SYMPOSIUM NN
Materials for Space Applications

November 29 - December 3, 2004

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Proceedings to be published in both
book form and online
(see ONLINE PUBLICATIONS at www.mrs.org)
as volume 851
of the Materials Research Society
Symposium Proceedings Series.

* Invited paper
Ceramic foams are a class of porous materials with unique physical, thermal, electrical and chemical properties. A novel foaming method demonstrated that the cell morphology and the microstructure of composite foams can easily be tailored by a molecular approach. Thermofoil foams were manufactured from a specific poly(silsesquioxane) as a preceramic polymer which was loaded with 30-70 wt. % of a blend of Si and SiC. The foaming process was carried out in the temperature range from 220 to 270 degrees C. The driving force of the foam formation is a condensation reaction of hydroxy and alkoxys of the preceramic polymer activated at the foaming temperature. Simultaneously, a viscosity increase due to curing reactions stabilizes the foam structure. The morphology of the foam was controlled by the foaming temperature. Foaming at temperatures of 270-300 degree C resulted in isotropic foams with a narrow cell size distribution with average cell sizes ranging from 0.5 to 2.0 mm. Foaming temperatures of 250-240 degree C lead to a structure with gradient porosity with the porosity varying linearly from 90 % to 40 %. Concurrently, the structure changed from completely open celled to close celled. The transition is accompanied by a permeability drop from 2.90 x 10^6 to 5 x 10^5, an exponential decay of the surface/volume ratio (16 mm^-1 to 2 mm^-1) and the connectivity density (3.9 mm^-3 to 0.1 mm^-3). The mean strut thickness rose from 0.2 to 1.0 mm, the cell diameter increased from 1.0 mm showing a spherical shape to 1.6 mm with a flattened shape. The thermal and mechanical properties were varied by changing the filler amount and the pyrolysis conditions. The electrical resistance was adjusted by pyrolysis temperature control between 10^-14 Wcm at 660 degrees C and 1 Wcm at 1600 degree C. High strength ceramic foams with compression strength exceeding 4 MPa and exceptional reliability at a porosity of 75 % were obtained from foams with a filler load of 60 wt. %. The thermal conductivity ranged between 0.15 and 0.45 W/mK, the coefficient of thermal expansion was adjustable via filler load, between 4 and 10 ppm/K. The thermal shock resistance was remarkably high reaching R > 1000 degrees C.

2:00 PM **NN1.2**

**Polymer derived ceramic foams for light weight applications.**

Jacek Zeschky1, Michael Schellinger2, Thomas Hofschat3, Claudia Arnold1, Nahum Trivizakis3, Peter Greil4 and Rajendra K. Bordia2.

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Ceramic foams are a class of porous materials with unique physical, thermal, electrical and chemical properties. A novel foaming method demonstrated that the cell morphology and the microstructure of composite foams can easily be tailored by a molecular approach. Thermofoil foams were manufactured from a specific poly(silsesquioxane) as a preceramic polymer which was loaded with 30-70 wt. % of a blend of Si and SiC. The foaming process was carried out in the temperature range from 220 to 270 degrees C. The driving force of the foam formation is a condensation reaction of hydroxy and alkoxys of the preceramic polymer activated at the foaming temperature. Simultaneously, a viscosity increase due to curing reactions stabilizes the foam structure. The morphology of the foam was controlled by the foaming temperature. Foaming at temperatures of 270-300 degree C resulted in isotropic foams with a narrow cell size distribution with average cell sizes ranging from 0.5 to 2.0 mm. Foaming temperatures of 250-240 degree C lead to a structure with gradient porosity with the porosity varying linearly from 90 % to 40 %. Concurrently, the structure changed from completely open celled to close celled. The transition is accompanied by a permeability drop from 2.90 x 10^6 to 5 x 10^5, an exponential decay of the surface/volume ratio (16 mm^-1 to 2 mm^-1) and the connectivity density (3.9 mm^-3 to 0.1 mm^-3). The mean strut thickness rose from 0.2 to 1.0 mm, the cell diameter increased from 1.0 mm showing a spherical shape to 1.6 mm with a flattened shape. The thermal and mechanical properties were varied by changing the filler amount and the pyrolysis conditions. The electrical resistance was adjusted by pyrolysis temperature control between 10^-14 Wcm at 660 degrees C and 1 Wcm at 1600 degree C. High strength ceramic foams with compression strength exceeding 4 MPa and exceptional reliability at a porosity of 75 % were obtained from foams with a filler load of 60 wt. %. The thermal conductivity ranged between 0.15 and 0.45 W/mK, the coefficient of thermal expansion was adjustable via filler load, between 4 and 10 ppm/K. The thermal shock resistance was remarkably high reaching R > 1000 degrees C.

2:05 PM **NN1.3**

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The degradation of thin polymer films is of major concern to designers of smart structures. However, assessment of relevant properties is not so simple because the determination of mechanical properties is complicated by the time-dependent response. Dynamic analysis techniques, such as dynamic mechanical thermal analysis (DMTA) can be used to characterize the viscoelastic properties of bulk polymers but this is not applicable to thin films. Nanoindentation is one of the methods able to determine the properties of thin films but has generally only been used to measure static properties. More recently dynamic nanoindentation with a heating stage has been developed. Most nanoindentation studies have concentrated on composites and nanocomposites based on polymeric matrices. Far more recently, dynamic nanoindentation with a heating stage has been developed. The data-sets were processed using the WLF equation to determine the tan δ thermogram and a glass transition temperature. DMTA was therefore be conducted isothermally at the selected temperature, while the frequency was ramped in steps of 2-5Hz from 10 to 100Hz. The data-sets were processed using the WLF equation to determine the considered geometry. However, the situation is slightly more complicated for mechanical properties, such as Young’s modulus. A key limitation of the Bruggeman theory is that the underlying equations are macroscopic. For example, the elasticity of a fiber composite depends on the volume fraction of the fibers but is independent of the fiber radius. When specific length scales are involved, then there are nontrivial corrections to the Bruggeman behavior. Examples are Doeb-Hückel corrections in liquids and exchange-length corrections in hard- and soft-magnetic materials. Focusing on the magnetic analogy [3], we analyze the structure of these corrections and show how they affect the materials properties of the composite. The simplest case, the difference between Bruggeman and non-Bruggeman regimes is analogous to the difference between the Coulomb and Yukawa potentials in particle physics, and the corresponding Yukawa screening length limits the applicability of the Bruggeman theory. Finally, we briefly discuss some aspects of a Bruggeman theory of multifunctional materials with interactions involving two or more physical properties, such as magnetoelastic coupling. This work is supported by NSF-MCBIC, the W. M. Keck foundation, AFOSR and ARO. [1] D. A. G. Bruggeman, Ann. Physik 272-276, 1476 (2004). [2] R. M. Christensen, “Mechanics of Composite Materials”, Wiley, New York 1979. [3] R. Slomski, J. Magn. Magn. Mater. 272-270, 1476 (2004).
work is presently being extended to include other carbon-based materials such as diamond; quantified the pathways by which organic molecules and films react with atomic oxygen & radiation commensurate with solar illumination in LEO. Out ability to focus experimental scattering and scanning probe imaging measurements in concert with appropriate theory and simulation gives the necessary foundation to probe incisively the fundamental materials chemistry issues characteristic of these systems. Whenever, since carbon materials are present in many astrophysical objects (comets, asteroids and interstellar dusts), it is interesting to study their formation and evolution under severe space conditions through suitable experiments in the laboratories. In this frame vibrational spectroscopies and in particular Raman spectroscopy are known to be among the most useful tools to characterize and control the structural properties of the obtained carbon materials. The aim of this work is to present some experiments on the formation and evolution of carbon films obtained by energetic particle irradiation of solids targets and by deposition of unusual carbonaceous species onto suitable surfaces. Vibrational spectroscopy will be considered to give decisive contributions to the understanding of the structure of the obtained carbon materials such as the evaluation of defects states, the bonding formation and rearrangement and the role of foreign species. Some special topics related to the use of vibrational spectroscopy for monolayer and sub-monolayer films will be given by discussing the so-called Surface Enhanced Raman effect applied to amorphous carbon and organic molecules.

Raman Spectroscopy for Carbon Based Amorphous Thin and Ultra-Thin Films. Giuseppe Compagnini, dipartimento di chimica, catania, Italy.

Space science has always devoted interest into carbon materials for two main reasons. First of all, all DLC, diamond films, carbon fibers and, more recently fullerene and nanotubes are considered materials appealing for aerospace applications. Secondly, since carbon materials are present in many astrophysical objects (comets, asteroids and interstellar dusts), it is interesting to study their formation and evolution under severe space conditions through suitable experiments in the laboratories. In this frame vibrational spectroscopies and in particular Raman spectroscopy are known to be among the most useful tools to characterize and control the structural properties of the obtained carbon materials. The aim of this work is to present some experiments on the formation and evolution of carbon films obtained by energetic particle irradiation of solids targets and by deposition of unusual carbonaceous species onto suitable surfaces. Vibrational spectroscopy will be considered to give decisive contributions to the understanding of the structure of the obtained carbon materials such as the evaluation of defects states, the bonding formation and rearrangement and the role of foreign species. Some special topics related to the use of vibrational spectroscopy for monolayer and sub-monolayer films will be given by discussing the so-called Surface Enhanced Raman effect applied to amorphous carbon and organic molecules.
regenerative air revitalization a critical technology. Current systems using disposable lithium hydroxide do not address the difficulties presented by long-duration missions. Solid amine systems offer the capability to regeneratively absorb CO2 using an amine-impregnated porous substrate. Description of CO2 is then achieved by exposing the system to vacuum or by increasing temperature. However, thermal inefficiencies and mass transfer limitations cause CO2 reduction to be slow and thus the toughness. The plastic flow at the MCNF/UHMWPE interface may be induced by the attached oligomeric groups on the surface of carbon nanofibers, which serve as a solvent to soften the UHMWPE chains and reduce the entanglement. The 209 nm synchrotron WAXD showed that the higher the MCNF content, the more plastic flow in the amorphous region, which is consistent with the mechanical properties.

11:00 AM NN2.7

Structures and materials in space are exposed to a number of harsh environmental conditions including high-energy protons and electrons, ultraviolet radiation, atomic oxygen, high and low temperature extremes, hard vacuum, galactic cosmic radiation, micrometeors, and micro-meteor debris. Because state of the art terrestrial materials are not capable of surviving in a space environment while maintaining their functions is critical for successful long duration space missions. High performance electroactive polymers (EAP) were developed for use as sensing/actuating components in future space vehicles and astronaut suits. Single wall carbon nanotubes (SWNTs) were incorporated to form a composite material in hopes of enhancing the multifunctionality of these polymers while maintaining or improving their already impressive mechanical, thermal, and electronic characteristics. In this presentation, sensing and actuating characteristics of SWNT-EAP nanocomposites are reviewed. Understanding the electrical and dielectric properties of these nanocomposites is critical to future efforts aimed at optimizing their capabilities for specific applications. Sensing properties of the nanocomposites were explored as a function of strain, stress, pressure, and temperature. Actuation was demonstrated by the large displacements observed in the nanocomposites at low applied electric fields relative to commercial actuating materials such as PZT and PVDF. Based on the results of analytical modeling and numerical simulation, the origin of sensing and actuation responses of the SWNT-EAP nanocomposites will be addressed. These SWNT-EAP nanocomposites are scheduled to be installed at the International Space Station (ISS) in the MISSE (Materials International Space Station Experiment) 3 and 5 experiments, which were designed to characterize the performance of new prospective spacecraft materials when subjected to the combined deleterious effects of the space environment. These nanocomposites will be reviewed for further evaluation after several years’ exposure in space.

