRATE PATTERNING. Min-Hao M. Lu, Conor F. Madigan, James C. Sturm, Center for Photonics and Optoelectronic Materials, Department of Electrical Engineering, Princeton University, Princeton, NJ.

In a typical OLED, the external quantum efficiency is severely limited by the great mismatch between the indices of refraction of air, glass substrate, ITO and the organic layer $n_{air} = 1$, $n_{glass} = 1.51$, $n_{ITO} = 1.8$, and $n_{org} = 1.67$ for the PVK/PBD/C6 blend used in this work. A large fraction of the light emission is trapped in the glass substrate and ITO/organic layers by total internal reflection. A simple ray optics model, ignoring microcavity effects and diffusive interfacial scattering, predicts ~ 80% of the light is lost to waveguide modes¹, although the actual figure has never been measured experimentally. In this paper we show how backside substrate (non-OLED side) features and high index-of-refraction substrates can be used to raise the external quantum efficiency by a factor of at least 3.0. Furthermore, we measure not only the change in the far-field intensity pattern, but also the change (reduction) in the substrate-waveguided light after the backside features are applied. Thus we can confirm, for the first time, that the ratio of the substrate-waveguided to the surface-emitted fractions in planar devices is well described by ray optics. Finally we will also show experimentally the dependence of the waveguided fraction and potential improvements in efficiency on substrate index of refraction. Although the initial external coupling efficiency is independent of n_{sub} , the limit to which η_{ext} can be raised by substrate patterning is higher for high index substrates. This work is supported by DARPA and NSF.

¹L.J Rothberg, J. Mat. Res., vol. 11, pp. 3174-3187, 1996.

11:15 AM Q3.8/S4.8**INTERFACIAL EFFECTS ON OPTICAL, ELECTRICAL AND TRANSPORT PROPERTIES OF TRIS-8-HYDROXYQUINOLINE (Alq3)-BASED ORGANIC LIGHT EMITTING DEVICES.**

Vincent V. Dinh, Peter Thielen, Univ of California, Davis, Dept of Applied Science, Davis, CA; Gil R. Delgado, Louis J. Terminello, Howard W. Lee, Boyd Taylor, Tony Van Buuren, Art J. Nelson, Nicolas Franco, Lawrence Livermore National Laboratory, Livermore, CA; Christoph Bostedt, Univ Hamburg, Dept of Physics, Hamburg, GERMANY.

We present current-voltage (I-V), photoluminescence (PL), photoluminescence excitation (PLE), and electroluminescence measurements for the ITO/PVK/Alq3/metal structure. In this study, we vary the Alq3 film thickness to isolate the interface effects on the device PL. We also measure the chemistry and bonding structure at the interface using element and chemical state specific synchrotron radiation-based spectroscopies. We present a charge injection and charge transport model for the OLED that is a conclusion of the observation of the measurements. Our results will be discussed within the context of devices performance and lifetime.

11:30 AM Q3.9/S4.9**NEW DENDRITIC MATERIALS AS POTENTIAL OLED TRANSPORT AND EMITTER MOIETIES.** Greg Schmett, Asanga Padmaperuma, Linda Sapochak, Department of Chemistry, University of Nevada, Las Vegas, NV; Kimba Ashworth, Luis Madrigal, Benjamin Reeves, Charles W. Spangler, Department of Chemistry and Biochemistry, Montana State University, Bozeman, MT.

Traditionally, organic light-emitting devices (OLEDs) are prepared with discrete layers for hole and electron transport. Different materials must be used for these layers because most materials will preferentially transport one charge carrier more efficiently than the other. In most cases, the emitter material serves a dual purpose as both the emitter and the hole or electron transporter. One of the major failure modes of OLEDs results from thermal instabilities of the insulating organic layers caused by joule heating during device operation. The problem is most pronounced for the hole transporting materials (HTM) which are usually tertiary aromatic amines (i.e., TPD and NPD). This has been attributed to the relatively lower glass transition temperatures (T_g) and resulting inferior thermal stabilities compared to the other materials making up the device. Many researchers have produced HTMs with higher T_g s, but with a corresponding decrease in charge transport properties. Dendritic materials offer the advantages of high thermal stabilities and multi-functionality. Model dendrimers based on bis-(diphenylamino)-E-stilbene subunits as the dendrimer repeat units have been shown to form exceptionally stable bipolaronic dications upon oxidative doping. These charge states can also be photogenerated in the presence of electron acceptors on the picosecond time scale and are currently being evaluated as optical power limiters. Replacement of P for N reduces the capability for bipolaron formation, but substitution of only some of the N atoms in the dendrimer allows the preferential formation of polaronic radical cations. Thus design of the dendrimer can predetermine which charge states dominate the photophysical processes, a key factor in OLED design. Thus we anticipate that dendrimers based on bis-(diphenylamino) and bis-(diphenylphosphino) substituents incorporated into the dendrimer repeat units can possibly function as not only efficient hole transport materials, but also as emitters in various OLED design configurations. We present a systematic study of the luminescence and thermal properties of dendrimers based on the design paradigms discussed above, and will illustrate the efficacy of controlling the P/N substitution patterns in the dendrimer in terms of device performance.

11:45 AM Q3.10/S4.10**RESONANCE PHOTOLUMINESCENCE OF CHELATE-BASED LANTHANIDE COMPLEXES.** Xiaowen Li, J. Yuan, K.W. Cheah

and W.T. Wong¹, Department of Physics, Hong Kong Baptist University, Kowloon Tong, HONG KONG. ¹Department of Chemistry, Hong Kong University, Hong Kong, PR CHINA.

Recently, there has been a significant interest on organic lanthanide (La) ion complexes due to their potential applications in full color flat displays, diode lasers, sensors, and so on. These complexes have luminescence spectra that are characterized by the absorption of energy by the ligand and the emission originating from the La ion. In the free La-ion, optical intra-4f shell transitions are parity forbidden. Incorporated in a solid host however, the crystal field of the host induces mixing of the states. This makes some of the transitions allowed. These optical transitions are sharp and atomic like, due to the fact that the partially filled 4f shell is shielded by filled 5s and 5p shells. La ions coordinated through an oxygen or nitrogen to organic ligands possess optical properties which closely parallel the properties

of the same ions observed in inorganic salts. The photoluminescence excited spectra (PLE), photoluminescence spectra (PL), and time-resolved PL of different Eu^{3+} and Tb^{3+} complexes were studied. When pumped by near ultra-violet light, the complexes emitted sharp and strong emission lines due to the intra 4f transitions of the La ions, accompanied by broad and weak emission originating from the ligand. From the time-resolved PL results, we conclude that the ligand was firstly excited by the excitation photon. Then the La ion was excited via energy transfer from the ligand. Some of the decay times of the luminescence of Tb^{3+} and Eu^{3+} were longer than the lifetimes of those ions implanted in an inorganic host. We explained this as the result of the mutual excitation between the La ion and the ligand because of the close proximity in the emission energy and the corresponding agreement between the decay time of ligand emission and rise time of the lanthanide emission.

SESSION Q4: ELECTROLUMINESCENCE

Chair: Sey-Shing Sun

Wednesday Afternoon, April 26, 2000

Franciscan II (Argent)

1:30 PM Q4.1**EFFECTS OF CO-DOPANTS ON THE EL PROPERTIES OF ZnS:TbOF.** Paul H. Holloway, Jongpyo Kim, Mark Davidson, David Moorehead and Barbara Speck, University of Florida, Department of Materials Science and Engineering, Microfabritech, Gainesville, FL.

Electron beam stimulated surface chemical reactions (ESSCRs) have been shown to lead to degradation of cathodoluminescent (CL) phosphors. We have studied in detail the effects of various gaseous partial pressures on the processes leading to degradation. We have demonstrated that either high partial pressures of H_2 or H_2O will cause degradation of ZnS P22 phosphors, but the ESSCR is very different. Degradation is much more severe and occurs at lower coulombic loadings when partial pressures of $\sim 10^{-8}$ Torr of H_2O are present. This partial pressure was controlled over a wide range by back filling the vacuum chamber from a stainless steel vessel containing H_2O isolated from the vacuum by a leak valve. Hydrogen partial pressures of $\sim 10^{-7}$ Torr were sufficient to result in degradation by an ESSCR in which H_2S was speculated to be formed. It was shown that the presence of SiO_2 coatings could accelerate this process, and a mechanism involving the formation of hydroxyl radicals will be discussed. The implications of ESSCRs for FEDs will be discussed. This work supported by DARPA through the Phosphor Technology Center of Excellence.

1:45 PM *Q4.2**INORGANIC ELECTROLUMINESCENT (EL) PHOSPHORS FOR COLOR EL DISPLAYS.** Shosaku Tanaka, Tottori University, Department of Electrical and Electronic Engineering, Tottori, JAPAN.

Yellow-light emitting ZnS:Mn thin-film electroluminescent displays are utilized in industrial instrumentation and for automotive applications because EL displays have many advantages, such as, solid state, light emitting, high contrast and immune to temperature extremes and long term reliability. However, application of EL displays are limited by lack of color. To overcome this problem, color thin film EL phosphors and color EL structures have been addressed in the last decade. In this paper, progress in the performance of color thin-film electroluminescent phosphors are reviewed with emphasis on phosphors for filtered color approach. ZnMgS:Mn phosphors, which is modified from highly efficient, commercialized yellow-light emitting ZnS:Mn phosphors, are promising for filtered green color, and also for filtered red color phosphors. Lattice expansion by Mg ions while maintaining zincblende structure, in other words keeping Td symmetry for Mn luminescent centers, is responsible for blue-shift of Mn luminescence. This is due to decreasing of crystal field for Mn centers, because energy levels of Mn ($3d^5$) excited state decrease with increasing crystal field. In SrS based phosphors, blue-green light emitting SrS:Ce and blue-light emitting SrS:Cu are applicable to filtered blue color phosphors. Intrinsic as well as Ce induced defects are responsible for space charge generation in SrS:Ce and it should be controlled to improve EL characteristics of SrS:Ce thin film EL devices. To grow blue-emitting SrS:Cu thin films, reduction of defects, control of concentration, and uniform doping of Cu^+ centers is essential, because formation of aggregated Cu^+ centers results in red-shift of luminescence, that is, bluish-green luminescence. Fabrication technique to obtain blue-light emitting SrS:Cu phosphors is discussed. Based on latest results of luminance and EL efficiency reported for ZnMgS:Mn, SrS:Ce and SrS:Cu phosphors, predicted characteristics of color EL displays are discussed.

2:15 PM Q4.3**ELECTROLUMINESCENT OXIDE PHOSPHOR THIN FILMS PREPARED BY SOL-GEL PROCESS.** Tadatsugu Minami, Toshihiro

This paper reports on the preparation of electroluminescent (EL) oxide phosphor thin films by a sol-gel process using dip-coating. The EL characteristics were investigated by using an ac single-insulating-layer thin-film electroluminescent (TFEL) device structure fabricated by depositing an oxide phosphor thin-film emitting layer onto a thick BaTiO₃ ceramic sheet insulating layer. Mn-, Eu- or Sn-activated oxide phosphor thin films, using host materials such as Ga₂O₃, SnO₂ and Ga₂O₃-SnO₂, were used as the emitting layer. In the sol-gel process, source materials composed of combinations of trimethoxy gallium, tetra-*i*-propoxy tin, europium chloride and manganese chloride were initially dissolved in methanol; water and hydrochloric acid were subsequently added into the solution. The dip-coated ceramic sheets were dried and then heated at depositing temperatures of 600-900 degree C. In addition, the coated oxide phosphor thin films were postannealed at 700-1100 degree C. High luminance green, red or blue emissions were obtained in TFEL devices with a Ga₂O₃:Mn, SnO₂:Eu or Ga₂O₃:Sn thin-film emitting layer, respectively. Luminances of 621 and 60 cd/m² were obtained in Ga₂O₃:Mn and SnO₂:Eu TFEL devices, respectively, driven at 1 kHz.

2:30 PM Q4.4

ELECTROLUMINESCENT DEVICES WITH NANOSTRUCTURED ZnS:Mn EMISSION LAYER OPERATED AT 16 V_{rms}.
Toshihiko Toyama, Daisuke Adachi, Hiroaki Okamoto, Dept of Physical Science, Graduate School of Engineering Science, Osaka University, Toyonaka, JAPAN.