11:15 AM NN2.8

Novel single-walled carbon nanotube (SWNT) materials are being developed at NASA Langley Research Center as durable, light-weight materials for aerospace applications. In the present work, the SWNT were randomly tethered with a di-functional, variable stiffness linker using diazonium chemistry. This functionalization was confirmed using Raman spectroscopy, and the amount of SWNT incorporation was determined using thermogravimetric analysis. After creating a thermal compression mold of the material, the room temperature storage modulus was determined as a function of depth and frequency via nanoindentation. These results were then compared with a detailed model of the constitutive properties of the material. The model development occurred in several stages. First, an atomistic model of the variable stiffness tether was developed using input from ab initio calculations to customize the force field. Then molecular dynamics simulation, equivalent...
continuum modeling, and micromechanics were used to determine the constitutive properties of the material as a function of nanotube concentration and functionalization. The paper will present results from the synthesis and experimental characterization of the material along with model predictions for its mechanical behavior.

11:30 AM **NN2.9**
Enhancement on the Mechanical Strength of Advanced Composites with Nano-structural Materials. Kin-tak Lau, Mechanical Engineering, The Hong Kong Polytechnic University, Hong Kong SAR, Hong Kong.

Since the discovery of carbon nanotubes a decade ago, many substantial works related to these nano-structural materials in different scientific and engineering aspects have emerged dramatically. The extraordinary mechanical, electrical and thermal properties of the nanotubes are governed by their atomic architectures, commonly called chiral arrangement. Ideally, all carbon atoms in the nanotubes are ideally covalently bonded and formed repeated close-packed hexagonal structures in each layer of shell(s). Due to these naturally chemically-formed atomic arrangements, the carbon nanotubes possess superior mechanical properties, which are stronger than any kind of known metallic materials in the World. Many critical results have been reported recently by using nanotubes as an atomic force microscope (AFM) probe, conductive devices in artificial muscles, nano-thermometer and fuel cells. Although all these works are still under research stage, it demonstrates that it is a high potential in the development of nanotube-related products and components in real-world applications. In the past few years, many researchers and engineers from the advanced composite community has attempted to use these tiny structural materials to enhance the properties of conventional advanced composite structures by altering their mechanical, thermal and electro-static behaviors for space and infrastructure applications. However, in order to achieve the goals, certain aspects such as (1) understanding the mechanical properties of both single-walled and multiwalled carbon nanotubes; (2) investigating appropriate fabricating processes of nanotube/polymer composites; (3) clarifying the interfacial bonding properties between the nanotubes and surrounding matrix and (4) justifying the benefit on the strength of composites after mixing with the nanotubes. This paper provides a critical review on the above aspects basing on the second to a layer of from 10 mcm up to, as a minimum, 100 mcm in thickness. The reference values of m/r, calculated for standard absorbed dose distribution depending on the specific space vehicle orbit. The assessment of reliable simulation of the radiation spectrum may be made, for example, by introducing a special numerical characteristic of the depth dose profile in a material - depth dose criterion. For this purpose, it is required to use the ratio of the exponent index of the depth dose profile (m) to the density of the material (r). In the simplest form, the depth dose profile can be represented as a sum of two exponentials. The first depth dose profile applies to a near-the-surface layer of 5 to 10 mcm in thickness, and the second to a layer of from 10 mcm up to, as a minimum, 100 mcm in thickness. The reference values of m/r, calculated for standard absorbed dose distribution for optical properties, for example, in a majority of nonmetallic materials, a linear response exists except at high doses, and this response in broad range of dose rates with irradiation in vacuum changes not more than two times. The recommended permissible difference between the m/r values for the adjustment process is about 30%.
space radiation absorbed dose developed in SINP MSU are presented. Results of tests of various materials (thermal control coatings, optical glasses, polymers) discussed. The developed in the dosimetric environment MIR station and ISS are described. Principle problems for contemporary and future research are proposed for discussion.

3:00 PM NN3.5 Near-Earth Radiation Environment During Solar Extreme Events. Mikhail Igerevich Panasyuk, Skobeltsyn Institute of Nuclear Physics of Moscow State University, Moscow, Russian Federation.

The main components of the radiation environment, surrounding the Earth are: galactic cosmic rays, solar energetic particles and the radiation belts. All these components are subject to studies from the point of view of radiation impact on spacecraft material and elements. Galactic cosmic rays which mainly consist of protons and nuclei and especially their highly ionizing component (heavy nuclei) are the predominant source of radiation damages in condensed matter at micro-columnar and micro-structured such as latch-up, single event upsets and etc. Enigmatic particles generated in solar flares and coronal mass ejections can also lead to serious radiation hazards. During periods of powerful solar events, lasting several days and accompanied by magnetic storms, the most highly energetic solar particles can overcome the barrier, induced by the magnetic field, reaching low altitudes. In this case, the radiation doses from solar particles can significantly exceed the corresponding doses from trapped particles. The solar energetic particles, especially MeV ions, exhibit a long-term variation associated with the 11-year solar activity cycle.

The physical interpretation and model representation of this variation is far from being complete. The fluxes of particles in the radiation belts are highly non-monotonic. Temporal variations of the particle fluxes (mainly electrons and protons) undergo intensity variations on time scales from about 1 minute to several years. Rapid variations, generally, are associated with the generation of electric fields and electromagnetic waves during solar storms, while slow variations are induced by variations of solar activity and, as a consequence, by variations of particle transport velocities and loss rates inside the radiation belts. Comprehensive engineering model of the radiation belts that would adequately describe their spatial and dynamic properties is yet available. Radiation hazard for space vehicles in near-Earth space is caused by a number of factors among which, besides the time of exposure to the radiation environment, the most significant are the orbital parameters of satellites, as well as the levels of solar and geomagnetic activities leading to radiation flux enhancement. This report devoted to near-Earth radiation environment effects during mainly solar extreme events.


The effect of MeV ion beams in their passage through various polymers will be discussed and compared to similar effects produced by Pyrolysis. Certain chemical species such as sulfur, chlorine, and other pendant and ligand molecules contributes to the cross linking of chains. The extent of cross linking and the density of these cross linking sites during Pyrolysis have been studied by polymer scientists and by chemists for many years. The effects of these cross linking agents on the ion beam modification processes are of interest to us. We will highlight the structure of certain polymer chains, such as partially cured resin, Polyethylene (PE), polyethersulfone (PES), polyvinyl chloride (PVC) and polystyrene (PS), before and after bombardment by MeV ions and observe change in their electrical, optical, and chemical structure. A direct comparison of the properties of the ion beams before and after exposure to MeV ion beam with the before and after thermal annealing (Pyrolysis) provides us with a conclusion that the energy transferred by MeV ions in their track, due to the electronic excitation (electronic stopping power), may be considered a soft effects and is similar to that of thermal annealing of polymers.

4:00 PM NN9.7 Nanodosimetry: Present and perspectives. Mircea Chipara, Indiana University Cyclotron Facility, Indiana University, Bloomington, Indiana.

More and more contributions concerning the synthesis and characterization of materials, confined, structured, or possessing interfaces at nanometer scale are reported. Some of these materials are changing already our life while many others are expected to be used in a wide variety of applications in the near future. Nanomaterials explosion is anticipated to change the fundamentals of radiation dosimetry. There is a general perception that the size reduction to nanometer scale will imply a significant increase of the radiation sensitivity of the material. The mechanisms of radiation transfer from the incident radiation to the nanometer sized features and determined the processes in the deconvolution of the confined energy yield in these features are not yet fully understood. The theoretical point of view supports the idea that the development of a new theoretical framework such as nanodosimetry is pointless as long as the modulation of the interaction of ionizing radiation with the matter are valid even at sub nanometer scale. These models represent the core of dosimetry. The extension of dosimetry to micron sized targets and the subsequent development of nanodosimetry did not affect the basic idea of energy transfer from the incident radiation to the target or of energy dissipation within the target. According, a thorough investigation of radiation effects in nanomaterials is required to assess their radiation sensitivity, to firmly establish the theoretical background, and to decide about the future of nanomaterials in harsh environments such as the space environment. An important step in the theoretical modeling of radiation-induced modifications in nanomaterials is an accurate and precise theory concerning the interaction of ionizing radiation with nanomaterials. Such a theory - named nanodosimetry - will allow us to predict and simulate the behavior of nanomaterials in extreme radiation environments. The very first step, representing the transition from macroscopic dosimetry to microdosimetry was successfully accomplished in the last two decades. The main theoretical ideas and experimental facts that would eventually trigger the development of nanodosimetry are still accumulating. This contribution will critically review the most important limits of dosimetry and microdosimetry generated by the nanometer size confinement of the target. Particular attention will be paid to the latest theoretical and experimental results that are essentially embedded in nanodosimetry. The main limits in the development of a nanodosimetry theory are analyzed and the need for such a theoretical development of dosimetry is seriously reviewed.

4:15 PM NN3.8 Total dose radiation effects in Si nanocrystal non-volatile memory transistors. Mikhail P. Petkov1, L. Douglas Bell2, Robert J. Walters3 and Harry A. Atwater4, 1Jet Propulsion Laboratory, Pasadena, California; 2T.J. Watson Laboratory, California Institute of Technology, Pasadena, California.

We report results pertinent to the high tolerance of prototype Si nanocrystal (nc-Si) field effect transistors (FET) to ionizing radiation. nc-Si crystals were formed in a thin SiO2 blanket layer on a Si wafer by Si implantation and subsequent high-temperature anneal. This structure was patterned into ring-gate FETs with different width-to-length ratio of the gate. The active part of the gate contained large number of nc-Si domains, on each of which charge can be deposited by suitable electric fields. This technology acts as conventional flash non-volatile memory (NVM), with the added novelty of statistically assessing bit status (open/closed FET). It is believed that the radiation-induced loss of charge on a large fraction of the crystals may not necessarily lead to information loss (bit flip correct error). Yet, studies of the radiation tolerance are quite scarce to-date. We monitored the FETs I-Vg characteristics, which exhibit a hysteresis that is the signature of a memory effect. An intense 60Co gamma-source, whose Compton-scattered electrons created the ionizing dose, was used to emulate high radiation environments. Devices were irradiated to different doses of up to 1.5 Mrad(Si) with a dose rate of 25 mrad/s. During the irradiation, the device terminals were either grounded, or a square wave 'write'/'erase' potential was applied to the gate. Changes in the hysteresis due to the cumulative dose were expressed in terms of changes in the gate threshold voltages for both the 'on' and 'off' states of the FETs. A comparison was made with conventional FETs with identical structure, shape and dimensions, but does not contain Si nanocrystals. While the conventional FETs exhibit shift in the threshold voltage for up to 2 Mrad(Si) the nc-Si FETs show no significant functional changes. Preliminary photoluminescence measurements have also confirmed that the radiation-induced defects remain unaffected up to at least 1 Mrad(Si) cumulative dose.

Radiation-induced defects, which remained charge for at least several hours, were also registered, although the 'write'/'erase' gate potential was applied to the gate. Changes in the hysteresis due to the cumulative dose were expressed in terms of changes in the gate threshold voltages for both the 'on' and 'off' states of the FETs. A comparison was made with conventional FETs with identical structure, shape and dimensions, but does not contain Si nanocrystals. While the conventional FETs exhibit shift in the threshold voltage for up to 2 Mrad(Si) the nc-Si FETs show no significant functional changes. Preliminary photoluminescence measurements have also confirmed that the radiation-induced defects remain unaffected up to at least 1 Mrad(Si) cumulative dose.

4:45 PM NN3.9 Radiation-Induced Modifications in Polymeric Materials Subjected to Ionizing Radiation. D. Hu1 and Magdalena D. Chipara2, 1Department of Mechanical Engineering, University of New Orleans, New Orleans, Louisiana; 2Indiana University, Bloomington, Indiana.

Polymeric materials present an particular importance for spacecraft applications due to their reduced weight and good mechanical properties. Nevertheless, the use of polymeric materials for spacecraft applications is restricted by the harsh conditions of the space.
environment. The complex space environment implies at least extreme temperatures, ionizing radiation, low gravity, and micrometeorites. The precursor is loaded into the matrix, the catalyst is released from the microcapsules driving the cross-linking of the HOPDMS and PDES forming PDMS in the crack plane, sealing it shut. The self-healing efficiency of the polymer composite is investigated by comparing the fracture toughness of virgin and self-healed samples. The addition of acryl ethoxy silane to the matrix as an adhesion promoter significantly improves the healing efficiency of the polymer composite. Due to the very low Tg and high char temperature of PDMS, this material system may be an excellent candidate for space applications.

**7:45 PM NN4.3**

**Molecular Self-Healing Processes in Polymers**

Mircea Chipara and Karen Wooley; 3 Indiana University Cyclotron Facility, Indiana University, Bloomington, Indiana; 3 Chemistry Department, Washington University in St. Louis, Saint Louis, Missouri.

Self-healing materials are obtained by dispersing small bubbles containing catalysts and monomers within various polymeric materials. The wall of these polymeric vesicles has to be fragile in order to release the catalysts and the monomers within the polymer during its mechanical solicitation. The size of these polymeric vesicles or bubbles is of the order of microns. This "classical" self-healing process is triggered by mechanical stresses that move the polymeric chains relative to each other. A "classical" self-healing process occurs at micron or larger scales and lasts as long as a sizable concentration of unreacted monomers or reagents is present in the polymer. Diffusion processes may limit the efficiency of the self-healing process mainly if the density of catalysts and monomers within the polymer is low. A self-healing process, operating at molecular scale, has been identified in a relatively narrow class of polymeric materials. In contrast with the "classical" self-healing process, this process may be triggered not only by mechanical stresses but virtually by a wide range of processes such as radiation, light, and temperature besides mechanical stress. This allows to use this class of polymeric materials extremely attractive for space applications and in particular for long-term mission. The theoretical mechanism involved by the molecular self-healing process, the main features of the molecular self-healing and the potential space applications of self-healing polymers are discussed in detail.

Preliminary experimental data, as obtained by electron spin resonance spectroscopy are reported.

**8:00 PM NN4.4**

**Multifunctional Carbon Nanotube/Polymer Composites.** Jian Chen, Rajagopal Ramasubramaniam and Haiyong Liu; 2 Zyvex Corporation, Richardson, Texas; 2Department of Chemistry, Michigan Technological University, Houghton, Michigan.

Carbon nanotubes, due to their high-aspect ratio, small diameter, lightweight, high-mechanical strength, high-electrical and thermal conductivity, high-thermal and air stability, are recognized as the ultimate carbon fibers for high performance, multifunctional composites. However, smooth carbon nanotube surfaces (i.e., single-walled carbon nanotubes) are not compatible with most constituencies. The interaction of nanotubes with most monomers or reactants is strongly reduced, which result in poor dispersion of nanotubes in the polymer matrix. We report here that homogeneous nanotube polymer composites can be fabricated using noncovalently functionalized, soluble single-walled carbon nanotubes (SWNTs). SWNTs soluble in commercial polymers such as polycarbonate, polyestirene etc. These composites showed dramatic improvements in the electrical conductivity with extremely low percolation threshold 0.05-0.1 wt% of SWNT loading. By significantly improving the dispersion of SWNTs in commercial polymers, we show that only very low SWNT loading is needed to achieve the conductivity levels required for various electronic and optoelectronic applications without compromising the host polymer’s other preferred physical properties and processability. In contrast to previous methods, our method is applicable to various host polymers and does not require lengthy sonication. The resulting polymer composites also show significant enhancements in mechanical strength. The mechanical measurement showed that 2 wt % of soluble SWNTs filled resulting in a 70% increase in the tensile strength of polycarbonate. We also observed a stress-induced SWNT alignment in polycarbonate, which is very difficult to achieve with insoluble SWNTs. The SEM study of the fracture surface indicates excellent interfacial interaction/load transfer between SWNTs and polycarbonate, possibly due to the considerably increased roughness of carbon nanotube surfaces by PPE non-covalent functionalization. We also will report an isotropic nanotube-based conducting thermoplastic with the tensile strength higher than aluminum. Reference: 1. Chen, J. et al. J. Am. Chem. Soc. 2002, 124, 9031-9035.
Conducting polymers are excellent microwave absorbers and they show technological advantage compared to inorganic electromagnetic absorbing materials. In this work, we focus on improving the ability of changing the electromagnetic properties with nature and amount of dopants, synthesis conditions etc. Among the conducting polymers, polyaniline is superior mainly because of its ability to exhibit varying electromagnetic properties by reversible proton doping. In this paper we report the synthesis, dielectric properties and expected application of conducting composites based on polyaniline. Cyclohexanone soluble conducting polyaniline composites of microweave composition synthesized by in-situ polymerization of aniline in the presence of emulsion grade polyvinyl chloride. The composites were characterized using TGA and DSC, which shows that the thermal stability of the composite was better compared to polyaniline. 1M HCl was optimized as the dopant for the composite with respect to its dielectric properties among the different dopants like sulfuric acid, nitric acid, perchloric acid, toluene sulfonic acid, camphor sulfonic acid etc. The dielectric properties of the composite, especially the dielectric loss, conductivity, dielectric heating coefficient was found superior to polyaniline. Moreover, the absorption coefficient of polyaniline was increased with polyvinyl chloride loading and it reaches a maximum at 1:1.5 PanI-PVC composite. The penetration depth was very low (below 0.004 m) for this composition. The microwave absorption of this particular composite was studied at different frequency bands i.e. S, C and X bands (12.42 - 8.26 GHz) and a high dielectric loss. The absorption found to be higher than 20% m-1 and it can be used for making microwave absorbers in space applications. The composite also shows selectivity in microwave absorption at different frequency bands. The dielectric properties were studied using HP 8510 vector network analyzer and cavity perturbation technique.


The performance of many U.S. Army systems depends on the efficient use of material mass and volume. In particular, many components on these systems are often dedicated to power generation and energy storage. Examples include next-generation ground vehicles, which utilize hybrid powertrains requiring large banks of batteries, unmanned aerial vehicles, whose range and speed are currently limited by battery life; and individual soldiers, whose sensing and communication equipment requires both continuous and burst power requirements. Many of these systems also include a significant amount of structural material. An important, yet often overlooked, system-level reduction in mass and volume is possible by creating multifunctional materials that simultaneously offer both power generation or energy storage capabilities with structural or armor properties. These composite materials are under investigation. First, structural lithium-ion batteries are being designed by formulating ion-conductive polymer electrolytes with continuous fiber reinforcement. The electrolytes are designed to balance structural and ion-conduction properties, through the use of functionalized structural polymers, block copolymers, or microscale mixtures of conductive and structural materials. Second, structural fuel cells have been fabricated by creating skin-core composite structures. In these fuel cells, the skins are composed of thin, high fiber or carbon fiber—reinforced composite laminates. The core consists of layers of open-cell metal foam with a Nafion®-based membrane electrode assembly interlayer. This core generates power when hydrogen and oxygen sources are circulated through the porous foam layers. Significantly, the high compressive and low thermal loading of the core transfers loads efficiently to the skins, resulting in a structure with high specific stiffness and strength. Finally, electroded surfaces have been integrated into continuos fiber—reinforced polymeric composite to create structural capacitors. Fabrication and design details for these multifunctional composites, as well as structural and power/energy performance results, will be reported.

9:00 PM NN4.7 Thermoplastic matrix composites for SPACE SOLAR POWER TRUSS (SSP). Hao Zhang1, Koorkoo Guhandane2 and Steven Nutt1, 1Materials Science, University of Southern California, Los Angeles, California, 2L’Garde Inc., Tustin, California.

ABSTRACT: Rigidizable thermoplastic matrix composites can be repeatedly softened and folded by heat. By using low Tg (Glass transition temperature) thermoplastic matrix, SPACE SOLAR POWER TRUSS can be easily packaged at room temperature, and expand in the outer space. The present paper discusses RFI (resin film infusion) and hot pressing process that were used to produce laminate tubes. Polyurethane and carbon plain-weave fabrics are used. Sample tubes have the dimension of length 16.76cm and diameter 2.54cm, which is formed according to the proportion 1:5 to the real tubes. The performance of the bent tubes under compression and compared with that of the un bent tubes. Results show that modulus increases after bending. Fiber waviness also affects the final stiffness properties of composites. High waviness results in easy of laminate failure, especially in bending. The damage of the laminate appears to affect compressive properties due to buckling. In order to improve resistance to delamination, stitching technique has been used. Stitching parameters have been investigated. Keywords: Thermoplastic matrix composites, composite properties, rigidizable, RFI, bent, stitching, fiber waviness.

SESSION NN5: Poster Session
Chair: Ramon Artilaga
Tuesday Evening, November 30, 2004
Exhibition Hall D (Hyatt)

NN5.1 Screening of the thermal endurance of space materials by kinetic modelling. Stan Heltzel, Jason R. Williamson, Gustavo Garcia Martin, Martin Moser and Christopher O.A. Sembromschnig; Materials Physics and Chemistry Section, ESA/ESTEC, Noordwijk, Netherlands.

The knowledge of the thermal endurance is an important aspect for ESAs upcoming missions to the inner part of the solar system. These missions require a precise understanding about the high temperature resistance of materials. In the optimum case, this requires to know the detailed space environmental behaviour at elevated temperature. That implies to know outgassing kinetics, decomposition kinetics, evolution of thermo-mechanical properties versus temperature and to know the general effect of high temperature ageing. To establish that knowledge is a very time consuming task and therefore methods are required to generate a faster screening methodology to down-select materials. We have worked to establish one way of methodology which allows us in a relatively short time to predict the thermal endurance of space materials. This is commonly known as kinetic modelling. Such models rely on test results obtained by TGA (Thermo-Gravimetric Analysis). By performing a minimum of three experiments such models enable lifetime predictions in a relatively short time. We applied two commonly used kinetic models. We have applied the model proposed in ASTM E 1641 that relies on a standard Arrhenius equation. We have also applied another model called model free kinetics proposed by Sergei Vinitskov. This one relies on a similar approach but it is able to establish the activation energy as a function of temperature. In this paper several space relevant materials were screened and test results are shown. The applicability and the limitations of the two models are discussed. It is shown that depending on what type of decomposition reaction occurs one model yields better results than the other. For that the results of the models are compared with a selected number of long term isothermal tests and additionally the impact of long duration ageing and the comparison with predictions are elaborated.

NN5.2 Nanocrystalline Soft Magnetic Alloys for Space Applications. Matthew A. Willard1; Thomas Francavilla2 and Vincent G. Harris2; 1Code 6324, U. S. Naval Research Laboratory, Washington, District of Columbia; 2Electrical and Computer Engineering Department, Northeastern University, Boston, Massachusetts.