The luminescent efficiency of ZnS:Mn, which has been used as an emission layer in thin-film electroluminescent (TFEL) devices [1], can be increased due to the quantum confinement effects in nanostructures [2]. Thus the application of the nanostructured ZnS:Mn to the emission layer is quite attractive. We report a novel TFEL device with a low operation voltage based on the emission layer consisting of a ZnS:Mn/Si₃N₄ nanometer-size multilayer. The ZnS:Mn/Si₃N₄ multilayer was deposited on an ITO-coated glass substrate by rf magnetron sputtering, and Al back-contacts with an area of 7.5 mm² were evaporated on the multilayer. The thicknesses of the monolayers were varied in the range of 0.9–4.5 nm for ZnS:Mn and fixed at 0.7 nm for Si₃N₄, respectively. The period of ZnS:Mn/Si₃N₄ was 20–40. The thicknesses were confirmed by a cross-sectional view of the multilayer taken with a transmission electron microscope. The Mn concentration in ZnS was 10 mol%. From the ZnS:Mn/Si₃N₄ multilayers, photoluminescence (PL) ($\lambda_{exc} = 325$ nm) is observed at ~670 nm due to *d-d* transitions of Mn²⁺. The PL efficiency at a spectral peak is increased with a decrease in the thickness of the ZnS:Mn monolayer and that of the multilayer with the 0.9-nm thick ZnS:Mn monolayers exceeds that of 200-nm thick ZnS:Mn film. In addition, the PL excitation spectrum monitored at 670 nm of the multilayer is shifted toward shorter wavelengths comparing with that of 200-nm thick ZnS:Mn film. These behaviors would be attributed to the quantum confinement. So far, as the results of the application of the nanostructured ZnS:Mn to the TFEL devices as an emission layer, red light emission of 2.2 cd/m² has been achieved from the nanostructured ZnS:Mn TFEL devices operated with a 1-kHz sinusoidal ac voltage at 16 V_{rms}. 1. Y.A. Ono, "Electroluminescent Displays", (World Scientific, Singapore, 1995). 2. R.N. Bhargava *et al.*, Phys. Rev. Lett. **72**, 416 (1994).

3:15 PM *Q4.5

ELECTRO-OPTIC MATERIALS DEVELOPMENT AND THE EVOLUTION OF FLAT PANEL DISPLAYS. Patrick Green, Planar Systems, Beaverton, OR.

The global market for flat panel displays (FPDs) is predicted to exceed \$22B in 2002. This demand is expected to continue growing with no end in sight. While as little as ten to fifteen years ago a leading FPD technology had not been established, today liquid crystal displays (LCDs) have clearly emerged as dominant in spite of extensive developmental efforts in plasma, electroluminescence, field emission, and other FPD technologies. The reasons for the success of LCDs and the difficulties (to date) of these other technologies will be discussed with reference to the level of electro-optic materials development required to successfully implement them. These observations will be applied to the latest promising FPD technology: organic light emitting diode displays.

3:45 PM Q4.6

PHOTOLUMINESCENCE CHARACTERISTICS OF SrTiO₃:Pr³⁺,Ga³⁺ SINGLE CRYSTAL. Jaedong Byun, Yongjei Lee, Boyun Jang, Dept. of Materials Science, Korea Univ., KOREA; Youngmoon Yu, Korea Research Institute of Chemical Technology; Kyungsoo Suh, ETRI, KOREA.

Photoluminescence characteristics of SrTiO₃:Pr³⁺,Ga³⁺ single crystals were investigated. The crystals were grown by floating zone method in N₂ atmosphere. And impurity concentrations in the crystals were analyzed by X-ray fluorescence. The distribution constants for Pr³⁺ in SrTiO₃ were 0.09 and 0.16 when the Pr³⁺ concentrations in the melts were 0.2 and 1.2 atom percent, respectively. When both Pr³⁺ and Ga³⁺ were added to the melt, the distribution constant for Pr³⁺ increased. When the concentrations of Pr³⁺ and Ga³⁺ in the melt were 1.2 atom percent each, distribution constants for Pr³⁺ and Ga³⁺ were 0.26 and 0.88, respectively. Comparing the ionic sizes of the hosts and dopants, it seems that the increase in distribution constants for Pr³⁺ is due to charge compensation achieved by the additional Ga³⁺. The addition of Ga³⁺ in Pr³⁺-doped SrTiO₃ resulted also in a considerable enhancement of Pr³⁺ emission band at 615 nm. The addition of 0.2 atom percent of Ga³⁺ increased the emission intensity of 0.2 atom percent Pr³⁺-doped SrTiO₃ by a factor of five in spite of the fact that the Pr³⁺ concentration increased only by a factor of 2.5. From the analysis of the experimental results, the following mechanism is proposed. Excitation into the SrTiO₃ host lattice leads to the formation of electrons in the conduction band and holes in the valence band. The electrons in the conduction band recombine radiatively with the holes trapped at Ga³⁺ ion and the energy is transferred to Pr³⁺ ion which gives its own characteristic red emission. This work was supported by Korea Research Foundation Grant.(1998-017-E00130)

4:00 PM Q4.7

Abstract Withdrawn

4:15 PM Q4.8

ANTIMONY TIN OXIDE THIN FILMS PREPARED BY REACTIVE ION BEAM SPUTTERING. C.Y. Koo, H.Y. Lee, Yeungnam University, Dept of Materials Sci. and Eng., Kyongsan, KOREA; M.K. Hong, K.J. Kim, Korea Research Institute of Standards and Science, Taejon, KOREA.

Antimony tin oxide (ATO) thin films were considered as possible low-cost alternative to rather expensive indium tin oxide (ITO) transparent conductive films for applications including flat panel display. Reported data by other researchers for ATO thin films to date, however, have not been any better than commercial sputtered ITO films. The processes used for thin film deposition in the literature include dc and rf sputtering, plasma-enhanced chemical vapor deposition and sol-gel or dip coating. In our study, ATO thin films with antimony content up to 15% were prepared using reactive ion beam sputtering technique. As deposited films were given annealing treatment at the temperature between 300 to 600 C in air or reducing ambient. It was found that both electrical resistivity and optical transparency were strongly influenced by chemical composition and annealing treatment. Resistivity data for 200nm thick film with 10.8% antimony were about 17 mΩcm when annealed at 500 C for 30 minutes in air. Optical transparency in 400 to 700 nm range is typically better than 80%. The microstructure of transparent film was X-ray amorphous, especially when antimony content was higher than a few percent. Detailed explanation on the influence of processing variables as well as composition will be presented.

4:30 PM Q4.9

STABILITY IN ELECTRICAL PROPERTIES OF ULTRA THIN TIN OXIDE FILMS. Yuji Matsui, Yoshio Goto, New Products Dev Ctr, Fabricated Glass General Div, Asahi Glass Co., Ltd, Yokohama, JAPAN.

Tin Oxide films of less than 30nm in thickness were developed as transparent electrodes for pen touch screens. The films were deposited onto glass substrates by APCVD method, from hydrolytic decomposition of stannic chloride. Fluorine was used as a dopant. Stability to thermal treatments in air at more than 500°C was studied. It was found decrease in carrier concentration and increase in Hall mobility took place at the same time on non doped films. Sheet resistance of the films decreased as a result, while the resistance increased on fluorine rich films. It was also found sodium migration from the substrates to the films increased with increasing fluorine doping. The migrated sodium ion would make a possible cause for degradation of the stability.

4:45 PM Q4.10

Al-DOPED ZnO TRANSPARENT CONDUCTING FILMS PREPARED BY MAGNETRON SPUTTERING. Meng Chen, Zhiliang Pei, Jun Gong, Chao Sun, Rongfang Huang, Lishi Wen, Institute of Metal Research, Academia Sinica, Shenyang, CHINA.

The most important materials of transparent conducting oxide (TCO) films commercialized nowadays are Sn-doped In₂O₃ (ITO) films. However, Al-doped ZnO (ZAO) thin films are attractive due to their cheap and abundant raw material, nontoxic feature, comparable with

ITO electrical optical and infrared (IR) properties, cost-effective and easy fabrication. In this paper, ZAO films have been prepared by reactive magnetron sputtering. Their electrical conductivity is shown to be in range of $10^{-4} \Omega \cdot \text{cm}$. The influence of the substrate-to-target distance and deposition temperature on the resistivity of ZAO films has been studied. Their IR and optical properties have been studied with UV/VL spectrometer and Fourier IR spectrometer. It was shown that the visible transmittance and IR reflectance of ZAO films deposited on polyester at room temperature, are comparable with those of ITO films. One of the critical factors limiting the application of ZnO as a transparent conductive film, is its thermal stability. However, it has been proved that films through addition of Al in ZnO, the variation range of resistivity is usually no more than 1% in the range of 50 - 400 °C in vacuum and 5% in the range of 50 - 400 °C in air. ZAO films have n-type conductivity, so as for all other transparent conducting semiconductor oxide films. Nevertheless, its detailed conduction mechanism is still not clear and has been analyzed, based on the data of XPS and ESCA.

SESSION Q5: POSTER SESSION:
FPD
Wednesday Evening, April 26, 2000
8:00 PM
Metropolitan Ballroom (Argent)

Q5.1
PHOTO-AND CATHODOLUMINESCENCE IN CERIUM-ACTIVATED YTTRIUM-ALUMINIUM BORATE BASED PHOSPHORS. V.Z. Mordkovich, Intl Center for Materials Research, Kawasaki, JAPAN.

Ce³⁺ luminescence in Ce-activated yttrium aluminium borates was studied. Photoluminescence was excited by continuous-wave UV or by pulse laser irradiation. Cathodoluminescence was excited at acceleration voltage in the range of 5 to 600 V. These phosphors show under continuous wave UV excitation three emission peaks: in near UV, deep blue and light blue ranges. The light blue peak at around 490 nm which may be connected to forbidden ²D_{3/2} - ²F_{7/2} transition appears in continuous wave-excited photoluminescence only and does not appear in cathodoluminescence nor under pulse excitation. The blue-emitting Ce-activated yttrium aluminium borates exhibit unusually strong activator ion-host lattice interaction. As a result of this interaction a substantial red shift in main emission band is induced by Ce concentration increase and complicated concentration dependence of the emission intensity is observed. The efficiency of luminescence may be substantially increased by activation in reducing atmosphere. The mechanism of the activation process is discussed.

Q5.2
EMISSION OF BLUE LIGHT FROM A WELL-TYPE LATERAL EDGE FIELD EMITTER DEVICE HAVING A THIN FILM PHOSPHOR OF ZINC OXIDE AND TUNGSTEN. Yasuda Bhatia, Jasleen B. Sobti, Hong-Ryong Kim, Texas A&M Univ., Dept. of Electrical Engineering, College Station, TX; Leonid D. Karpov, Stellar Display Co., Austin, TX; Mark H. Weichold, Texas A&M Univ., Dept. of Electrical Engineering, College Station, TX.