Flywheel and magnetic bearing systems require soft magnetic materials possessing high strength and low eddy current and hysteretic losses. Although amorphous alloy magnets exhibit good loss characteristics, their long-term use at elevated temperatures, near 300 to 400°C, degrades their properties. In recent years, nanocrystalline magnets with exceptional soft magnetic properties have been developed with potential use for such applications. Nanocrystalline soft magnetic materials possess higher magnetization and operation temperatures than amorphous alloys with similar compositions. Recently, nanocrystalline alloys with the nominal composition (Fe6Co79Ni6Zr2B4) have been produced by a single wheel melting and spinning technique, followed by an isothermal anneal and a primary crystallization temperature. The resulting materials are multi-phase with residual amorphous phase between nanocrystallites. The high frequency response of these magnets is aided by the multi-phase microstructure, primarily by the reduction of eddy current losses by the high resistivity of the residual amorphous phase. This study focuses on a Co-based nanocrystalline alloy (Co40.45Fe4.57Zr2B4) with potential for long-term high temperature
use. Differential thermal analysis and X-ray diffraction have been used to determine the primary crystallization temperature (e.g., 480°C at 20°C/min) for various compositions (e.g., FCC and BCC grains when annealed at 500°C), respectively. Vibrating sample magnetometry provided the magnetization and hysteretic losses as a function of temperature. The resulting magnetization of 120 emu/g was reduced by less than 50% at room temperature and decreases to 0% at 400°C. As an indication of their performance, core losses have been measured on toroidal samples using a Walker AC permeameter over a frequency range of 0 to 50 kHz and at induction amplitudes of 0.1, 0.3, and 0.5 T. A sample annealed at 550°C for one hour had a core loss of 0.025 W/kg at an operation frequency of 1 kHz and applied magnetic induction of 100 mT. References. 1) M. A. Wallard, J. H. Claassen, R. M. Stroud, and V. G. Harris, Journal of Applied Physics 91(10) (2002), 8420-8422.

NN5.5 Multifunctional Metal/Polymer Hybrid Fiber for Space and Aerospace Applications, Yue-Wa Lee1, Tom W. Onouhara2, David P. Zikes2, Dale L. Hart3, Erik Schomburg3, Elizabeth T. Shinn4, Abigail J. Cooley5, Edward L. White5, Paul W. MacDowell5, George A. Slinski5, Anthony N. Watkins5 and Robert L. Yang5,5 Sycom Technology, Inc., Columbus, Ohio; 3The Boeing Company, St. Louis, Missouri; 4University of Dayton Research Institute, Dayton, Ohio; 5Langley Research Center / NASA, Hampton, Virginia.

The stringent weight and space requirements of advanced space and aerospace systems have lead to a need for stronger, lighter, smaller, and more flexible cable and wiring components. Sycom has fabricated a multifunctional metal/polymer hybrid fiber from a rigid-core polymer, such as poly(p-phenylene benzobisxazole) (PBO) fiber, for signal transfer and electromagnetic interference (EMI) shielding in wiring and cable applications. The test results indicated that the metal/polymer hybrid fiber can provide the electrical conductivity, 75% the weight and 200% the breaking strength of a comparable size copper-beryllium CS95 wire. Additional experimental results of electric current carrying capability, cable shielding performance, atomic oxygen erosion protection and potential electronic textile applications will also be discussed.

NN5.4 Effect of Temperature on the Luminescence and Up-Conversion Dynamics of Praseodymium in LiLuF4 Laser Crystal, Gonul Ozen1,2, John M. Collins3, Ottavio Forte3, Misha Meyjman2, Reny Abdulsabirov3 and Baldassare DiBartolo1, 1Department of Physics, Boston College, Chestnut Hill, Massachusetts; 2Department of Physics and Astronomy, Wheaton College, Norton, Massachusetts; 3Laboratory of Quantum Electronics and Radiospectroscopy, Kazan State University, Kazan, Russian Federation; 4Department of Physics, Istanbul Technical University, Istanbul, Turkey.

Rare-earth doped crystalline solids are very attractive because of their important applications in lasers and nonlinear optics. Praseodymium (Pr3+) in various crystals has been widely studied because of its energy level structure and suitable lifetimes of the meta-stable levels in 4f2 configuration. Praseodymium, in general, enters solid host lattices in its trivalent state. There are at least two exponential only at low temperatures. Under excitation into the 1D2 energy levels of the Pr3+ ions in 4f2 configuration and 4f2 to 4f5d transitions, the 1D2 level is meta-stable, indicating an increased elastic modulus. This increased Young's modulus under cryogenic temperature further validates the stiffness change with temperature.

The experimental results show that the thermal conductivity of Si/Ge nanocomposites is reduced below that of the homogeneous alloy.

NN5.6 Investigation upon Mechanical Properties of Thin Film Silicon Under Cryogenic Temperature, Yi Zhang and Xin Zhang, Department of Manufacturing Engineering, Boston University, Brookline, Massachusetts.

With growing micro-satellite technologies, more and more instruments are being compacted into a limited space for scientific concept validation. These instruments, especially the imaging components, need to be maintained within a narrow cryogenic temperature range for an acceptable signal-to-noise ratio. Most of the passive cooling approaches are not appropriate due to the extreme temperature condition in outer space, while it calls for an efficient cooling mode in which the cooling rate should be adjustable in response to surrounding environment. Micro pump array is a feasible option which transfers liquid cryogen through inlet and outlet flapper at a desired rate via the actuation of the thin silicon diaphragm. The mechanical properties of the diaphragm are critical for cooling rate estimation. However, little is known about that under the cryogenic temperature. In this paper, we present the preliminary work about the investigation upon the stiffness of thin film silicon under liquid nitrogen temperature. It is expected to shed some light on the further application of thin film silicon in extreme temperature environment. The thin film silicon (30 μm in thickness) was mounted in double layered dewar which was filled with liquid nitrogen. The film was actuated using compressive gas and its deflection was achieved using Michelson interferometer. Given the lateral dimension and the thickness, Young’s modulus of the film was derived. It is found that the Young’s modulus increases with decreasing temperature, which indicates a much stiffer film under cryogenic environment. The stiffness change is compared with semi-empirical equation and the discrepancy is explained mainly in two folds: the difference in mechanical properties (Young’s modulus, CTE, and etc.) between the thin film and doped silicon and the difference in mechanical properties (Young’s modulus, CTE, and etc.) between the thin film and doped silicon and the mismatch between silicon and doped boron when temperature changes. Moreover, it is discussed that the direct contact of the silicon film with sample holder in as the experimental setup may also serve as a contribution. As the calibration, a skewed Michelson interferometry was built using a 532-nm Nd:YAG laser for surface wave generation and a 514.5 nm Ar/ion laser as the detection probe. A smaller propagating time was found associating with cryogenic temperature, indicating an increased elastic modulus. This increased Young’s modulus under cryogenic temperature further validates the stiffness change with temperature.

NN5.7 InAs Quantum Dot Development for Enhanced InGaAs Space Solar Cells, Hyne R. Raffaelli1, Sam Sinhavong2, William King3 and Sheila G. Bailey2, 1NanoPower Research Labs, Rochester Institute of Technology, Rochester, New York; 2Essential Research Incorporated, Cleveland, Ohio; 3NASA Glenn Research Center, Cleveland, Ohio.

The majority of high-efficiency space solar cells being produced today are based on multi-junction design of lattice matched III-V materials. An alternative which has been receiving an increasing amount of attention is the a lattice mis-matched or metamorphic approach to multi-junction cell development. In the current state-of-the-art metamorphic triple junction cell, the InGaAs junction (bottom cell) of the three-cell stack is the current limiting entity, due to the current matching which must be maintained through the device. This limitation may be addressed through the incorporation of InAs quantum dot array into the depletion region of an InGaAs cell. The
InAs quantum dots in the InGaAs cell would provide sub-gap absorption and thus improve its short circuit current. This cell could then be integrated into a tandem cell stack to achieve a space solar cell whose efficiency would dramatically exceed current state-of-the-art standards. A theoretical estimate predicts that a InGaAsP(1.95 eV)/InGaAs(1.2 eV) triple junction cell incorporating quantum dots to improve the bottom cell current would have an efficiency exceeding 49%. In addition, theoretical estimates have demonstrated that the use of quantum dot structures may also hold other cell benefits such as improved temperature coefficients and radiation tolerance, which are especially important for utilization in space. As a first step towards achieving that goal, we have initiated the development of InAs quantum dots on lattice-mismatched InGaAs (1.2 eV bandgap) grown epitaxially on GaAs by metalorganic chemical vapor deposition (MOCVD). These quantum dots have been characterized via photoluminescence (PL) and atomic force microscopy (AFM). The correlation between the quantum dot size and resulting optical band structure as a function of the synthesis conditions will be presented. Incorporating these quantum dots into prototype InGaAs devices will be reviewed. The resulting optoelectronic performance the prototype devices, including photovoltaic efficiency under simulated 1 sun intensity and air mass zero (AM0) illumination and spectral response, will be presented.

N5.8 In-situ Polymerization of Poly(methyl methacrylate)/clay Nanocomposites in Supercritical Carbon Dioxide, Qian Zhao and Edward T. Samulski. 1, 2, 3 Curriculum in Applied Materials Sciences, University of North Carolina, Chapel Hill, North Carolina; 2Chemistry, University of North Carolina, Chapel Hill, North Carolina.

A novel route to synthesize PMMA/clay nanocomposites was presented by a pseudo-dispersing polymerization of MMA in presence of fluorinated surfactant modified clay (10F-clay) in supercritical carbon dioxide. The nanocomposites were characterized by SEM, TEM, X-ray Diffraction (XRD), TGA, and DMA, and showed partially exfoliated/intercalated structures as well as enhanced thermal stability, glass transition temperature and mechanical properties. It was also found that 10F-clay served not only as inorganic filler, but also an effective stabilizer for PMMA growth in CO2. More stabilizing mechanisms were suggested by FTIR studies. This general route allows for clean synthesis of nanocomposites with high yields in supercritical CO2, without the need for adding extra surfactant to stabilize the polymerizing system.


Long-term missions to extraterrestrial surfaces such as the Moon or Mars will require habitats to protect humans and electronic equipment from the effects of high-energy radiation from galactic cosmic rays, solar energetic particles (SEP), and solar proton events (SPE). Shielding from this radiation is best accomplished by using materials composed of elements with small atomic numbers. The best shield would be liquid hydrogen, though obviously that would not be practical. Polymers have the advantage of being lightweight, low cost, and a reasonable alternative. Materials or synthetic or naturally derived materials that are lightweight, low in cost, and have low atomic number are desirable. Habitats constructed on the surface of the Moon could utilize surface material (regolith) along with polymeric material to provide shielding. Structures made from carbon and hydrogen provide a reasonable alternative. Polymers and synthetic or naturally derived materials, such as CNT/polymer composites, are being studied for use in shielding applications. These materials were evaluated using a variety of techniques in order to determine the optimal shielding material for extraterrestrial surfaces.

N5.10 Electron Spin Resonance Studies on Electron Beam Irradiated Carbon Nanotubes Dispersed in Styrene-Isoprene-Styrene Block Copolymer, Mireciu Chipara, Wendland Bezbidd, Jeffery Zaleski, Kristina Stephenson, David Dye, and Kin-tak Lau; 1Indiana University Cyclotron Facility, Indiana University, Bloomington, Indiana; 2Mechanical Engineering, The Hong Kong Polytechnic University, Hong Kong, Hong Kong; 4Chemistry Department, Indiana University, Bloomington, Indiana.

Irradiated carbon nanotubes (CNTs) dispersed in electron beam (EB) irradiated styrene-isoprene-styrene (SIS) block copolymers were characterized using an X-band electron spin resonance (ESR) spectrometer. The SIS dispersion was obtained by coprecipitating the CNTs from a solvent mixture containing toluene and chloroform. The resulting CNT/SIS composite was characterized using electron spin resonance (ESR), X-ray diffraction (XRD), and transmission electron microscopy (TEM). The results showed that the CNTs were well-dispersed in the SIS matrix and that the electron spin resonance spectrum was consistent with the presence of CNTs.

N5.11 Preparation and Characterization of Electrospun poly(ethylene oxide) (PEO) Nanofibers-reinforced Epoxy Matrix Composites, Jay-Rock Lee, Soo-Jin Park, and Joung-Man Park; 1Adventive Materials Division, Korea Research Institute of Chemical Technology, Yusung, Daejeon, South Korea; 2Department of Polymer Science and Engineering, Engineering Research Institute, Gyeongsang National University, Chinju, South Korea.

In this work, electrospinning was carried out using 12 wt. % poly(ethylene oxide) (PEO) solution under fixed tip to collector distance (10 cm) and voltage (15 kV) in order to fabricate nanofibers-reinforced composites. The content of PEO nanofibers was varied from 0 to 10 wt. % in the epoxy (EP) matrix resins. The PEO powders were mixed with the EP matrix resin at room temperature to prepare the nanocomposites. The resulting nanocomposites were characterized by thermal gravimetric analysis (TGA) and dynamic mechanical analysis (DMA). The results showed that the thermal stability of the nanocomposites was decreased with increasing PEO content due to the reduced weight of these composites and to the capability to obtain multifunctional composites based on carbon nanotubes. Experimental data confirmed an increase in the mechanical properties of PEO nanocomposites due to the reinforcement with carbon nanotubes but the results are still below expectations. Most efforts are focused on the interface between nanotubes and polymeric matrix, which controls the adhesion of the polymeric chain to nanotubes and finally governs the mechanical properties of the composite. The results of this research have particular relevance to space applications due to the reduced weight of these composites and to the capability to obtain multifunctional composites based on carbon nanotubes. The results of this research have particular relevance to space applications due to the reduced weight of these composites and to the capability to obtain multifunctional composites based on carbon nanotubes. The results of this research have particular relevance to space applications due to the reduced weight of these composites and to the capability to obtain multifunctional composites based on carbon nanotubes.

N5.12 Computer Simulation of Displacement Damage in Silicon Carbide, Ram Devanathan, Pei Gao and William J. Weber; 1Graduate School of Science, Tokyo Institute of Technology, Tokyo, Japan; 2Department of Chemistry, University of California, Berkeley, California.

Silicon carbide is a wide-bandgap semiconductor that is a promising candidate material for radiation-resistant electronic applications. In the space environment, irradiation by energetic protons and electrons can result in displacement damage leading to new energy levels in the
band gap. These defects can degrade the electrical as well as physical properties of the material. In an effort to understand the atomic-level details of the process, we conducted a dynamics simulation of displacement events on Si and C substrates for displacement doses ranging from 0.005 to 0.5 displacements per atom. Our results indicate that the displacement threshold energy is about 35 eV for Si and 30 eV for C, and amorphization can be promoted by dislocation energy and accumulation of displacement damage regardless of whether Si or C is displaced. In addition, we have simulated defect production in high-energy cascades as a function of the primary knock-on atom energy and observed features that are different from the case of damage accumulation in Si. These systematic studies shed light on the phenomenon of non-ionizing energy that is relevant to understanding space radiation effects in semiconductor devices.


The relatively low density of Ti (4.5 Mg/m3) implies high strength/density ratio for Ti-based alloys which make them suitable for aerospace applications. Typical commercial Ti-based alloys have a central part of the ingot being tested by an Instron-type machine

NN5.14 Optical and Upconversion Studies on New Electro-Optic Ceramic Materials. Xuesheng Chen1, Kewen Li1, Yanyun Wang1, Kevin Zou2, Gonul Ozen3 and Hua Jiang2, 2Boston Applied Technologies, Inc., Woburn, Massachusetts; 3Department of Physics, Boston College, Chestnut Hill, Massachusetts.

We report optical studies, including the non-linear effect of upconverting frequency of light, on newly developed transparent electro-optic ceramic materials, Er or Nd doped PLZT. These materials have many important applications such as high-efficiency high power lasers for remote sensing and space exploration. These ceramic materials have successfully been made highly transparent in the wavelength range 500nm-7000nm with intrinsic absorption bands due to the rare-earth doping ions, Er or Nd. Transparent ceramic laser materials have several critical advantages over popular single crystal laser materials - they are easy to accommodate high-concentration rare earth ions and to be fabricated in large size. The host ceramic material PLZT also has high electro-optic coefficient that might have unique features in phase and mode self-modulation that would lead to an innovative laser system with higher efficiency, more compactness, and integrated multi-functions. In this presentation, we focus on the luminescence and upconversion luminescence studies on this ceramic material family, rare-earth doped PLZT. This work provides crucial information for promising applications in new optical devices including high-efficiency high-power ceramic lasers. This work was supported in part by NSF and DOE.

NN5.15 TRANSFERRED TO NN11.4

NN6.16 FIB-Based Cryogenic Characterization and Testing of Silicon Nitride Thin Film Devices for Space Applications. Wen-Hsin Chuang1, Rainer Fettig2 and Reza Ghodssi1, 1Electrical and Computer Engineering, Institute for Systems Research, University of Maryland, College Park, Maryland; 2NASA Goddard Space Flight Center, Greenbelt, Maryland.

Two-dimensional microshutter arrays are currently being developed at NASA Goddard Space Flight Center, to be used as programmable aperture masks for a Multi-Object Spectrometer on the James Webb Space Telescope (JWST). These microshutter arrays, made of silicon nitride thin films using microelectromechanical systems (MEMS) techniques, require cryogenic operation at 30 K to reduce thermal emission into the instrument. Since the JWST’s second Lagrange point orbit will be inaccessible to space shuttle re-servicing mission, the microshutter arrays must operate in a cryogenic vacuum environment reliably over a 10 year mission lifetime without repair after launch. Therefore, a complete understanding of mechanical properties and reliability of silicon nitride thin films at cryogenic temperatures is critical for the development of the microshutter arrays. We have developed a cryogenic measurement setup installed inside a Focused-Ion-Beam (FIB) system to emulate the operating environment of the microshutter arrays. To obtain an accurate temperature measurement, a thin-film thermo-resistor with a sensitivity of 7.85 ohm/K was fabricated with test devices as an integrated temperature sensor. The device temperature down to 20 K with a FIB chamber pressure lower than 10^-10 torr has been successfully obtained using this setup. In situ measurement techniques for Young’s modulus and fracture strength characterization were also developed based on this setup. In our experiment, the average Young’s modulus of silicon nitride thin films varies from 230.5 GPa at room temperature (298 K) to 266.6 GPa at 30 K, and the average fracture strength ranges from 6.9 GPa at room temperature to 7.9 GPa at 30 K. For reliability tests of the microshutter arrays, a novel MEMS test device with the same stress operating condition was designed. Unlike slow magnetic actuation utilized in the microshutter arrays, this device was actuated with electrostatic force to achieve accelerated lifetime tests. In addition, the disadvantage of high input voltages in most electrostatic MEMS devices was solved using a mechanism of vibration amplification. In this device design, two resonators were connected serially with a common torsion bar. Electrostatic energy was transferred to the first resonator via a small fixed gap between electrodes and then transferred to the second resonator which can be moved freely with the common torsion bar. The frequency of the applied energy matched the resonant frequency of the second resonator, large vibration movement of the second resonator can be obtained due to a high quality factor inside the vacuum chamber while keeping the vibration of the first resonator small. The stress amplitude of the second resonator can then be controlled by the frequency and amplitude of the input electrostatic energy. From the test results, no device failure has been found even up to 10^9 loading cycles when testing at the operating stress lower than 6.6 GPa.

NN6.17 Whisker Formation in Sn Coatings on Cu. Eric Claxton, Lucine Kabakian and Sharvan Kumar; Division of Engineering, Brown University, Providence, Rhode Island.

In the electronics industry, Cu conductors are often coated with pure Sn and Pb-Sn alloys to enhance corrosion resistance and solderability. However, pure Sn layers have a tendency to develop whiskers that may cause component failures. Currently, Pb is alloyed with the Sn to suppress whisker formation, but the push towards Pb-free processing will make this unacceptable in the future. In space applications, the whiskers can become electron emitters and carry large amounts of current; Sn whiskers have been implicated in the loss of several satellites. We have been studying pure Sn coatings on Cu in order to understand the driving forces and mechanisms of whisker formation so that we can develop alternative and functional alternatives systems that are reliable and environmentally acceptable. Using a real-time, wafer-curvature based system we have measured the evolution of stress in vapor-deposited layers of Sn on Cu. We will present measurements of how stress depends on the Sn and Cu and describe a model for how interface reactions between the Sn and Cu leads to whisker formation.

NN6.18 Energetics of Interstitial Oxygen in Cr and V. Brian S. Good1,2; 1Materials Division, NASA Glenn Research Center, Cleveland, Ohio; 2Case Western Reserve University, Cleveland, Ohio.

The deleterious effects of dissolved oxygen in high-temperature materials are well known, yet the details of many aspects of the phenomenon remain poorly understood. In particular, the solubility of
oxygen in group IIIA-VA (Nb, Ti, Zr, Y) based alloys is a fundamental problem affecting both mechanical properties and oxidation resistance. In particular, at concentrations above 0.5%, oxygen is more stable dissolved in the metal than it is as an oxide-compound. Protective oxidation behavior is obtained when the alloy is saturated with oxygen and equilibrium is approached at the metal-scale interface, but this leads to unacceptable mechanical properties. In contrast, alloys based on Fe, Ni, Al and Cr exhibit almost no oxygen solubility and readily form protective oxide layers. Therefore, it is important to understand the fundamental differences in the oxygen solubility in these alloys. As a first step toward this understanding, we consider the energetics of interstitial oxygen in pure-V and pure-Cr. Both of these metals are BCC, yet their oxygen solubilities are very different, with that of V being much higher than that of Cr. We obtain total energies, densities of states, band structures and population analyses using the CASTEP plane-wave pseudopotential density functional computer code. The differences in the energetics and electronic structures of the two materials, particularly the partial densities of states associated with the individual metal ions and the interstitial oxygen, are discussed.

**SESSION NN6: Radiation Effects in Composite Materials**

Chair: Mathias Cella
Wednesday Morning, December 1, 2004
Room 207 (Hyts)

8:30 AM **NN6.1**

An Overview and Status Report of the Center for Integrated Space weather Modeling (CISM). H. Spence, Department of Astronomy, Boston University, Boston, Massachusetts.

The Center for Integrated Space weather Modeling (CISM) is a new NSF-funded research center at Boston University, comprising the first ever-improving, comprehensive, physics-based numerical models describing the coupled Sun-to-Earth space environment. These models will be used as scientific tools for increased understanding of the complex space environment, as specification/forecast tools for space weather prediction, and as tools for teaching about the space environment. Headquartered at Boston University, CISM coordinates and integrates the scientific efforts of a diverse set of existing research groups from over 12 different institutions to form a focused team of focused collaborators who are creating a product with multiple applications. In this talk, I will provide an overview of CISM and a status report on its activities, with an emphasis on those elements relevant to material science concerns.