Displays based on the principles of field emission hold a promising future for the emergence of next generation flat panel displays. However, their commercial application has been delayed because of the complex sub-micron processing involved in the fabrication of microtips for the cathode and non-availability of blue phosphors operational in low voltage regimes. This paper presents the fabrication and characterization of a monolithic lateral edge well emitter field emission device, implementing a phosphor of ZnO:W for blue light emission and operating at voltages as low as 300 V. The well type edge field emission device design considered for fabrication is based on a design reported by L. D. Karpov, et al [1]. The device has features similar to that previously reported by Legg, et al. [2]. The device design has arrays of small wells having sides of a dielectric material. Phosphors, for producing light, lay at the bottom of the wells and above anode lines. Cathode lines, in this device, have been fabricated by depositing metal-carbon-metal layers on top of the dielectric material and hang slightly over the well edges. Light from the display is produced by the excitation of the phosphor by electrons emitted from the thin edge of the cathode. The device design reported here provides more stability to the display as compared to conventional field emission display designs since it eliminates complex fabrication steps involved in fabricating microtips. The blue phosphor used in this device has been fabricated at Texas A&M University [3] by annealing thin films of co-deposited ZnO and W in presence of oxygen and argon [4]. Cathodoluminescent spectrum of the phosphor obtained during the excitation of the phosphor by beam of electrons at a voltage of 300V shows that the phosphor emits blue light at 490 nm. XRD and infrared spectroscopy of the ZnO:W phosphor has

shown the presence of ZnWO₄ in the annealed films. ZnWO₄ has been reported to emit blue light [5], and thus is attributed to be the source of blue light in the phosphor. Current-voltage characteristics and optical emission properties of the lateral edge well-type device as obtained at voltages as low as 300 V are reported in this paper, and demonstrate the device performance in terms of required power consumption and efficiency of the phosphor. References: [1] L.D. Karpov, V.A. Dratch, V.S. Zasemkov, A.P. Genelyev, Y.V. Migorodsky, and S.B. Proskournin, Some ways to increase brightness stability of flat panel displays based on field emission, Technical digest of the 6th International vacuum Microelectronics Conference, Newport, RI, 1993. [2] J.D. Legg, M.E. Mason, R.T. Williams, and M.H. Weichold, Improved Monolithic Vacuum Field Emission Devices, Journal of Vacuum Science Technology B, Vol. 12, No. 2, pp. 666-671, March/April 1994. [3] Technology Disclosure to TAMU Technical Licensing Office (1993) [4] J.B. Sobti, P.M. Babuchna, V. Bhatia, M.H. Weichold, Film Preparation, Conditions, and Characterization of Co-Deposited Tungsten doped ZnO Phosphor, MRS Spring Meeting, 1999, San Francisco, CA. [5] H. Wang and F. Medina, M.S. Antonious, C. Parkanyi, J.E. Hanky, D.M. Biard and Ya- Dong Zhou, Chem. Phys. Lett. 205 p. 497 (1993).

Q5.3
VERY LOW FIELD ELECTRON EMISSION FROM HFCVD GROWN MICRO-CRYSTALLINE DIAMOND. B.S. Satyanarayana**, X.L. Peng*, G. Adamopoulos, J. Robertson, W.I. Milne and T.W. Clyne*, Dept of Engineering, Cambridge University, Cambridge, UNITED KINGDOM. *Dept. of Material Science, Cambridge University, Cambridge, UNITED KINGDOM. **Present address, Dept. of Electronic & Photonic Systems Engr., Kochi University of Technology, Kochi, JAPAN.

There is an increasing interest in field assisted electron emission from diamond. The attraction stems from its properties like the electro-negativity, thermal stability, mechanical hardness and chemical inertness. All forms of diamond including crystalline, poly-crystalline, doped diamond and nano-diamond have been studied. Generally low threshold field emission has been reported for doped diamond films grown by various process. Here we report very low threshold field emission from undoped nanocrystalline / micro-crystalline diamond films grown by the hot filament chemical vapour deposition (HFCVD) process using methane and hydrogen as source gases. The effect of crystal size [1 μm to ~ 100 nm], methane concentration [0.5 % to 3 % CH₄/ H₂] and temperature [775 C to 925 C] were studied. Threshold fields as low as 0.4 V/μm were observed, which we believe is the lowest value to be reported for a current density of 1 μA/cm². The threshold field is defined as the field at which an emission current density of 1 μA/cm² is obtained. The observed correlation between the emission characteristics, morphology and I(D)/I(G) peak ratio of the Raman curves is also presented. The low threshold films exhibit an emission site density of nearly 10⁵/cm² for an applied field of 2-3 V/μm.

Q5.4
GREEN EMISSION FROM Er-DOPED AlN THIN FILMS PREPARED BY RF MAGNETRON SPUTTERING. Valentina Dimitrova, Florentina Perjeru, Hong Chen, Martin Kordesches, Ohio Univ, Dept of Physics and Astronomy and Condensed Matter and Surface Science Program, Athens, OH.

Recently, the success of the visibly emissive rare earth-doped III-V semiconductors as GaN and AlN has drawn significant attention because of potential applications for fabrication of visible light-emitting diodes (LED), thin-film electroluminescent (TFEL) displays, plasma displays (PDs) and field-emission displays (FEDs). For this purpose AlN films with a different Er concentration between 1 and 5 at.% were grown by RF magnetron sputtering at low and room temperatures. The AlN:Er thin films, 300-1000 nm thick, were deposited onto p-Si (111) and glass substrates coated with a conductive layer of indium tin oxide (ITO). To optically activate Er films were a subject of post-deposition annealing in flowing nitrogen atmosphere at atmospheric pressure at temperatures between 650-950°C for 30 or 60 minutes. The AlN:Er film crystal structure and composition were checked by means of X-ray diffraction, Rutherford backscattering spectroscopy and scanning electron microscopy. The films were found to have good optical properties-refractive index, extinction coefficient and high transmission in the visible and infrared regions. The band gap of AlN:Er films was reduced from 6.0 to 5.1 eV with the increasing of Er concentration, which is attributed to the low band gap of ErN. The visible cathodoluminescence (CL) in the green also was detected at low and room temperatures. At 11 K very bright CL emission was observed for the films annealed at 850°C for 60 minutes. The strongest CL peak was noticed at 556 nm, which corresponds to transmission from ⁴S_{3/2} state to the ground ⁴I_{15/2} level of the Er³⁺ ions. A weak emission was observed at 405 nm corresponding to the transition from ²H_{9/5} to ⁴I_{15/2}. The electroluminescence (EL) measurements and making of AlN:Er TFEL devices will be reported.

Q5.5

ELECTROLUMINESCENCE CHARACTERISTICS OF METAL/OXIDE/SILICON LED. H.L. Tam, J. Yuan and K.W. Cheah, Department of Physics, Hong Kong Baptist University, Kowloon Tong, Hong Kong, PR CHINA.

Strong visible electroluminescence was obtained from simple metal/oxide/silicon (MOS) structure. The electroluminescence was sufficiently strong to observe under moderately lighted environment. The current-voltage, electroluminescence of the MOS LED were investigated as a function of temperature and contact metal type. We have shown that the electroluminescence is a function of the contact metal, doping concentration of the silicon and the oxide integrity. This indicates that the electroluminescence originated from interface states located at the silicon and silicon oxide interface, and with careful controlled oxidation/oxide deposition, it is possible to engineer the luminescence characteristics. This simple MOS LED structure can potentially be used for flat panel display, opto-coupler and part of silicon based opto-electronic integrated circuit.

Q5.6

EFFECT OF TiO₂ ADDITION ON THE SECONDARY ELECTRON EMISSION AND DISCHARGE PROPERTIES OF MgO PROTECTIVE LAYER FOR AC PLASMA DISPLAY PANEL. Younghyune Kim, Rakhwan Kim, Jong-Wan Park, Dept. of Metallurgical Engineering, Hanyang Univ., Seoul, KOREA; Hee Jae Kim, Dept. of Ordnance Engineering, Korea Military Academy, Seoul, KOREA.

The current MgO protective layer for the promising wall hanging TV, AC plasma display panel is thought to be still not one of the best materials to meet the demand of advanced high vision PDP with good light emission efficiency, low power consumption and high image fidelity. Therefore, to improve the overall performance of PDP, it is indispensable to develop new protective materials with better electrical characteristics than MgO. In this study, Mg_{2-2x}Ti_xO₂ protective layers evaporated from the starting materials with different [TiO₂/(MgO+TiO₂)] ratios were introduced, and then the effects of TiO₂ addition on physical and electrical characteristics were investigated. The pure MgO films exhibited the crystallinity with strong (111) orientation. The Mg_{2-2x}Ti_xO₂ films, however, had the crystallinity with (311) preferred orientation. When the [TiO₂/(MgO+TiO₂)] ratios of 0.1 and 0.15 were used, the deposited films exhibited the secondary electron emission yields improved by 50% compared to that of the conventional MgO protective layer, which resulted in reduction in discharge voltage by 12% and also increase in the luminous efficiency of panel.

Q5.7

EVALUATION OF MAGNESIUM OXIDE FILMS BY SPECTROSCOPIC ELLIPSOMETRY. Hiroshi Kimura, Device Analysis Technology Laboratories, NEC Corp., Kanagawa, JAPAN.

Magnesium oxide (MgO) is used as protecting layer in AC-type plasma display panels (PDPs). PDPs performance strongly depends on the crystallographic orientation, the surface morphology, and the grain size of MgO films [1, 2]. Density of a film is also expected to be an important factor to produce PDP with long lifetime. Lifetime of PDP is determined by sputtering yield of MgO film, and sputtering yield of a MgO film is affected directly with its density [3]. Monitoring densities is necessary to produce long-life PDPs, however, there is no tool to evaluate the densities of MgO films quantitatively. Densities of films are correlated with their refractive indices, and film density can be quantitatively estimated by observing its refractive index. We examined spectroscopic ellipsometry for quantitative evaluation of densities of MgO films by characterizing its optical constants. Spectroscopic ellipsometry is a very powerful tool for characterizing the optical properties quantitatively and layered structure of thin film [4]. We assumed that deposited MgO film had two-layered structure. The upper layer represents rough layer near to surface, and the lower layer is the body of MgO film. Several types of MgO films were prepared by e-beam evaporation with various oxygen gas fluxes to investigate the influence of oxygen on the film density. We found that the refractive index of film became smaller as increasing oxygen flux in film deposition. Thus, smaller film density was obtained by film deposition with more oxygen. Low sputtering yield is achieved with small density [3], and it is supposed that lifetime of PDP become long with MgO deposited with oxygen flux. On the other hand, the film deposited without oxygen has the upper layer of the smallest density. We consider that the density of the upper layer affects on not only PDP lifetime, but also discharge characteristics. [1] C.H. Park, et al., Mat. Sci. and Engineering, B60, 149 (1999) [2] R.F. Cook, et al., J. Mat. Sci., 27, 4751(1992) [3] P. Sigmund, Phys. Rev., 184, 343 (1969) [4] S. Charvet, et al., J. Appl. Phys., 85, 4032 (1999)

Q5.8

MORPHOLOGY CONTROL OF PHOSPHOR PARTICLES PREPARED BY SPRAY PYROLYSIS. Seung Bin Park and Yun Chan Kang, Korea Advanced Institute of Science and Technology, Dept of Chemical Engineering, Taejeon, KOREA.

Multi-component oxide phosphor particles prepared by a spray pyrolysis are known to have fine size, narrow size distribution, phase purity, and non-aggregation characteristics. But the fatal problem of the spray pyrolysis is the formation of hollow particles, which reduces the luminescence and long-term stability of phosphor particles. To overcome this problem, colloidal seed-assisted spray pyrolysis is introduced, which is a modified spray pyrolysis using stable colloidal solution obtained by the liquid phase reaction method. The phosphor particles prepared by this method have spherical and filled morphology, and the spherical shape of particles remains unchanged even after annealing at high temperature. To improve brightness of phosphor particles, alkaline flux is introduced in spray pyrolysis. The roles of flux in spray pyrolysis are to promote the activation of dopant and to remove surface defects of particle, which are different from those prepared by the solid state reaction method.

Q5.9

BLUE AND RED LIGHT EMISSION FROM EUROPIUM IONS IMPLANTED SILICON OXIDE THIN FILMS. M. Zhu, F. Liu, Graduate School, Univ of Science and Technology of China, and State Key Laboratory of Materials Chemistry and Applications, Beijing, CHINA; Y. Hou, Northern Jiaotong Univ, Inst of Optoelectronics, Beijing, CHINA; T. Liu, High Energy Physics Inst, Synchrotron Radiation Laboratory, Beijing, CHINA.