9:00 AM **NN6.2**

Processing and Characterization of Carbon Nanotube/Nanofiber Films and Nanocomposites. E. Grossman1, N. Eliaz2, M. Fraenkel1, S. Maman1, F. Beckmann3 and K. Pranzas4; Department of Mechanical Engineering, University of South Alabama, Mobile, Alabama.

Carbon nanotubes and carbon nanofibers have extraordinary mechanical, electrical, and thermal properties. These nanomaterials are being considered for use in a large number of applications. The advantage of their unique properties, carbon nanotubes and carbon nanofibers were preformed as nano-films through a filtration process. A high quality of dispersion of carbon nanotubes and nanofibers in films is achieved when a benzene solvent was achieved with the aid of surfactants under sonication. The nano-films consisted of densely packed, highly interconnected networks of carbon nanotubes and nanofibers and were further used as multi-functional reinforcements by integrating them into composite structures. The microstructures of the nano-films and nanocomposites were characterized with SEM and AFM. The properties of the nanocomposites were studied with tensile test and dynamic mechanical analysis.

9:15 AM **NN6.3**

Nanostructured Carbon Thin Films as Space Radiation Shields. Sanju Gupta, Gerardo Morell and Brad R. Weiner; Physics, NCSU, Raleigh, North Carolina.

Severe environmental tolerability is the prime factor in the development of novel space materials exhibiting excellent physical properties accompanied by lightweight, reusability, and multifunctional capabilities. Diamond is known for its reputation being radiation hard besides a range of other outstanding physical properties such as electronic, optical, mechanical, and chemical and hence it is preferable over the other existing semiconductors as detectors used in harsh environments. Thin films of micro- and nanocrystalline diamond were deposited by microwave plasma-assisted CVD technique. They were then submitted to gamma radiation doses of 1, 5, and 20 Mrads sequentially in order to study the radiation induced structural transformation and the corresponding changes in the electron field emission properties in order to establish
property-structure correlations [1]. Microstructural characterizations include Raman spectroscopy (RS), scanning electron microscopy (SEM), atomic force microscopy (AFM), and X-ray photoelectron spectroscopy (XPS). Nanocrystalline diamond showed a dramatic improvement in the field emission properties, while nanocrystalline carbon showed a relatively small but systematic decrease in turn-on field strength and electron emission current density. The enhancement in emission characteristics associated to the radiation induced microstructural transformation shows the critical role of defects with their associated electronic defect states and sp3-bonded carbon atoms in the complex emission mechanism of these so-called nanocomposite carbon materials. The results also indicate that nanocrystalline carbon tends to reach a state of damage saturation when subjected to 20 Mrad doses of gamma radiation, suggesting that the sp2 C sp2 C conversion while absorbing or scattering ionizing and/or electromagnetic radiation without changing their average microstructure, which can be employed for extending field emission technologies [1]. [1] S. Gupta, B. L. Weiss, B. R. Weiner, L. Pilione, A. Badzian, and G. Morell, J. Appl. Phys. 92, 3311 (2002) and references therein.

9:30 AM *NNG.4

Proton Beam Induced Modifications in Multi-Functional Polyethylene-Based Carbon Nanotubes Composites. Merlyn X. Pulikkathara1, Kristina Steffen2, Laura Laura Penn-Parme3, Danesh Moblot3, Richard Wilkins1, David Dys1, Jeffrey Zaleski1, Enrique V. Barrera4, and Mircea Chipara5.

Enrique V. Barrera 4 and Mircea Chipara 5.

High-density polyethylene (HDPE) is currently considered the best material for space radiation shielding. In addition to its high concentration of hydrogen atoms, light, and reduced radiation-induced activation, HDPE is a structural material with good mechanical properties and high radiation stability. During HDPE irradiation cross-linking reactions are dominant. The mechanical and thermal capabilities of HDPE are further boosted by filling the polymer with various materials. For certain applications, antioxidant or even electrical conductivity is required. These functions can be achieved by using conducting fillers below and above the percolation threshold, respectively. Particular attention is paid to carbon-based fillers in particular to carbon nanotubes. Minute amounts of nanotubes increase significantly the Young modulus of HDPE, and can add electric conductivity to the insulating polymeric matrix. In previous studies, percolation thresholds lower than 0.5% in weight were reported for long nanotubes dispersed within polymeric matrices. The radiation stability of nanotubes is still under debate. It has been reported that electron beam irradiation of nanotubes in vacuum resulted in nanotubes fusion and eventually in the grafting of HDPE chains onto the nanotubes. The irradiation of nanotubes in oxygen may degrade the nanotubes resulting in the formation of volatiles. These effects are amplified if oxygen is replaced by single oxygen (which is present in Low Earth Orbits). We report a comparative study on the thermal and mechanical stability of HDPE composites doped with graphite and single wall nanotubes (SWNT). The composites were obtained by dispersing 5% weight of SWNT fillers (including functionalized SWNT, fluorinated-SWNT, F-C11H23 doped-SWNT and graphite). The samples were irradiated in vacuum with protons accelerated at 40 MeV and 10 MeV at three fluences (3x108 protons cm-2, 3x109 protons cm-2, and 3x1010 protons cm-2). Proton irradiation is important for space applications, as accelerated protons have one of the most important contributions to the radiation component of the space environment. After irradiation, the samples were stored in air, at room temperature. The radiation-induced modifications were investigated by electron spin resonance spectroscopy, using a Bruker ESP 300 spectrometer operating in conjunction with a variable temperature accessory. Additional measurements were performed by Raman spectroscopy and thermal analysis. Raman spectra revealed that the nanotube signature was unaltered by the irradiation, and that the functionalization of the nanotubes with peroxido (F-C11H23) was not affected by the irradiation. The analysis of ESR data revealed that the composites based on SWNT have a higher resistance to proton irradiation than the composite based on graphite. Due to the special characteristic of the thermal transformation of the preceramic polymer to ceramic is the release of hydrocarbons in the temperature range from 400 to 600 degree C which overlaps with the temperature range of CNT formation by CVD processing. In this work preceramic polymers (polycarbosilanes, polialoxanes) were doped with transition metal compounds (Fe, Co, Ni and mixtures thereof), crosslinked and pyrolyzed in argon atmosphere between 800 degree C and 1200 degree C. The pyrolysis products were investigated with respect to the formation of CNTs and their morphology. Characterization was performed by thermal analysis, XRD, SEM and TEM analysis. The decomposition residue was in the range 70 to 80 %. The samples doped with transition metals showed the formation of CNTs after pyrolysis in argon atmosphere. The morphology of the CNTs was found to be influenced by the type and concentration of transition metal, and the pyrolysis parameters. The in-situ formation of CNTs decomposition gases of preceramic polymers offer potential for the in-situ formation of carbon nanotubes in a (polymer derived) ceramic.
matrix for high temperature light weight applications.

11:15 AM *NNG-8
Investigation of Space Radiation Resiliency of Carbon Nanotube Based Nanocircuits. B. W. Jacobs1, V. M. Ayres1, M. A. Crimp1, R. M. Ronningen1, A. F. Zeller1, H. C. Shaw2, J. B. Benavides2, A. J. Kogut3, M. P. Potok3 and J. B. Halpern4
1Michigan State University, East Lansing, Michigan; 2NASA Goddard Space Flight Center, Greenbelt, Maryland; 3NASA Jet Propulsion Laboratory, Pasadena, California; 4Howard University, Washington, District of Columbia.

Space exploration is entering a new era, with the advent of widespread use of new micro space probes. However, the increased use of miniaturized equipment corresponds to a decreased availability to carry radiation shielding against the space radiation environment. It is well documented that silicon electronics based on diffusive transport through a channel are degraded or damaged by space radiation environments that alter the conduction path, by any of several mechanisms1. The interest to new nanocircuitry opens doors to the problems encountered current electronics. In prototype carbon nanotube transistor circuits, there are no conventional pn junctions or isolated gates to damage, as transistor action occurs primarily by varying the contact resistance rather than the channel conductance.

In previously reported research, single and multi-walled carbon nanotubes have exhibited enhanced heavy-ion radiation resilience1,2. Enhanced proton radiation resilience has been observed in GaAs quantum dots3. We present recent results on fundamental radiation issues in the new nanoscale materials and circuit architectures. We have fabricated simple nanocircuits to investigate the electrical characteristics of carbon nanotubes and gallium nitride nanowires so as to analyze the radiation resilience of these novel circuits, and specifically how robust the nanotube-metal contact is after significant doses of radiation. Total dose and heavy-ion irradiation experiments are ongoing at the NASA JPL Propulsion Laboratory, and at the National Superconducting Cyclotron Laboratory, Michigan State University. Electrical characterization is ongoing at the NASA Goddard Space Flight Center. Scanning probe microscopies, transmission and scanning electron microscopies and Raman and FTIR spectroscopies are used to analyze damage points on the samples. The research goal is to determine if the promise of ultra light weight circuits with improved space radiation resilience can be realized. J. P. Conley, Jr., 4A comprehensive physically based predictive model for radiation damage in MOS systems5, Appl. Phys. Lett., Vol. 71, pp.2413-2423 (1998) 6. H. Heineke, J. Tesoff, R. Martel, V. Derycke, J. Appenzeller, and P. Avouris, "Carbon nanotubes as Schottky barrier transistors", Phys. Rev. Lett., Vol. 89 (2002) 7. W. B. Jacobs, V. M. Ayres, M.A. Crimp, and H. C. Shaw, "Nanotube and nanowire devices in the space radiation environment", Bull. Am. Phys. Soc., Vol. 49, No. 1, p. 249 (2004).

130 PM *NN7.1

The overall goal of this ongoing research is to modify the structure of aromatic polyimides to attain solubility in common organic solvents without substantially decreasing the rigidity of their backbones. The primary approach of this research has involved the introduction of trifluoromethyl-substituted, twisted-biphenyl structures in polyimide backbones. This steric repulsion of the substituents in the 2- and 7-positions of the biphenyl moieties in such monomers twists the rings dramatically out of plane. The resulting twisted conformation inhibits chain packing and crystallization. The severe twist also breaks the conjugation of the biphenyl moieties and turns the colorless films. It was initially postulated that polymers obtained from these monomers would be soluble in common organic solvents and would form optically-clear films that would be transparent in the visible light region. A second approach which has involved the polymerization of trifluoromethyl-substituted 3,5-diharylamidazole. The pendant substituents also break up the chain packing resulting in solubility in organic solvents. Space applications of the polyimides are being developed. The polymers had intrinsic viscosities as high as 10 dl/g (n-cresol) at 30 °C and glass transition temperatures (Tg) as high as 370 °C. Many of the polymers, particularly those based on the substituted diamidines and 2,5-bis (3,5-diaryl)imidazole. These polymers display high thermal and mechanical properties. Depending on their structure, the polymers could be cast from phenolic or ketone solvents into 10-20 μm-thick, colorless films. WAXD and FTIR analysis revealed that the chains aligned parallel to the substrate surface during the casting process. The extent of in-plane orientation was found to depend on the polymer chain rigidity and linearity and on the polymer molecular weight. The orientation resulted in nanostuctured thermal, mechanical, optical and dielectric properties. The Tg along the out-of-plane direction was lower than the Tg determined along the in-plane direction. The coefficient of thermal expansion (CTE) was approximately one order of magnitude higher out-of-plane than that in-plane, which was as low as 6.98 x 10^-6 °C^-1 for BPDA-PFMB films. The refractive index in-plane was 0.02 to 0.2 higher than the refractive index out-of-plane, which varied from 1.500 to 1.710. This anisotropy in refractive index was utilized in the development of retardation layers for liquid crystal displays. The out-of-plane dielectric constant, which was determined according to ASTM-150-181, ranged from 2.25 to 2.75 at 1 MHz.

Fiber Properties. Fibers were prepared from BPDA-PFMB from meso-resolution and p-chlorophenol solutions using a dry-jet wet spinning method. The fibers were elongated and annealed above 400 °C to achieve tensile strengths of 3.3 GPa and tensile moduli over 130 GPa. The fibers were more thermally stable than any other reported high performance fiber.

SESSION NN7: Irradiation Effects in Materials for Space Applications
Chair: Zelina Iskonderova
Wednesday Afternoon, December 1, 2004
Room 207 (Hynes)

1:30 PM *NN7.2
Nanocomposites made out of nanoclusters as building blocks for space applications. You Qiang, Jiji Antony, Amit Sharma, Sweta Pendyala, Joe Nutting, Daniel Meyer and Daniel Sikes; Department of Physics, University of Idaho, Moscow, Idaho.

The development on new advanced nanocomposites that possess unique mechanical, thermal, magnetic, electrical and chemical properties with sustainability in different harsh space environments will be a future challenge in materials science and engineering industry. To successfully make these nanocomposites into real-life applications, we have developed new types of nanocomposites assembled by monodispersed nanoclusters as building blocks from our newly developed ultrahigh-intensity nanocluster source. Different nanostructured composites are synthesized by controlling independently the incident nanocluster size, concentration, and impact energy to have a wide variety of controlled electronic, magnetic, mechanical and chemical properties for many possible space applications. Nanocluster size, size distribution and nanocrystalline structures have been studied by TOF, AFM, TEM and HRTEM. Superhard nanocomposites (e.g. TiN and TiAIN coatings) are deposited at room temperature by energetic nanocluster impact on the surface of a substrate (HSS steel, glass even Telfon and plastic). These coatings can enhance greatly the lifetime of high-speed bearings in satellite gyroscopes and other heat-resistant systems in space. Magnetic properties of soft nanocomposites made out of Fe or Co nanoclusters have been investigated by SQUID, MFM and magnetic x-ray circular dichroism (MXCD). An interesting dependence of magnetization was found on the cluster size and the concentration in a matrix. Ultrahigh magnetic moment has been found due to more enhanced orbital moment of nanoclusters in the nanocomposites. We also found the photoluminescence of ZnO nanostructures at room temperature is size dependent. There is a blue shift from 3.13-eV of bulk ZnO to 3.45-eV of ZnO nanocluster films that is important for space applications of photodetector devices. * Research supported by Idaho NSF-EPS-00R, Battelle-PNNL, ONR and DOE-EPS-CoR. Contact information: youqiang@uidaho.edu

2:00 PM *NN7.3
Simulation of InAsSb/InGaAs Quantum Dots for Optical Device Applications. Paul von Allmen, Seungwon Lee and Fabiano Oyanuso; Jet Propulsion Laboratory, Pasadena, California.

Self-assembled InAsSb/InGaAs quantum dots are candidates for optical detectors and emitters in the 2-5 micron band with a wide range of applications for atmospheric chemistry studies. While photoluminescence peaks at wavelengths as high as 2.2 μm have been measured in InAsSb dots 1, the present study aims at determining the maximum wavelength theoretically achievable. The energy band gap of unstrained bulk InAs(1-x)Sb(x) is smallest for x=0.62 but biaxial strain for bulk InAs(1-x)Sb(x) grown on In(0.53)Ga(0.47)As shifts the energy gap to higher energies and the maximum wavelength is reached for x=0.51, which seems therefore to be the preferred concentration for long wavelength optical devices. We next examine how the electronic confinement in the quantum dots modifies these air-gap considerations. We have calculated the electron and hole band structure of less shaped InAsSb(1-x)Sb(x) quantum dots with diameter 37 nm and height 4 nm embedded in In(0.53)Ga(0.47)As matrix of thickness 7 nm and lattice matched to an InP buffer. The relaxed atomic
positions were determined by minimizing the elastic energy obtained from a valence force field description of the inter-atomic interaction. The electronic and ionic charge transfer in our model was treated employing a binding approach with the parameters obtained from Ref. [2]. We find that for Sb concentrations larger than x=0.5, the electrons are not confined in the dot, which results from the conduction band edge in the In(x)Ga(1-x)As system at higher energies than in the In(0.53)Ga(0.47)As matrix. The respective positions of the bulk conduction and valence band edges clearly illustrate that the InSb/In(0.53)Ga(0.47)As heterostructure is of type II. We will further show the variation in the excitation energy and oscillator strength as a function of Sb concentration throughout the region where the electron is confined in the In(0.53)Ga(0.47)As buffer material.\[1]\ Y. Qiu and D. Uhl, Appl. Phys. Lett. 84, 1510 (2004).\[2]\ J.M. Jancu, R. Scholz, F. Beltran and F. Bassani, Phys. Rev. B 57, 9453 (1998).

2:15 PM *NN7.3 Correlation of Optical Luminescence with Radiation Hardness in Doped LiNbO3 Crystals, Kelly Simmons-Potter 3, William J. Thomas 2, Barrett G. Potter, Jr. 3 and Louis Weichman 2; 1Electrical and Computer Engineering, University of Arizona, Tucson, Arizona; 2Sandin National Laboratories, Albuquerque, New Mexico; 3Materials Science and Engineering, University of Arizona, Tucson, Arizona.

Transient ionizing radiation fields have been observed to cause substantial optical loss in undoped LiNbO3 crystals operating at 1.06 microns. The loss is slow to recover and appears to be the selection of this material for Q-switch applications in radiation environments unfeasible. We have studied the effects of Mg doping on the radiation response of LiNbO3 crystals, and have investigated the optical luminescence (EL and PL) of undoped and Mg doped samples. Our results indicate a strong correlation between crystal defects, mainly formed during crystal growth, and the radiation response of the crystals. These findings have enabled us to produce radiation resistant LiNbO3 crystals for use in some of the harshest environments. This work was partially supported by Sandia National Laboratories. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy’s National Nuclear Security Administration under contract DE-AC04-94AL85000.

2:30 PM *NN7.4 Nanosensors for Rapid Hydrogen Detections, Zhi Li 1,2, Michael P. Zisch 1, Tao Xu 1, Ulrich Welp 1, Wai-Kwong Kwok 1 and George W. Crabtree 1; 1Materials Science Division, Argonne National Laboratory, Argonne, Illinois; 2Department of Physics, Northern Illinois University, DeKalb, Illinois.

The successful transition to a hydrogen based economy depends on the ability to fully control and monitor hydrogen. Hydrogen sensors will play an important role in this endeavor. Currently, commercial sensors have slower response times (8s or longer) than is needed for most hydrogen safety, environmental and for vehicular transportation, components such as the D-type centers [3]. We have been able to show that some of these point defects are fociosensitive in situ illumination with Ar+ and Kr+ ions at various laser energies. New theoretical estimations of stability and properties of the intrinsic point defects in cBN, possible structural models shall be discussed. The results of ESR measurements shall be also compared with results of TL (Thermo Luminescence), micro-PIXE (Particle Induced X-ray Emission) and micro-IL (micro-Ion Luminescence) measurements.

Low Earth Orbit environment is rich in atomic oxygen, degrading protective coatings since a mixing layer is created providing superior adhesion to the substrate. We will report on the implantation of magnesium ions into light-weight composite electronic housings. However, this may present a myriad of integration and bonding issues. Here we present data on the use of a novel form of nanosized metal (Nanostrands) which when directly incorporated into the composite structure provides shielding equivalent to metal bonded structures. These systems have been tested in both the DC (static dissipation) and high frequency (Shielding Effectiveness) regimes at a variety of low loading resulting in the determination of the corresponding structure-property relationships. The durability of these materials will also be reported under a variety of testing conditions.


Cubic boron nitride (cBN) crystals, the second hardest known material, with sphalerite structure exhibits properties which are superior to diamond in what concerns its lower chemical reactivity, higher thermal stability and semiconductor properties. The energy band-gap of boron nitride, varying between 5.4 and 7.0 eV at room temperature, is the highest among all covalent-bonded semiconductors known so far. This band-gap is suitable for ultraviolet (UV) detectors and UV light emitting diodes operable at wavelengths in the deep UV regime. Moreover, it has been shown [1] that p-n junctions and UV light emitting diodes can be operated at temperatures as high as 900 K without significant parameters changes. It is also highly resistant to radiation damage [2]. It all shows that cBN is a very promising material for semiconductor and optical devices in extreme conditions, as found in the space environment. In spite of the increasing technological interest in cBN, its growth and characterization are in a relatively early state of development. In particular, very little progress has been made to understand the defect structure and associated energy states, essential in controlling the majority of most important materials properties. We shall present the recent results of X(0.4GHz) and W(98GHz)-band Electron Spin Resonance (ESR) studies in cBN crystalline powders and single crystals, respectively. Such correlated multifrequency ESR studies in a broad temperature range have resulted in the clear identification of several paramagnetic species with axial <100> and <111> type symmetry and different g-tensor components, such as the D-type centers [3]. It has also been found that some of these point defects are fociosensitive in situ illumination with Ar+ and Kr+ ions at various laser energies. New theoretical estimations of stability and properties of these intrinsic point defects in cBN, possible structural models shall be discussed. The results of ESR measurements shall be also compared with results of TL (Thermo Luminescence), micro-PIXE (Particle Induced X-ray Emission) and micro-IL (micro-Ion Luminescence) measurements.

3:00 PM NN7.5 Composite Satellite Housings Materials Containing Nickel Nanostrands for Elimination of Metal Sheet Electromagnetic Interference (EMI) Shielding. George Huang 1, Max D. Alexander 1, Matt Pettit 1 and Heather J. Dowdy 1; 1Polymer Branch, Air Force Research Laboratory, Dayton, Ohio; 2Metal Matrix Composites, Heber City, Utah.

EMI shielding of electrical boxes and electrostatic discharge are both of key concern for satellites and other space systems. Without the correct electrical discharge management and shielding technologies, large structures and then destructively discharge, damaging sensitive electrical systems. Likewise, the electrical components require EMI shielding to prevent system interference from adjacent or external sources. Traditional solutions involved the use of various metal sheets bonded to the increasingly more popular light-weight composite electronic housings. However, this can present a myriad of integration and bonding issues. Here we present data on the use of a novel form of nanosized metal (Nanostrands) which when directly incorporated into the composite structure provides shielding equivalent to metal bonded structures. These systems have been tested in both the DC (static dissipation) and high frequency (Shielding Effectiveness) regimes at a variety of low loading resulting in the determination of the corresponding structure-property relationships. The durability of these materials will also be reported under a variety of testing conditions.

4:00 PM NN7.7 Magnesium Implantation by Plasma Immersion in Kaption for Oxidation Protection in Low Earth Orbit. Mario Ueda 1, Ing Hwie Tsai 2, Renato S. Dallauqua 1, Jose O. Rossi 1, Nicole Minks 1 and Antonio F. Ionescu 2; 1Associated Laboratory of Plasma, National Institute for Space Research, Sao Jose dos Campos, S.Paulo, Brazil; 2Associated Laboratory of Materials and Sensors, National Institute for Space Research, Sao Jose dos Campos, S.Paulo, Brazil.