The strong visible emission from SiO₂:Eu³⁺ prepared by sol-gel method has been studied. The preparation of the SiO₂:Eu³⁺ thin films with the silicon-integrated technique is particularly interest for optoelectronic application. This paper presents the photoluminescence (PL) and PL excitation spectra from Eu³⁺ implanted thermal growth SiO₂ thin films with the implantation doses of 1×10^{14} and $1 \times 10^{15}/\text{cm}^2$. The concentration of Eu ions was determined by Rutherford back scattering to be less than 0.5 at.%. The annealing behaviors of the PL and PL excitation spectra were investigated for the films annealed in the temperature range of 800-1200°C in N₂. Three PL peaks at 584, 604 and 620 nm, with the full width at half maximum of 24.1, 20.3 and 9.5nm, respectively, were observed from as-implanted and annealed films, which is corresponding to the ⁵D₀₋₇F_J transition. The PL intensity of SiO₂:Eu³⁺ films increases with the annealing temperature. A strong blue light emission (450 nm) appeared after the film annealed at 1200°C for 30 min in N₂. The structure of the SiO₂:Eu³⁺ films was characterized by Eu-L_{2,3} edge X-ray absorption fine structure (XAFS). X-ray absorption near edge structure spectra show a doublet peak structure (the energy difference for split peaks is about 10 eV) as film annealed above 1100°C for 30 min in N₂. The doublet peak could be coexistence of Eu³⁺ and Eu²⁺ species. It is consistent with the 450 nm PL band observed above. The conversion of Eu³⁺ to Eu²⁺ for film annealed in N₂ atmosphere at high temperature is discussed.

Q5.10

INTENSE PHOTOLUMINESCENCE AND PHOTOLUMINESCENCE ENHANCEMENT UPON ULTRAVIOLET IRRADIATION IN HYDROGENATED NANOCRYSTALLINE SILICON CARBIDE. M.B. Yu, E. Rusli, S.F. Yoon, J. Cui, K. Chew, J. Ahn and Q. Zhang, Nanyang Technological University, School of Electrical and Electronic Engineering, Singapore, SINGAPORE.

Hydrogenated nanocrystalline silicon carbide (nc-SiC:H) films were deposited in an electron cyclotron resonance chemical vapor deposition (ECR-CVD) system using silane (SiH₄) and methane (CH₄) as source gases. It was found that under the deposition conditions of strong hydrogen dilution and high microwave power, nanometric crystalline grains embedded in the amorphous matrix can be obtained, as confirmed by TEM study. Steady state and time-resolved photoluminescence (PL) from these films were investigated. The films exhibit intense visible PL at room temperature under laser excitation. The PL emission peaks at 2.68 eV, which is higher in energy compared to the bandgap of cubic SiC. Temporal evolution of the emission peak exhibit a double-exponential decay features. Two distinct decay time of ~200ps and ~1ns were identified, which are at least 2 orders of magnitude faster than that of bound excitation transitions in bulk 3C-SiC at low temperature. It was found that upon ultraviolet irradiation using an Ar⁺ laser (351 nm, 20mW) the PL intensity of the films were enhanced. After 10 minutes irradiation, the PL intensity increased about two times. This result suggests that the UV light may have introduced some stable or metastable states as luminescent centers in these samples. These nc-SiC:H films are promising for application in large area flat panel displays and in optoelectronic storage technology.

Q5.11

NITRIDE PHOSPHORS FOR LOW VOLTAGE CATHODOLUMINESCENCE DEVICES. Hisashi, Kanie, Takahiro Kawano, Kose Sugimoto, Ryoji Kawai, Science Univ of Tokyo, Dept of Applied Electronics, Chiba, JAPAN.

GaN is a wide band gap (3.4eV) semiconductor and has low resistivity, high luminescence efficiency, and chemical stability. Zn doped GaN shows intense blue luminescence. We successfully synthesized microcrystalline GaN and InGaN powders by the reaction between Ga₂S₃ or In₂3 and NH₃. We reported that a GaN:Zn phosphor is feasible for the application in low-voltage cathodoluminescent devices, such as a field emission display or a vacuum fluorescent display. The phosphors showed a threshold voltage as low as ZnO:Zn phosphors because of its low resistivity, however, showed violet cathodoluminescence and a low luminance efficiency in blue region. We intended to shift the violet emission band toward longer wavelength region and to improve intensity of blue emission band by preparing Zn doped InGaN mixed crystal. This paper describes structural and optical properties of Zn doped GaN and InGaN synthesized under various conditions, such as reaction temperature and In contents. Hexagonal microcrystals were obtained. The samples has a brownish body color. The InGaN samples with higher In content showed a metal In phase in a X-ray diffraction pattern. The samples showed blue-room-temperature-cathodoluminescence and 77K-photo-luminescence. The Zn doped InGaN with high In content showed a broader blue luminescence at RT and 77K than those without In or with low In content. Photoluminescence excitation measurement showed that fundamental absorption edge was located at 3.47 eV for both the GaN:Zn sample and the low In content samples. The intensity of a blue band of InGaN:Zn was as intense as those of GaN:Zn. A new peak appeared at 3.15eV besides the band edge peak for the high In content samples. When we excited the sample by monochromatized 3.15 eV light we were able to excite a green emission band selectively. We think that we can obtain shift the Zn violet band toward low energy by controlling Zn and In contents more precisely.

SESSION Q6: TFT I-DEPOSITION AND CRYSTALLIZATION

Chairs: Patrick M. Smith and Ki-Bum Kim
Thursday Morning, April 27, 2000
Franciscan II (Argent)

8:30 AM *Q6.1

VERY LOW TEMPERATURE INSULATORS FOR THIN FILM TRANSISTORS. G.N. Parsons, C.S. Yang, C. Makosiej, A. Gupta, T. Klein, and L.L. Smith, Dept. of Chemical Engineering, NC State University, Raleigh, NC.

Dielectric thin films deposited at 100°C and below are of interest for thin film transistors (TFT's) on plastic substrates and for a variety of other device applications. We have used plasma enhanced chemical vapor deposition to form silicon dioxide and silicon nitride thin films at temperatures between 350°C and room temperature, and studied the effect of temperature and other process conditions on film nucleation and growth (using AFM), bonding structure and composition (using IR and RBS), post-deposition oxygen absorption and transmission, and electrical performance (IV, CV) in capacitors and TFT devices. We find that as temperature is reduced below 200°C, optimal bonding structure and good leakage integrity of silicon nitride films can be maintained over a wide range of process conditions, but charge trapping rates at silicon nitride/silicon interfaces in TFT's can increase significantly. For silicon dioxide films deposited at <200°C, significant changes in bonding structure, oxygen transmission, and electrical performance are observed, indicating a more porous covalent network with significantly increased bulk charge trap state density. Effects of process conditions on bonding structure in oxide films can be tracked by infrared transmission by understanding effects of strain and near-neighbor charge induction. Bond structural changes correlate well with electrical performance and stability. Approaches to modify bond structure at low temperatures to achieve films with bonding composition approaching that in films deposited at higher temperatures will be presented and discussed.

9:00 AM *Q6.2

FABRICATION OF LOW TEMPERATURE POLY SILICON TFTS BY METAL INDUCED LATERAL CRYSTALLIZATION FOR HIGH PERFORMANCE LCD. Seung-Ki Joo, School of Materials Science and Engineering, Seoul National University, Seoul, KOREA.

There is no doubt in a new millennium that the flat panel display device is going to replace the current CRTs in its most applications and Liquid Crystal Display (LCD) which is the only one commercially available yet is going to dominate the world wide market for a considerable period of time in the future. Differently from the

integrated circuits, a display device has to be large so that the yield problem as well as selection of the substrate is more closely related to the fabrication cost than VLSI. In order to meet the essential requirements as a display device such as high resolution, large screen, and low fabrication cost, there are two main technical barriers to be overcome. The one is the reduction of the crystallization temperature of the amorphous silicon thin films below 400° so that the common glass substrate can be utilized a substrate for high functional poly silicon TFTs and the other is a technology which enables the large substrate area defect free. The laser scan annealing which is known to be the most advanced technology in this field suffers from the latter problem. A new noble method which is able to meet these two requirements at the same time will be introduced in this presentation. When an ultra thin film of Ni metal of which thickness is less than 50° is applied on top of amorphous silicon thin film locally, it has been found that the area without Ni can be crystallized into the poly silicon below 400° through catalytic action of NiSi₂ for phase transformation. This phenomenon has been called MILC (Metal Induced Lateral Crystallization) and MILC TFTs where the channel area is crystallized into poly silicon selectively by this new technology show almost the equivalent performance to TFTs fabricated by the laser scan annealing. Physical mechanism for catalytic action of the nickel silicides and the performance of MILC TFT will be discussed in detail and the whole fabrication process of the low temperature poly silicon TFT will be presented in this seminar.

9:30 AM Q6.3

SOLID PHASE CRYSTALLIZATION (SPC) BEHAVIOR OF AMORPHOUS Si BILAYER FILMS WITH DIFFERENT CONCENTRATION OF OXYGEN: SURFACE VS. INTERFACE NUCLEATION. Myung-Kwan Ryu and Ki-Bum Kim, School of Materials Science and Engineering, Seoul National University, Seoul, KOREA.

We have deposited amorphous Si (a-Si) bilayer films [a-Si(I)/a-Si(II) (30 nm/30 nm)] with different amount of oxygen in the film on SiO₂ substrate and investigated its solid phase crystallization behavior. The oxygen concentration in the upper layer of a-Si[a-Si(I)] is of about 3x10²⁰/cm³ while that in the lower layer [a-Si(II)] is of about 5x10²¹/cm³. The oxygen concentration in the layer varied by changing the deposition rate at the similar background pressure. During the solid phase crystallization process of the layer, it is identified that the nucleation and growth of the polycrystalline Si (poly-Si) started at the surface of the film with the formation of large size, equiaxial grains. The size of the grains is about 1-1.5 μ. The lower layer is remained as an amorphous layer even after annealing at 600°C for 9 hours. It is shown that the grain morphology of the SPC poly-Si film can be significantly improved by adopting surface nucleation and growth scheme instead of interface nucleation and growth scheme.

SESSION Q7: TFT II-LASER CRYSTALLIZATION

Chairs: Ryoichi Ishihara and James S. Im
Thursday Morning, April 27, 2000
Franciscan II (Argent)

10:15 AM *Q7.1

EXCIMER LASER ANNEALED POLY-Si TFTS FOR AMLCDS. S.D. Brotherton, D.J. McCulloch, J.P. Gowers, J.R. Ayres, F. Rohlffing and C.A. Fisher, Philips Research Laboratories, Redhill, Surrey, ENGLAND.

Excimer laser crystallization is now the preferred technique for the formation of the high grain quality poly-Si, which is used in the fabrication of high performance TFTs. However, in spite of the wide spread use of this technique, there are still serious concerns about certain aspects of the process, and in particular the uniformity of the material. Depending upon film thickness and the irradiating energy density, the film may be partially melted, fully melted or nearly fully melted and we will relate the primary causes of material non-uniformity to these fundamental aspects of the crystallisation process. The most attractive regime in which to work is the large grain, near-melt-through SLG regime; however, this potentially poses the largest issue with respect to uniformity, unless the size of the laser processing window can be enlarged. In this paper, we will describe recent work in which the inter-relationship between the number of laser shots, the shape of the beam and the resulting film uniformity has been established. It will be demonstrated that by suitably broadening the trailing edge of a swept beam, a 10-20 shot process can be implemented in the SLG regime, in which the device uniformity, and the size of the laser processing window, is comparable to that from a 100 shot process using a top hat beam and considerably better than a low shot process using this latter shape. Even with high quality, uniform material, if the subsequent device processing degrades the material, the resulting TFTs will have sub-optimal performance. The fundamental influence of device

architecture (self-aligned or non-self aligned) on these effects will be reviewed and implantation damage, both in the directly implanted regions themselves and laterally beneath the gate, in self-aligned structures will be shown to be a significant issue. Suppression of this damage and the introduction of drain field relief in these structures will also be discussed.

10:45 AM Q7.2

3D NUMERICAL MODELLING OF LASER CRYSTALLIZATION PROCESSES IN SILICON THIN FILMS. John P. Leonard, A.B. Limanov and James S. Im, Program in Materials Science and Engineering, Columbia University, New York, NY.

Although pulsed laser induced annealing of silicon has been studied extensively, the capability to rigorously and quantitatively simulate certain aspects of the process is presently lacking. This is particularly true in the case of excimer laser crystallization of thin silicon films on glass substrates, where both heat-flow and phase field evolution (i.e. melting and solidification) can be 2- and 3-dimensional in nature. As well, the transitions can take place under highly transient and far-from equilibrium conditions where there is substantial undercooling of the interface, and deep supercooling of liquid that can lead to nucleation. In order to predict the final crystallized microstructure or determine optimal processing conditions, these effects must be properly considered. By developing a true 3-dimensional model and incorporating such features, we demonstrate in this paper how it is now possible to accurately simulate a number of technically important crystallization processes. The calculation of heat-flow and non-equilibrium phase evolution are fully 3-dimensional, and the stochastic nature of nucleation is captured both in space and time. We show how the simulation can be used to: predict grain size in films crystallized under complete melting conditions; calculate superlateral growth (SLG) distances (and determine external parameters necessary for avoidance of nucleation); model crystallization in geometrically complex film structures; and model lateral crystallized microstructures in various controlled-SLG methods. The technical details of the simulation will be discussed, including the 3D finite-differences alternate direction explicit (ADE) heatflow algorithm, interface-response-function determined melting and solidification rates, and a probabilistic algorithm for the introduction of stochastic nucleation events. Implementation on a standard PC platform and optimized algorithms can provide tractable and relevant quantitative simulations within hours. This work was supported by DOE under project DE-FG02-94ER45520.

11:00 AM Q7.3

SINGLE-SHOT EXCIMER-LASER CRYSTALLIZATION OF A ULTRA-LARGE Si THIN-FILM DISK. Mitsuru Nakata, Chang-Ho Oh and Masakiyo Matsumura, Dept of Physical Electronics, Tokyo Inst. of Tech., Tokyo, JAPAN.

We will present here the experimental result that a single-shot of KrF excimer-laser light pulse with uniform intensity could crystallize a circularly pre-patterned Si thin-film of 14 μ m in diameter; much larger than a TFT feature size in present AM-LCD panels. Samples were of an SiO₂(85nm)/Al(80nm)/SiO₂(105nm)/Si(200nm)/SiO₂(50nm)/SiON(1.6 μ m)/ substrate cross-sectional structure. The top Al film of a light reflector was 4 μ m in diameter, while the Si film was more than 10 μ m in diameter. We found, for the first time, that although the excimer-laser light does not irradiate the center of the Si disk, it can melt the covered (inner) Si region by the effects of a lateral heat flow from the uncovered (outer) Si region of about 3.5 μ m-wide, which results in a temperature gradient to the center and triggers lateral crystallization from there. Since the SiON underlayer outside of the Si disk is heated up to an extremely high temperature of about 3500°C by absorbing the laser light¹⁾ and produces temperature gradient in the outer Si region, the lateral crystallization having started from the center can continue to whole the Si disk. As a result, the Si disk of 14 μ m in diameter could be crystallized by a single shot irradiation. It is worthy to note that although we have used an Al light reflector, it will be replaced by a circular phase-shift mask²⁾. References ¹⁾M. Ozawa, et al: AM-LCD 99, 93. ²⁾C.H. Oh, et al: Jpn. J. Appl. Phys., 37 (1998) 5474.

11:15 AM Q7.4

LOCATION-CONTROLLED LARGE-GRAINS IN NEAR-ABLATION EXCIMER-LASER CRYSTALLIZED SILICON FILMS. Paul Ch. van der Wilt, Ryoichi Ishihara, DIMES, Delft University of Technology, Delft, THE NETHERLANDS.

To make c-Si TFTs with a single-pulse excimer-laser crystallization (ELC) process, it is necessary to irradiate the a-Si film at an energy density at which near-complete melt-through results in super-lateral growth (SLG). Furthermore, the location of the large grains should be controlled. With the heat-sink location-control method [Solid State Phenom. **67 – 68** (1999) 169] we have been able to control the

location of the small unmolten islands from which the large grain growth starts, however, the yield of single large grains was at the most 8%. This can be attributed to the beam non-uniformities causing a variable size of the islands, which will have a variable average number of seeds for large grain growth. In this report, a new method of location-control is proposed that allows for accurate control of the diameter of the unmolten islands. A small diameter (<100 nm) hole in the underlying layer is filled during LPCVD of a-Si to create a locally increased effective thickness, whilst retaining a planar surface. When the film is irradiated above SLG, some unmolten islands remain in the holes. Not only the location but also the size of these islands is now exactly controlled. In a preliminary experiment, the yield of single large grains was 30%. When further increasing the depth of the hole, the film can be irradiated at near-ablation energy density resulting in larger grains more than double the diameter of grains grown in the SLG-regime (e.g. 4 μ m in 140 nm thick films). Grain growth starts at the bottom of the hole and is followed by a vertical growth phase. When growth does start on more than one seed, there will be competitive grain growth dependent on the crystal orientation. At the top of the hole, a single grain appears, resulting in single-grain location-control.

11:30 AM Q7.5

LASER ANNEALING OF SILICON FOR THIN FILM TRANSISTOR APPLICATIONS: DEFECT POPULATION AND ELECTRICAL PROPERTIES. S.H. Christiansen¹, M. Nerdling¹, H.P. Strunk¹, G. Andrae², J. Bergmann², F. Falk². ¹University of Erlangen-Nurnberg, Erlangen, GERMANY, ²Institut für Physikalische Hochtechnologie, Jena, GERMANY.

Melt mediated crystallization of amorphous silicon (a-Si) layers (thickness α 100nm-500nm) on glass is utilized to produce the starting material for thin film transistor applications. The crystallization is carried out with an Ar⁺-laser (Gaussian beam shape, beam diameter of 10⁻³m), which is operated in the continuous wave mode. To utilize lateral epitaxial crystallization, which is a prerequisite to obtain large grained material we scan the laser beam at a velocity of 5cm/sec switching on and off the laser periodically. This experimental setup allows solidification velocities of the melt, that are smaller by a factor of 200 compared to conventional excimer laser crystallization processes. The melt duration time is about 1msec, without however affecting the temperature sensitive glass substrate. As a result we obtain location control of the crystalline, oval shaped areas under optimized energy conditions and via beam shaping (using a 'sickle shaped' beam). For characterizing the crystal structure, optical microscopy, electron back scattering patterns (EBSP) in the scanning electron microscope and convergent beam electron diffraction (CBED) in the transmission electron microscope are applied. Single crystalline oval regions lie in the center of the crystallized area and are as large as 60 μ m in width and several 100 μ m in length, as dependent on the scanning length. About 50% of all ovals are completely defect free. The other 50% contain usually one grain boundary, seldomly two or more. These grain boundaries are usually first or second order twin boundaries. It is well known from bulk material, that generally, in pure material, these twin boundaries do not cause a potential barrier nor show recombination activity. We analyze by resistivity topography, electron beam induced current (EBIC) and Kelvin probe microscopy the electrical properties of these defects and relate defect population to electrical behaviors of defects and this in turn to carrier mobilities. The role of twinning in the laser crystallization process is discussed and a model of twin formation during crystallization is presented.

11:45 AM Q7.6

RELATIONSHIP BETWEEN FLUENCE GRADIENT AND LATERAL GRAIN GROWTH IN DIRECTION AND LOCATION CONTROLLED EXCIMER LASER CRYSTALLIZATION OF a-Si THIN FILMS. Ming-Hong Lee, Seungjae Moon, Costas P. Grigoropoulos, University of California, Dept of Mechanical Engineering, Berkeley, CA; Mutsuko Hatano, Kenkichi Suzuki, Hitachi Ltd., JAPAN.

High-quality polycrystalline Si (poly-Si) thin films with controlled grain size, direction, and location are required in order to improve both the performance and uniformity of poly-Si thin film transistors (TFTs). To accomplish this objective, a number of different excimer laser beam modulation techniques have been devised, utilizing spatially selective melting and lateral fluence modulation. In this study, the fluence distribution was modulated by a beam mask and was measured using a photoresist. Hence, the relationship between the fluence gradient produced by the beam modulation and the lateral growth length was clarified. The samples under investigation were 50 and 100 nm a-Si films deposited by LPCVD on fused quartz substrates. Lateral grain growth was achieved by using an Al beam mask with 20 μ m line patterns placed in a 2:1 projection optical system. The fluence distribution across a line pattern was measured using a negative photoresist exhibiting a linear relationship between laser fluence and resist thickness after development. Utilizing the

mapped fluence distribution it was therefore possible to vary the fluence gradient at the lateral growth region by applying different laser pulse energies. Lateral growth lengths close to 1.0 and 1.5 μm were achieved by a single laser shot without substrate heating for the 50 and 100 nm films respectively by enforcing high fluence gradients. It was found that the lateral growth length increases and the directionality of the grains improves as the fluence gradient increases.

SESSION Q8: TFT III-DEVICES

Chair: S. D. Brotherton
Thursday Afternoon, April 27, 2000
Franciscan II (Argent)

1:30 PM *Q8.1

THIN FILM TRANSISTORS ON PLASTIC SUBSTRATES. Patrick M. Smith, Paul G. Carey and Paul Wickboldt, FlexICs Inc., Mountain View CA; Steven D. Theiss and Thomas W. Sigmon, Lawrence Livermore National Laboratory, Livermore CA.

As amorphous Si TFT-LCD technology has matured, the focus of silicon TFT research has shifted toward poly-Si, and in recent years progress has been made in fabricating poly-Si TFT's directly on plastic substrates. Although glass substrate poly-Si TFT displays are no longer considered novel, the potential benefits of plastic-substrate displays are pushing process temperatures below 250°C and even to 100°C. While high performance poly-Si TFT's (n-channel mobilities in excess of 150 $\text{cm}^2/\text{V}\cdot\text{s}$) can be fabricated on glass and high-temperature plastics at processing temperatures of 250°C and higher, it is only recently that comparable performance has been attained with lower temperature processes (100°C to 150°C). Using polyester substrates and a 100°C process, we have fabricated self-aligned top gate poly-Si TFT's with mobilities of over 100 $\text{cm}^2/\text{V}\cdot\text{s}$. The process incorporates aluminum gates and uses a low-temperature laser doping step to obtain source/drain sheet resistances of 100-200 Ω/square . Recent progress in TFT's on plastic and future prospects will be discussed.

2:00 PM Q8.2

UNIFORM, HIGH PERFORMANCE POLY-Si TFTS FABRICATED BY LASER CRYSTALLIZATION OF PECVD-GROWN a-Si:H. D. Toet, T.W. Sigmon, Lawrence Livermore National Laboratory, Livermore, CA; T. Takehara, C.C. Tsai, W.R. Harshbarger, Applied Komatsu Technology, Santa Clara, CA.

We report the fabrication of uniform, high performance poly-Si thin film transistors (TFTs) using a laser crystallization-based process that does not involve beam manipulation or film pre-patterning and has a maximum temperature of 350°C.

The starting material for this process is 42 nm of amorphous Si grown by plasma-enhanced chemical vapor deposition on 4" glass substrates. These films are exposed to a scanned XeCl excimer laser beam (67% overlap between adjacent pulses) at 350 mJ/cm^2 . At this fluence the Si film completely melts (full melt threshold: 310 mJ/cm^2) and crystallizes in the form of uniformly distributed grains with an average size of 50 nm [1]. Half of the wafers are then subjected to a low fluence laser scan (250 mJ/cm^2 , 50% overlap) that results in a drastic reduction of the surface roughness, as reported previously [1]. Seventy-five sets of 64 top-gate n-channel TFTs with different sizes (W/L) were fabricated, on each wafer, from these poly-Si films, using a 4-step photolithographic process.

Electrical measurements reveal that TFTs fabricated without smoothing procedure have low average OFF-currents of less than 0.7 pA per μm of gate width and an average mobility of about 50 $\text{cm}^2/\text{V}\cdot\text{s}$. Device properties and uniformity show substantial improvement when the smoothing method is used. For example, for "smoothed" TFTs with channel lengths and widths both equal to 10 μm (W/L=10/10), the average mobility is $(182\pm 18) \text{cm}^2/\text{V}\cdot\text{s}$, the average threshold voltage is $(1.0\pm 0.6) \text{V}$, and the average ON-current is $(300\pm 45) \mu\text{A}$. The OFF-currents, however, increase by about an order of magnitude. A detailed discussion of these results and their interpretation will be presented.

[1] D. Toet, P.M. Smith, T.W. Sigmon, T. Takehara, C.C. Tsai, W. R. Harshbarger, and M.O. Thompson, J. Appl. Phys. 85, 7914 (1999).

2:15 PM Q8.3

LOW TEMPERATURE POLY-Si TFTS FABRICATED USING DIRECTIONALLY CRYSTALLIZED Si FILM. Y.H. Jung, J.M. Yoon, M.S. Yang, W.K. Park, H.S. Soh, Anyang Laboratory, LG. Philips LCD Co. Ltd, Dongan-gu, Anyang-shi, Kyungki-do, KOREA; H. Cho, A.B. Limanov and James S. Im, Prog. in Materials Science, Columbia Univ., New York, NY.

It is established that the device characteristics of polycrystalline (poly-Si) TFTs can depend on the microstructural details of the active channel portion of the device. Among the several crystallization

methods that can transform as-deposited amorphous Si on glass substrates to polycrystalline material, SLS is unique in that it can produce either directionally solidified or single-crystal microstructures. In this paper, we report on performance characteristics of non-self aligned, coplanar n- and p-channel low temperature TFTs which have been fabricated using directionally solidified (via SLS) 1000-Å-thick polycrystalline Si films on Corning 1737 glass substrates. The devices were aligned so that the grain boundaries are parallel to the source-drain current flow. Additional details of the device fabrication steps—all of which were performed under 400°C—include: deposition of PECVD a-Si films followed by dehydrogenation; pre-patterning and pre-doping prior to concurrent crystallization and activation via SLS; SLS processing in air and without any preheating; and no explicit hydrogenation of Si (but furnace annealing in a mixed gas atmosphere). A portion of the film was crystallized using a conventional ELA method (average grain size of $\sim 3000 \text{Å}$), to enable a direct comparison of the resulting TFTs.

The characteristics of the SLS TFTs are: μ_{FE} of $\sim 370 \text{cm}^2/\text{V}\cdot\text{sec}$ for n-channel and $\sim 140 \text{cm}^2/\text{V}\cdot\text{sec}$ for p-channel TFTs; $I_{on}/I_{off} > 10^7$ at $V_d=0.1 \text{V}$; leakage currents lower than $10^{-13} \text{A}/\mu\text{m}$ at $V_d=0.1\text{V}$; and subthreshold slopes less than 0.5 V/dec. When compared to the TFTs made on ELA crystallized poly-Si (which were otherwise identically processed), the main differences were higher on-currents and mobilities ($\sim 370 \text{cm}^2/\text{V}\cdot\text{sec}$ vs. $\sim 100 \text{cm}^2/\text{V}\cdot\text{sec}$ for n-channel TFTs and $\sim 140 \text{cm}^2/\text{V}\cdot\text{sec}$ vs. $\sim 60 \text{cm}^2/\text{V}\cdot\text{sec}$ for p-channel devices). We note that due to the long-channel lengths of the devices (ranging from 8 μm to 200 μm), the values of extracted mobilities are not affected by the channel shortening effect. We will discuss physical implications of the results and present additional details of the devices.

2:30 PM Q8.4

LOW-TEMPERATURE LASER-DOPING PROCESS USING PSG AND BSG FILMS FOR POLY-Si TFTS. Cheon-Hong Kim, Sang-Hoon Jung, Juhn-Suk Yoo, Min-Koo Han, School of Electrical Engineering, Seoul National University, Seoul, KOREA.

Polycrystalline silicon thin film transistors (poly-Si TFTs) employing the excimer laser annealing have attracted considerable attention because of possible applications in high quality active matrix liquid crystal displays (AMLCDs). However, the low-temperature doping method for source and drain regions is not well established. The ion implantation or the ion shower doping method requires high-cost complex equipments and the post-annealing is required to activate the dopants after the ion doping. The excimer-laser doping using doping gases or dopant-containing films is a useful method because it is a simple and low-temperature doping process. In case of laser-doping using doping gases, sophisticated gas chamber and control system are required. The purpose of our work is to report a simple low-temperature laser-doping method using phosphosilicate glass (PSG) and borosilicate glass (BSG) films as dopant-containing films. These films have been deposited on amorphous silicon (a-Si) film by chemical vapor deposition (CVD) method, which is compatible to conventional poly-Si TFTs process and easy to achieve uniformity, using SiH_4 , O_2 and PH_3 or B_2H_6 . The deposition temperature was varied from 175°C to 375°C and the dopant concentration in dopant-containing films was controlled by PH_3 or B_2H_6 flow rate. During the XeCl excimer laser irradiation, dopants diffuse into the molten a-Si and thus the doped poly-Si film is successfully formed. We have measured the sheet resistance and the doping profiles of doped poly-Si films. Our experimental results show that the sheet resistance decreased with increase in the laser energy density and the number of laser pulses. The junction depth was increased with laser energy density. The sheet resistance was also controlled by the dopant concentration in dopant-containing films. For n-type doping, we have obtained the sheet resistance of 200 Ω/sq , which is sufficient for source and drain doping. The proposed laser-doping technique using PSG and BSG films is promising for very low temperature (<200°C) poly-Si TFT process.

2:45 PM Q8.5

HIGH VOLTAGE EFFECT IN TOP GATE AMORPHOUS SILICON THIN FILM TRANSISTORS. N. Tosic, F.G. Kuper, T. Mouthaan.

The results of a comprehensive study of the high voltage effect in top gate amorphous silicon Thin Film Transistors (TFT) will be presented, including analyze of the self-heating effect. Experimental results are obtained by means of Transmission Line Model, a standard ESD technique which had to be modified for amorphous silicon TFT's testing. The applied stepped ESD stress creates stepped degradation of electrical parameters (such as lowering of the threshold voltage and increasing of the electron mobility) and at the end catastrophic breakdown. The sub-threshold slope measured between stress pulses shows that creation of positive interface states is responsible for degradation. The created traps are non-equally distributed along the channel length. Influence of distributed interface traps on electrical characteristics is simulated by SILVACO-ATLAS device simulator [1]. Creation of interface states is thermally activated. Annealing at

200°C for 1 hour removes created interface states. The degradation level is different among TFT's with channel length variations at the moment of breakdown. The results suggest that process leading to dielectric breakdown and to degradation is different. In the top gate TFT's, dielectric breakdown appears in two variations. The most often failure mechanism is breakdown of gate dielectric. It appears as a rupture of dielectric localized close to the drain, with a center at the edge between drain and channel (with exception of short channel devices, where the rupture completely covers channel length). The size of the rupture is analyzed and the result indicates that the breakdown is a high temperature event. The center of the rupture indicates the position of the highest temperature (peak of temperature distribution). After inspection of failed devices the assumption is made that the temperature peak should be located at the edge between drain and channel. The temperature distribution over TFT's area is simulated by means of electrothermal simulations performed by PSTAR circuit simulator. Simulation shows that the peak of distribution is located at the drain/channel edge. [1] N. Tosic, F.G. Kuper, T. Mouthaan, paper submitted for IRPS 2000 Conference. Acknowledgment: We acknowledge Jeremy Sandoe, John Hughes and Steve Deane, from Philips Research Laboratories, Redhill, U.K for help with electrothermal simulations.

3:00 PM Q8.6

PLASTIC DEFORMATION OF THIN FOIL SUBSTRATES WITH AMORPHOUS SILICON ISLANDS INTO SPHERICAL SHAPES. P.I. Hsu, M. Huang, S. Wagner, Z. Suo, J.C. Sturm, Center for Photonics and Optoelectronic Materials, Princeton University, Princeton, NJ.

There is a growing interest in the application of large area electronics on curved surfaces. One approach towards realizing this goal is to fabricate circuits on planar substrates of thin plastic or metal foil, which can subsequently be deformed to arbitrary shapes. The major challenge is that inorganic semiconductor materials and dielectrics are brittle. Both of these materials may fracture once the substrate experiences a tensile strain that exceeds 0.5%. Previous work has demonstrated amorphous silicon TFTs on rolled metal foils [1]. In this case, the strain is reduced by using thinner substrates. The more challenging problem that we consider here involves deforming substrates into a spherical shape, where the strain is determined by geometry and cannot be reduced by simply using a thinner substrate. The issue is to achieve plastic deformation in the substrates (for permanent deformation) without exceeding fracture or buckling limits in the device materials. Our experiments consist of the planar fabrication of amorphous silicon device structures on stainless steel or Kapton(R) polyimide substrates, followed by permanent deformation into a spherical shape. We will present both mechanical modeling and experiments showing the dependence of the results on the substrate type, island/line size of the device materials, and the deformation temperature. We have achieved the deformation of Kapton(R) polyimide substrates with $\sim 100 \mu\text{m}$ wide amorphous silicon islands into a one steradian spherical cap, which subtends 66 degrees, without degradation of the silicon. This was possible despite a 5% average biaxial strain in the substrate after it was deformed. Continuous metal interconnections between islands after deformation have also been achieved. The results of ongoing fabrication of complete devices and circuits will also be discussed. [1] E.Y. Ma, S.D. Theiss, M. H. Lu, C.C. Wu, J.C Sturm, S. Wagner, "Thin Film Transistors For Foldable Displays," IEDM '97 Tech. Dig., Paper 20.6.1, pp. 535-538.

SESSION Q9: IN-ROOM POSTERS: TFT IV: PROCESSES AND DEVICES

Chairs: Alexander B. Limanov and Silke H. Christiansen
Thursday Afternoon, April 27, 2000
3:45 PM
Franciscan I (Argent)

Q9.1

CRYSTALLIZATION OF AMORPHOUS Si FILMS USING A VISCOUS Ni SOLUTION. Jin Hyung Ahn, Sung Chul Kim, Byung Tae Ahn, Korea Advanced Institute of Science and Technology, Dept of Materials Science and Engineering, Taejon, KOREA.

Annealing of a-Si films with a metal on its surface is a method to lower the crystallization temperature of a-Si films. Metals can be adsorbed on a-Si films using metal solutions both chemically and physically. Metal solutions are generally prepared by dissolving a metal compound into a diluted acid. The adsorption of metal on Si from the metal solutions is dominated by electrochemical reaction. Thus, metals of which electronegativity are not larger than Si (Al, Ni, etc.) cannot be directly adsorbed enough on the a-Si surface. These metals can also be adsorbed physically by drying the solution on the a-Si surface. But the solutions exist on the surface in forms of droplet because Si surface is hydrophobic, resulting in non-uniform

adsorption. In this study we prepared a Ni solution by dissolving NiCl_2 in 1M HCl and mixing it with propylene glycol. Propylene glycol is used to make the solution viscous. The viscous metal solution provided a uniform spin-coated film and a uniform physical metal adsorption after oven dry. The LPCVD a-Si film coated with Ni from the solution containing propylene glycol completely crystallized in 5h at 550°C, while the film coated with Ni from the solution with only HCl completely crystallized after 30h at 600°C, we further lowered the crystallization temperature down to 495°C by microwave heating for 5 h. The crystallization behaviors are under investigation and will be presented.

Q9.2

TOP GATE SELF-ALIGNED $\mu\text{c-Si}$ TFTs USING LAYER-BY-LAYER METHOD AND IONDOPING METHOD. Yuki Nakata, Sharp Labs of America, LCD Process Tech. Dep., Camas, WA; Yasuaki Murata, Masaya Hijikigawa, SHARP Corporation, LCD Development Group, Nara, JAPAN.

a-Si TFTs are usually used for large size LCD panels, but its mobility is small such as $0.5 \text{ cm}^2/\text{Vs}$. In the opposite, Poly-Si TFTs have larger mobility, such as more than $100 \text{ cm}^2/\text{Vs}$, but there are many issues of Poly-Si TFTs in order to apply to large size LCD panels. Therefore, it is expected for new materials to easily apply to large size LCD with high mobility. One of the candidate is microcrystal Si ($\mu\text{c-Si}$). However incubation layer is necessary and the crystallinity is improved as increasing of the film in the case of $\mu\text{c-Si}$ deposition. Therefore, Layer-by-Layer method is used in order to get the high quality $\mu\text{c-Si}$ from the thin layer. And iondoping method is used to make the top gate self-aligned $\mu\text{c-Si}$ TFTs with the channel at the top of the high quality $\mu\text{c-Si}$. As the Layer-by-Layer method, H_2 gas is flowed continuously, SiH_4 gas is turned on and off periodically for a-Si deposition and hydrogen plasma treatment. Dependencies of a-Si film thickness of one time, hydrogen treatment time and total film thickness on the conductivity of $\mu\text{c-Si}$ are investigated in order to optimize the Layer-by-Layer method. As the result, good quality $\mu\text{c-Si}$ films can be obtained at 600 \AA by Layer-by-Layer method compared with Si films without hydrogen plasma treatments. By iondoping to I-type $\mu\text{c-Si}$, dependence of $\mu\text{c-Si}$ quality and cap layer thickness on the resistivity are investigated. As the results, n+-type $\mu\text{c-Si}$ with low resistivity of 4 ohm cm can be obtained. This resistivity is 3 order lower than it of n+-type a-Si. By combination of the Layer-by-Layer method and Ion doping method, top gate self-aligned $\mu\text{c-Si}$ TFTs are made. The mobility of the $\mu\text{c-Si}$ TFT with 800 \AA thickness of the channel is $1.3 \text{ cm}^2/\text{Vs}$, which is more than twice of a-Si TFT. $\mu\text{c-Si}$ TFT is very promising technology for large LCD with requirement of high mobility.

Q9.3

Nd:YVO₄ LASER CRYSTALLIZATION FOR THIN FILM TRANSISTORS WITH A HIGH MOBILITY. Ralf Dassow, Juergen R. Koehler, Juergen H. Werner, Universitaet Stuttgart, Institut fuer Physikalische Elektronik, Stuttgart, GERMANY; Youri Helen, Karine Mourgues, Olivier Bonnaud, Tayeb Mohammed-Brahim, Groupe de Microélectronique et Visualisation Université de Rennes 1, Rennes Cedex, FRANCE.

Future generations of large area electronics such as active matrix liquid crystal displays, imaging units or thin film solar cells require large grained polycrystalline silicon on cheap and/or transparent substrates (e. g. glass). Homogeneous device properties are required over the whole substrate area. To fabricate the polycrystalline film, we crystallize amorphous silicon with a frequency doubled Nd:YVO₄ laser. A sequential lateral solidification process yields polycrystalline silicon with grains longer than $100 \mu\text{m}$ and a width of approximately $1 \mu\text{m}$. The grains have the same size over the whole crystallized area of 25 cm^2 . This homogeneity is the result of the crystallization process which tolerates variations of the laser beam energy density of up to 20 %. Thin film transistors fabricated from the polycrystalline films have an average field effect mobility of $410 \text{ cm}^2/\text{Vs}$. As a result of the homogeneous grain size, the standard deviation of the mobility is only 5 %. A calculation of the potential crystallization rate of $35 \text{ cm}^2/\text{s}$ shows that the process could compete with the throughput of existing excimer laser crystallization processes.

Q9.4

LOCATION CONTROL OF LATERALLY COLUMNAR Si GRAINS BY DUAL-BEAM EXCIMER-LASER MELTING OF Si THIN-FILM. Ryoichi Ishihara, Delft Univ. Technology, DIMES-ECTM, Delft, THE NETHERLANDS.

Location control of a large Si grain is essential to produce crystal-Si TFTs on glass. In this study, a novel two-dimensional location control of large Si grains is proposed using a lateral heat flow at edge of Si / SiO_2 / metal structure on glass. $100 \mu\text{m}$ wide island of a-Si (100nm) / SiO_2 (550nm) / TiW (550nm) is formed on glass with an offset of TiW with a length of $0.5 \mu\text{m}$ at the edge by over-etching of a-Si and

SiO₂ layers. Two XeCl excimer-laser lights were irradiated to both front and backside of the sample. The TiW offset absorbs the two laser-lights from front and backside resulting in higher temperature compared with that covered with SiO₂ and a-Si. With a wide range of irradiated energy densities, laterally columnar Si grains with a length of 3.5 μm were grown from the inside of the island, which experienced near complete melting, towards the edge that was completely melted due to lateral heat flow from an extra heat source in the TiW offset. With an irradiated energy density higher than that for super-lateral growth (SLG) inside the island, Si grains having numerous petals with a length of 2 μm were obtained in the island. The petal-shaped grain has a defective portion in the center that seems to be a nucleation point from supercooled liquid Si. At the edge of the islands, the petals also grew perpendicular to the edge of the island resulting in a laterally columnar petal with a length of 5 μm. Electron backscatter pattern (EBSP) measurement indicates that the laterally columnar petals, which survived competitive grain growth, have surface texture with low index numbers.

Q9.5

CRYSTAL GROWTH OF LASER ANNEALED POLYCRYSTALLINE SILICON AS A FUNCTION OF HYDROGEN CONTENT OF PRECURSORS. Takuo Tamura, Kiyoshi Ogata, Hitachi Ltd., Production Engineering Research Laboratory, Yokohama, JAPAN; Michiko Takahashi, Kenkichi Suzuki, Hitachi Ltd., Image-Related Device Development Center, Displays, Mobaru, JAPAN.

Laser annealed (LA) polycrystalline silicon is important for TFT-LCD applications. A crystallization behavior by LA was investigated to realize a good quality polycrystalline silicon film. Amorphous silicon films with thickness of 50 nm were prepared by plasma-enhanced chemical vapor deposition (PECVD) and low pressure chemical vapor deposition (LPCVD) on SiO₂ substrates. The PECVD films were annealed in furnace for dehydrogenation. Hydrogen content of the precursors was analyzed by SIMS measurement. The precursor films were crystallized by excimer laser irradiation. Grain size of these polycrystalline silicon films was observed by using AFM and SEM. Crystal orientation and d-spacing of the silicon films were analyzed by X-ray diffraction measurement. Intensity ratio of 111 to 220 was used as an index of (111) preferred orientation. Random oriented film with index of 2 at lower energy density had changed to highly (111) oriented phase with index of more than 20 at higher energy density. The increase of orientation index was in good accordance with grain size of the silicon film, therefore the random oriented grains should have grown laterally by secondary crystal growth or zone melting growth with higher energy density. While PECVD films were observed, increasing hydrogen in precursor films decreased the orientation index. The silicon film with hydrogen content of 1.2% and 0.8% showed the indices of 20 and 27 respectively. The LPCVD film with 0.1% hydrogen showed the index of 25 after laser annealing at higher energy density. It was proved that the film had similar crystal growth rate to the dehydrogenated PECVD film. (111) d-spacing of the laser annealed LPCVD silicon was found to be 0.3% smaller than that of the PECVD silicon. It is estimated that the LPCVD deposited precursor with low hydrogen content crystallized to have denser network structure by laser annealing.

Q9.6

INTRAGRAIN DEFECTS IN SEQUENTIAL LATERAL SOLIDIFICATION PROCESSED Si FILMS. M.A. Crowder, D. Kim, A.B. Limanov and James S. Im, Program in Materials Science and Engineering, Columbia University, New York, NY.

Sequential lateral solidification (SLS) is a crystallization method that permits flexible control of grain boundaries during crystal growth of thin Si films; this capability can be used in order to produce low defect-density crystalline Si films with various microstructures. In crystallization processes in general, there can potentially be a variety of intragranular structural defects that may form during the growth. In this paper, we focus on identifying and analyzing primary intragrain defects that can be found in SLS crystallized Si films. It is found that the most prevalent intragrain corresponds to sub-grain boundaries (i.e., low-angle grain boundaries). Twin boundaries represent an additional intragrain defect which can, on occasion, be observed in SLS crystallized materials. The sub-grain boundaries appear when the width of a grain becomes large, and highly twinned grains tend to appear more frequently in thicker films (≥ 2000 Å thick).

We report on two additional trends that have been identified in the formation of these intragrain defects: 1) as the thickness of the film decreases, the average spacing between the sub-grain boundaries decreases and the appearance of grains with high densities of twins decreases, and 2) upon utilizing a shorter pulse length laser (16 ns vs. 32 ns) with relatively thin films (≤ 1000 Å thick), twin boundaries appear uniformly throughout the crystallized film. We discuss the origin of these defects in terms of the following factors: stress arising

from lateral thermal gradients, in the case of sub-grain boundaries; crystallographic orientation of the growth front and/or defect mediated growth mechanism that becomes operational at high interface velocities (above the epitaxial growth velocity but below the amorphization threshold), in the case of twin boundaries. Based on these concepts, we discuss possible steps that can be implemented to alleviate their presence.

This work was supported by DARPA under project N66001-98-1-8913.

Q9.7

CRYSTALLIZATION OF PECVD, LPCVD, AND SPUTTER DEPOSITED Si FILMS VIA SLS. M.A. Crowder, Robert S. Sposili, A.B. Limanov and James S. Im, Prog. in Materials Science and Engineering, Columbia Univ., New York, NY.

One enabling characteristic of the sequential lateral solidification (SLS) process—a method that can produce low defect-density crystalline Si films—is that it is compatible with low-cost, low-temperature substrates. As such, it is important to evaluate the applicability of the SLS method to those films that can be deposited using low-temperature techniques (e.g., PECVD, sputter-deposited films, and LPCVD via disilane decomposition). In general, as these films can contain different concentrations of impurities, varying degrees of structural relaxation, and different distributions of microcrystals, it is conceivable that the crystallization characteristics and resulting microstructures may not be identical. In this paper, we show that the results of parametric analysis of SLS on PECVD, sputter-deposited, and LPCVD (via disilane decomposition) films reveal that there are no major differences in both the process characteristics and the resulting microstructure (provided that the films are dehydrogenated in the case of PECVD a-Si). The experimental details include: 1) projection irradiation of the films using a straight slit, 2) varying the incident energy density and per-pulse translation distance, and 3) analyzing the microstructures using SEM, TEM, and optical microscopy. We discuss how these findings can be attributed to the fact that the SLS method involves — as one of its essential features — complete melting of the Si film, during which the premelting microstructural/phase details are erased. This work was supported by DARPA under project N66001-98-1-8913.

Q9.8

NEW EXCIMER LASER CRYSTALLIZATION SYSTEM FOR CONDUCTING THE SEQUENTIAL LATERAL SOLIDIFICATION (SLS) PROCESS. Robert S. Sposili, M.A. Crowder and James S. Im, Program in Materials Science, Columbia University, New York, NY.

Sequential lateral solidification (SLS) is a pulsed-laser crystallization process that can produce a number of low-defect-density crystalline microstructures that can be useful for a number of microelectronic applications. To date, it has been shown that (1) a variety of microstructurally optimized materials, such as those consisting of directionally solidified or single-crystal microstructures, can be obtained; (2) the process can be effectively implemented because it is relatively insensitive to variations in the processing parameters; and (3) the characteristics of TFT devices fabricated using the material are superior to those that can be obtained using other crystallization techniques.

In order to perform more careful, quantitative experiments, and to demonstrate the technological viability of the method, we have designed and constructed a new SLS system that contains a number of important features; while built primarily for research purposes, this system can also be viewed as a prototype of a production-class system, which can, for example, be utilized in the production of TFT-based products such as active-matrix liquid-crystal displays (AMLCDs). The system, which bears some similarity to excimer laser irradiation systems utilized in photolithography, micromachining, and projection GILD, consists of a high-repetition-rate, high-power excimer laser operating at 308 nm; two-axis projection-irradiation beam-shaping optics, including a 9 × 9-element multi-lenslet homogenizer; in situ video observation of the substrate and mask; and high-precision mask and sample translation stages, including an ultra-high-precision air-bearing/linear motor stage with vertical-axis translation capability. The system also incorporates a novel energy density-modulation unit that can be used to planarize the surface of the films and block stray beams, as well as for other purposes. The system is fully integrated such that computer control allows for coordinated operation of the various elements, enabling automated experimentation and large-area crystallization. We will also present recent results obtained using the system.

Q9.9

PULSED LASER INDUCED MELTING AND SOLIDIFICATION OF ULTRA-THIN a-Si FILMS. H.S. Cho, D.B. Kim, A.B. Limanov, M.A. Crowder, and James S. Im, Program in Materials Science and Engineering, Columbia University, New York, NY.

Pulsed laser irradiation of ultra-thin (thickness below 500Å) a-Si films

is of technological interest for the fabrication of microelectronic devices, as well as for the investigation of far-from equilibrium phase transformation scenarios.

In this study, ultra-thin films were irradiated using a 308 nm wavelength excimer laser at various energy densities. Three experiments were performed: (1) irradiation of large areas with a beam of uniform energy density; (2) irradiation of selected narrow regions (5 μm wide), using projected masked slits to induce controlled super-lateral growth (C-SLG); and (3) parametric analysis of the sequential lateral solidification (SLS) method. The resulting microstructures were studied using optical, SEM, and TEM microscopy, and experiment (1) was monitored in situ using transient reflectivity analysis.

The most notable result, corresponding to the study of C-SLG, was that the lateral crystal growth distance was substantially small compared to that of thicker films. The theoretical model of the SLG phenomenon [1] predicts, and identifies several factors that account for, the observed decrease. These are, (1) the prompt onset of nucleation in the completely melted region due to the lower thermal mass and subsequent rapid quenching; (2) substantially reduced interfacial recalescence; and (3) breakdown of crystalline epitaxial growth and ensuing interfacial amorphization. We will discuss a quantitative analysis using numerical simulations that corroborate the experimental observations and support the above interpretation. As a consequence of the much-reduced lateral crystal growth distances, the SLS process requires a very small per-pulse translation distance ($\sim 0.1 \mu\text{m}$) to produce continuous directionally crystallized material. Nonetheless, this study demonstrates that SLS can be implemented to directionally crystallize ultra-thin films, and further suggests that longer pulse duration and/or substrate heating may enhance the SLS process.

This work was supported by DARPA under project N66001-98-1-8913.

Q9.10

THE REQUIREMENTS, DEFINITIONS, ANALYSIS AND OPTIMIZATION OF CONTROLLED SUPERLATERAL GROWTH (C-SLG) PROCESSES. James S. Im, D.B. Kim, A.B. Limanov, J.P. Leonard, R.S. Sposili and S.Y. Kang, Dept. of Materials Science and Engineering, Columbia University, New York, NY.

The controlled super-lateral growth (C-SLG) method is a particular form of pulsed-laser crystallization process that is currently being investigated and successfully implemented by a number of research groups. As it happens, the method is revealing itself to be both flexible (in regards to various technical schemes through which it can be implemented) and effective (in yielding low-defect density materials with predictable microstructures). As well, the method appears to be more general in its applicability than originally envisioned; it appears to be capable of being implemented not only for Si, SiGe, and Ge films on oxide-coated substrates, but also to a selected combination of other films and substrates as well.

In this paper, we will start by reviewing and discussing the fundamentals and current status of the C SLG method; we will then present results from our C-SLG work that quantitatively aid in characterizing and optimizing the method. Specifically, we will address: (1) the basic definition of the method (i.e., what C-SLG is and what C-SLG is not); (2) the requirements that are essential vs. the features that are incidental; (3) the physical factors (i.e., internal parameters) that control rapid melting and solidification of the films; and (4) the technical details and major external parameters that, along with the internal parameters, dictate the microstructural outcome of the process. We will also present recent results from experimental and numerical analyses that reveal the dependence of the microstructural outcome on parametric variations of, among other variables, film thickness, incident energy density, and pulse duration. We will conclude by discussing (1) the pros and cons associated with various technical schemes that have been proposed to induce C-SLG of Si films, and (2) a sensible and enabling extension to sequential lateral solidification (SLS) of Si films.

Q9.11

HIGH-PERFORMANCE POLY-Si TFTS WITH MULTIPLE SELECTIVELY DOPED REGIONS IN ACTIVE LAYER.

Min-Cheol Lee, Juhn-Suk Yoo, Kee-Chan Park, Sang-Hoon Jung, Min-Koo Han, Seoul Nat'l Univ., School of Electrical Engr, Seoul, KOREA.

Poly-Si TFTs fabricated by excimer laser annealing are promising device for active matrix liquid crystal display (AMLCD) application. One of the problems in poly-Si TFTs is relatively large leakage current which degrade display quality. In order to reduce the leakage current, several device structures have been reported such as undoped-offset structure, LDD structure and GO-LDD. However, ON-current is sacrificed considerably due to the addition of the series resistance in these structures. The purpose of this paper is to report a new poly-Si TFTs in order to reduce leakage current considerably. In the active layer of proposed TFTs, multiple selectively doped regions

in a stripe shape are regularly arranged and their dopant concentration is equivalent to that of source/drain. The direction of the stripe is perpendicular to the channel direction and width/gap size of the stripe is limited to 1-2 micrometer. Under OFF-state, the lateral electric field of proposed TFT is partially applied in multiple depletion regions, which are formed at undoped/doped region interface in active layer. Therefore the electric field induced at drain junction is considerably reduced and leakage current is also reduced. Under ON-state, ON-current could be increased because effective channel length is considerably decreased. In experimental data, leakage current is 2 order lower than that of the conventional TFT and ON-current is 0.3mA which is 4 times higher than that of the conventional one when W/L of the measured TFTs is 10/10 micrometer and width/gap of doped regions in proposed TFT is 1/1 micrometer. The simple process is another merit of the proposed TFTs, that is, the selectively doped region and source/drain doping could be achieved by one ion-implantation or ion-shower step simultaneously. In addition, the following recrystallization of a-Si film and the activation of impurity ions are simultaneously achieved by excimer laser irradiation, while two laser irradiation steps are needed for the crystallization of a-Si film and for the activation of the impurity in conventional TFT.

Q9.12

OXIDE CHARGING EFFECTS BY PH₃/He ION SHOWER DOPING. Cheon-Hong Kim, Juhn-Suk Yoo, Kee-Chan Park, Min-Koo Han, School of Electrical Engineering, Seoul National University, Seoul, KOREA.

Polycrystalline silicon (poly-Si) thin film transistor (TFT) employing the excimer laser annealing is a promising device for active matrix liquid crystal displays (AMLCDs). For source and drain doping, the ion shower doping using a broad ion beam without mass separation and beam scanning is widely used. It is well known that long-term plasma treatment usually causes electrostatic charging damages to the integrity of gate oxide. However, the oxide charging effects by ion shower doping have been reported scarcely. Unlike conventional plasma treatment, ions diffused from the plasma region to a mesh are accelerated by a potential difference between the mesh and a sample stage and are radiated onto samples in the ion shower apparatus. The purpose of this work is to report the oxide charging effects on metal oxide semiconductor (MOS) structure caused by PH₃/He ion shower doping. Plasma-enhanced tetra-ethyl-ortho-silicate (PETEOS) film was deposited on p-type Si wafer with the resistivity of 10 $\Omega\cdot\text{cm}$. The thickness of PETEOS films was 40nm and 80nm. The PH₃/He ion shower doping was performed for some samples using RF plasma source at room temperature. The ion current density was fixed at 20 $\mu\text{A}/\text{cm}^2$ and the acceleration voltage was 3kV. The ion doping time was varied from 10min to 20min. After Al metallization, we have investigated high frequency (1MHz) capacitance-voltage (C-V) characteristics. The parallel negative shift of flat-band voltage occurred for ion-doped PETEOS samples. When the ion dose was higher, this shift was larger. When the ion dose was 7.5 $\times 10^{16}\text{cm}^{-2}$ and the thickness of PETEOS was 80nm, the shift of flat-band voltage was larger than -7V. These results show that many positive ions exist inside the oxide films after ion shower doping process. Even after thermal annealing at 400 $^{\circ}\text{C}$ for 2hours, which is required to activate dopants in semiconductors, the positive ions remained considerably.

Q9.13

DEGRADATION OF PASSIVATED AND NON-PASSIVATED LOW-TEMPERATURE N-CHANNEL POLYCRYSTALLINE SILICON TFTs. Chun-Yao Huang, Ching-Wei Lin and Huang-Chung Cheng, Department of Electronics Engineering & Institute of Electronics, National Chiao-Tung University, Hsin-Chu, TAIWAN.

Degradation mechanisms of passivated and non-passivated n-channel polycrystalline silicon thin-film transistors (TFTs) prepared by conventional furnace annealing (CFA) and excimer laser annealing (ELA) processes have been investigated. The instability phenomena of devices are revealed by different stress conditions such as gate bias stress, hot carrier stress, and high current stress. It is found the states created at poly-Si/oxide interface and/or in the bulk of poly-Si layer accompanied with charged trapping in oxide. However, there are distinct instability mechanisms between plasma passivated and non-passivated poly-Si TFTs. The plasma-passivated devices show bias annealing effect under positive gate bias stress due to H⁺ and/or N⁺ ion drifting from oxide to poly-Si channel by electric field enhance. For the hot carrier stress, the characteristics of plasma passivated TFTs are degraded more seriously than the non-passivated ones. It could be the trap state creation due to bond breaking of H-Si and N-Si in plasma passivated poly-Si films as well as the breaking of Si weak bonds. For the high current stress, it shows the opposite results against hot carrier stress. The possible reason is that the conducting electrons have lower energy in high current stress mode than hot electrons in hot carrier stress mode. That makes less created states (Maybe, only the Si-Si weak bond is broken). Another possible

reason is that states created by high current flow are passivated by residue of H and/or N drifting from oxide to poly-Si channel by electric field enhance. In addition, the Bias-Temperature-Stress (BTS) will be introduced to realize the instability mechanisms in detail.

Q9.14

THE DEPENDENCE OF POLY-Si TFT CHARACTERISTICS ON THE RELATIVE MISORIENTATION BETWEEN GRAIN BOUNDARIES AND THE ACTIVE CHANNEL. Y.H. Jung, J.M.

Yoon, M.S. Yang, W.K. Park, H.S. Soh, Anyang Laboratory, LG. Philips LCD Co., Ltd., Hogae-dong, Dongan-gu, Anyang-shi, Kyungki-do, KOREA; H. Cho, A.B. Limanov and James S. Im, Prog. in Materials Science, Columbia University, New York, NY.

One of the low-defect-density materials that can be readily generated via sequential lateral solidification (SLS) of Si films is to polycrystalline Si (poly-Si) films with a directionally solidified microstructure. For TFTs that are fabricated on materials with such a microstructure (which essentially consists of long and parallel grains), the relative misorientation between the grain boundaries and the active channel orientation of the devices is expected to affect at least some aspects of the resulting TFT characteristics. Quantitative characterization of such a dependence can be of interest not only for acquiring a better understanding of device physics, but can also have technical ramifications for actual utilization of the material.

In this paper, we present device-related experimental results that quantitatively reveal the effect of varying the active channel/grain boundary misorientation on the resulting TFT characteristics. Specifically, using low-temperature (less than 400°C) and SLS processes, we have fabricated and analyzed n-channel and p-channel devices (40 μm wide x 8 μm long) with three relative orientations (parallel, 45° inclined, and perpendicular) on Corning 1737 glass substrates.

The results reveal, not surprisingly, that the TFTs with the best (worst) characteristics were obtained for the devices with parallel (perpendicular) alignment. In general, for both n-channel and p-channel devices, the most prominent orientation effects were observed in the on-currents and field effect mobilities (e.g., 340 cm²/Vsec, 227 cm²/Vsec, and 141 cm²/Vsec for n-channel transistors, and 145 cm²/Vsec, 105 cm²/Vsec, and 80 cm²/Vsec for p-channel transistors). In contrast, no notable effect was manifested in the leakage currents (e.g., ~5 × 10⁻¹⁴ A/μm for n-channel and ~2.5 × 10⁻¹⁴ A/μm for p-channel devices with V_d=0.1V), and small effects were seen for the subthreshold slopes and threshold voltages, particularly for the perpendicularly aligned transistors. We will discuss the technical and fundamental implications and inferences of the results.

Q9.15

CHARACTERIZATIONS OF ELA-PROCESSED P-Si THIN FILMS AND COMPARISON WITH TFT CHARACTERISTICS.

Sung Kyun Yim, Kook Chul Moon, Pilmo Choi, Hoonkee Min,
Samsung Electronics, Kyunggi-do, SOUTH KOREA.

We measured the orientation of ELA-prepared p-Si with XRD. The (111) orientation gets stronger with the crystallization energy density (CED) and this had the same trend as the grain size. But the TFT characteristics, including I_{on} and I_{off}, showed different behavior over some critical CED. We infer that the crystals get more oriented in the grain and more disoriented at the grain boundary, giving bad effects on the TFT characteristics, over some critical CED. This was confirmed by ellipsometry, which showed the same behavior as TFT characteristics.