Low Earth Orbit environment is rich in atomic oxygen, degrading protective coatings since a mixing layer is created providing superior adhesion to the substrate. We will report on the implantation of magnesium ions
into Kapton films to create a protective MgO layer. Direct implantation is accomplished in a vacuum arc system with a straight magnetic duct that is oriented parallel to the plane of the substrate to prevent contamination by macroparticules and minimize deposition. Implantation with and without magnetic field will be compared since charging effects are expected to be severe in the much denser magnetically confined plasma. A third implantation approach is described which consists of depositing a thin Mg coating on the samples and subsequently blazing it to high voltages in a nitrogen plasma for recoil implantation. All samples will be tested for oxygen degradation resistance by exposure to oxygen plasma generated in an RF plasma reactor. Thermal cycling test is accomplished through successive dips in liquid nitrogen and in a pre-heated oven. Adhesion enhanced in-plane thermal and electrical conductivity. The concept extremely low permeability for any chemical for a large temperature interval make GPC composites an almost ideal candidate primarily for heat management structures, but also for radioactive fuel containment.

In this paper, we report the results of modeling the photovoltaic response of p-n GaAs solar cells following 33 MeV proton irradiation. Jeffrey Hamilton Warner, Aaron L. Crespin 2 and Robert J. Walters 3

In this paper, we report the results of modeling the photovoltaic response of p-n GaAs solar cells following 33 MeV proton irradiation using Silvaco. Jeffrey Hamilton Warner, Aaron L. Crespin 2 and Robert J. Walters 3

Illuminated completed in fall of 2003. Their applicability to radiation hardness is described which consists of depositing a thin Mg coating on the samples and subsequently blazing it to high voltages in a nitrogen plasma for recoil implantation. All samples will be tested for oxygen degradation resistance by exposure to oxygen plasma generated in an RF plasma reactor. Thermal cycling test is accomplished through successive dips in liquid nitrogen and in a pre-heated oven. Adhesion enhanced in-plane thermal and electrical conductivity. The concept extremely low permeability for any chemical for a large temperature interval make GPC composites an almost ideal candidate primarily for heat management structures, but also for radioactive fuel containment.

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monitor instability as well the BPA-PC films degradation as the emitted gases under SHI irradiation. The results related to the irradiations under vacuum (without any pressurized gas) and under pressurized gas (acrylic, silicone, or silicate) and pigments (inorganic and/or organic). The paper provides a more detailed description on the various types of thermal control coatings used and as well as some examples of data that have been generated. Functional properties and characteristics, such as durability in an imitated LEO environment, thermal-optical characteristics, and so on, were determined. Analysis of the surface resistivity, adherence, stability at thermal cycling, and outgassing characteristics of the Photosil(TM)-treated coatings are being verified. Pristine (untreated) and Photosil(TM)-modified samples are tested in an AO ground-based accelerated simulator and evaluated for changes in mass loss, thermo-optical properties, surface morphology, and surface chemistry changes.

9:30 AM NN8.5 Preventive Surface Treatment of Silicone Materials for Outgassing and Contamination Reduction in Space Applications. Zelina Iskanderova, Jacob Kleiman, Yuri Gudimenko, Richard Ng, David Kaute.

Preventive Surface Treatment of Silicone Materials for Outgassing and Contamination Reduction in Space Applications. Z. Iskanderova, J. Kleiman, Y. Gudimenko, R. Ng, D. Kaute.


Enhancement of Surface Durability and Stability of Conductive and Non-conductive Paints in Space Environment. Y. Gudimenko, R. Ng, J. Kleiman, Z. Iskanderova, A. Grigoriev, D. Edwards, M. Shuiskiy, M. Finckenor. Various space environmental factors have shown to cause damage and degradation to thermal control components and materials on orbiting spacecrafts, producing changes in optical, mechanical, and chemical properties. Prolonged exposure of these sensitive spacecraft materials to the space environment can result in degraded system performance. Due to the importance of thermal control material durability and performance in various space missions, a surface modification program was conducted at Integrity Testing Laboratory Inc. to evaluate their surface modification technology. Known as Photosil, this surface modification was used to evaluate a variety of space-related thermal control coatings, and assess its impact on the stability of coatings functional properties and space durability. Significant enhancement of AO erosion resistance was achieved on organic-based conductive and non-conductive paints, treated by various versions of the developed technology. For some of the paints, identical samples are still being exposed to the LEO space environment as part of the Material on International Space Station Experiment (MISSE). This protective technology has shown, as per ground-based accelerated testing, to significantly improve AO resistance characteristics of paints (Acrylate), Russian acrylic-based conductive advanced EKOM and other types of paints, while leaving their functional properties almost unchanged. Various examples of these applications are presented. Recent results have been presented to further improve the AO stability of a wide range of thermal control coatings, never previously treated by Photosil(TM). The thermal control coatings evaluated in this program represent the materials from various international development and manufacturing sources. They include conductive and/or non-conductive white, black, gray, and silver-gray space paints. These paints vary in the types and concentrations of binders (acrylic, silicone, or silicate) and pigments (inorganic and/or organic). The paper provides a more detailed description on the various types of thermal control coatings used and as well as some examples of data that have been generated. Functional properties and characteristics, such as durability in an imitated LEO environment, thermal-optical characteristics, adherence, stability at thermal cycling, and outgassing characteristics of the Photosil(TM)-treated coatings are being verified. Pristine (untreated) and Photosil(TM)-modified samples are tested in an AO ground-based accelerated simulator and evaluated for changes in mass loss, thermo-optical properties, surface morphology, and surface chemistry changes.

10:00 AM *NN8.6 Surface Modification of Polymers, Paints and Composite Materials Used in the Low Earth Orbit Space Environment. Jacob I. Kleiman, Integrity Testing Laboratory Inc., Markham, Ontario, Canada.


Highly Stable Polymers Based on Poly(m-Carborane-Siloxane) Elastomers. Julian James Murphy, Organic Materials, Inc., Toronto, Ontario, Canada; 2PlasmaTreat, Mississauga, Ontario, Canada; 3Institute Kompozit-Test, Korolev, Moscow Region, Russian Federation; 4NASA Marshall Space Flight Center, Huntsville, Alabama. We present here an investigation of oxidative degradation of BPA-PC under SHI irradiations and post-irradiation short-term storage. SHI irradiations were performed at 10^15 at. cm^-2 with 2 MeV/nuc and 10 MeV/kg/cm^2. To distinguish the contribution to the gaseous carbon oxides production of the BPA-PC oxygen from the atmosphere oxygen, the SHI irradiated samples were tested using FAO facility, with fluencies (1-2)x10^20 at./cm^2. The FTIR analysis shows that the radiochemical yields of C(160^-80) and C(180^-80) are lower than those measured on irradiated films analysis shows that the radiochemical yields of C(160^-80) and C(180^-80) are lower than those measured on irradiated films.
Many commonly used polymer materials contain significant amounts of inorganic fillers. These are incorporated to decrease the cost of polymer feed stocks but also to modify and improve the materials properties. Many ageing effects seen in polymers are caused by suble modifications/filler incorporation. This can be extremely complex developing a predictive ageing model is exceedingly difficult. Poly(dimethyl siloxane) is a commonly used elastomeric material, which in general isstable. Important properties of the polymer are, however, dependent upon the incorporation of particular fillers. The interaction of such fillers with the polymer phase is complex, in addition it is intimately dependent upon a layer water situated at the interface. When the in service environment that such materials experience is strongly desiccating certifying the performance of components is exceedingly difficult. Poly(siloxane) polymers incorporating small closed polyhedral C2B1OH2 species, commonly referred to as a carborane, have been produced. The carborane has been incorporated into the polymer chain and acts essentially as a micro filler. This overcomes some of the difficulty associated with changes in the filler/polymer interface upon ageing. In addition, incorporation of the carborane is shown to yield a significant increase in the thermal stability of the material.

10:45 AM N8N.8

Twelve years of research on POSS-polymers has resulted in numerous publications on both the nanoscale mechanical reinforcement and physical property improvements of incorporating truly compatible silicon oxide frameworks within polymer matrices. However, it has only been within the last few years that we have attempted to control and predict property improvements while taking advantage of their inherent multi-functional benefits. This talk will center around the engineering of 2-D and 3-D POSS networks within polymer systems, maximizing improvements through crystal/aggregate optimization, and multi-functionality with respect to space-survivable, self-healing polymers. The future need for studying the processing of POSS-polymers will also be discussed.

11:00 AM N8N.9
Volatilization from Polymer Materials Induced by Irradiation with Accelerated He++ Ions. Julian James Murphy, Organic Materials, AWE, Reading, United Kingdom.

Experimentally investigating ageing caused by irradiation with energetic particles is very difficult. Firstly, performing the irradiation experience is harsh and strongly desiccating certifying the quality, and multi-functionality with respect to space-survivable, self-healing polymers. The future need for studying the processing of POSS-polymers will also be discussed.

11:15 AM N8N.10

In deep space, radiation doses to personnel from galactic cosmic rays (GCR) become a significant issue that largely constrains potential missions. In the present work a range of possible materials is being evaluated for personnel shielding against GCR in spacecraft. Conventionally spacecraft structural materials, such as aluminum or higher atomic number structural alloys, provide little shielding and can under certain conditions substantially increase radiation doses to personnel. Materials containing high proportions of hydrogen and other low atomic mass components, which also include higher atomic mass components, provide improved GCR shielding. Polyethylene is generally considered as a good performance benchmark shield material. In this work we are investigating both shielding materials that are superior to polyethylene in shielding performance, and spacecraft materials that incorporate desirable shielding properties and are multifunctional in ways that polyethylene is not. Candidate materials that we are investigating can be classified as Si-C-H based polymers and polyetherimide-based polymers and polyamide composites, and novel materials such as hydrides. Work is in progress to identify the most promising materials and to assess their key properties with respect to space radiation shielding and suitability for other spacecraft applications. Assessments of materials are being carried out with respect to physical, mechanical and shielding properties. Desirable attributes such as 1.) potential performance in structural applications, 2.) hydrogen storage, 3.) thermal management, and 4.) electrical performance will be assessed on a material specific basis. Calculations of shielding effectiveness for realistic GCR spectra are underway. These will be compared with experiments utilizing heavy ion beams with energies of GeV per nucleon at the NASA Space Radiation Laboratory located at the Brookhaven National Laboratory AGS booster accelerator.

11:30 AM N8N.11
Conducting and Antistatic Composites for Space Applications. Mirece Chipara1, Jagannathan Sankar 2, Petre Notinger3, Denis Panaiteoscu4, David Hui5, Gheorghe V. Aldica6, Magdalena Chipara 7 and Kin-tak Lam8, Indiana University Cyclotron Facility, Indiana University, Bloomington, Indiana; 2Department of Mechanical Engineering, North Carolina A&T State University, Greensboro, North Carolina; 3Department of Mechanical Engineering, University of New Orleans, New Orleans, Louisiana; 4Department of Mechanical Engineering, The Hong Kong Polytechnic University, Hong Kong, Hong Kong; 5Politehnica University, Bucharest, Romania; 6National Institute for Materials Sciences, Tokyo, Japan.

Conducting polymers (CP) are of particular interest for space applications due to their high conductivity (in highly doped forms) and lightweight. Among potential space applications of CP are EMI shielding, antistatic coating, rechargeable batteries, gas separation membranes, and actuators (artificial muscles). CP exhibit either good mechanical properties and poor thermal/thermo-oxidative stability (such as polycrylates) or good thermal/thermo-oxidative properties and poor mechanical properties (such as polypyrrole and polyaniline). To overcome these drawbacks several research directions were considered. Most of these studies were focused on the dispersion of polymers with high thermal and thermo-oxidative stability in polymeric matrices with good mechanical properties. For space applications, CP should present a high stability. The thermo-oxidative stability is of particular importance for polymer designed to be used in Low Earth Orbit, where the presence of atomic oxygen (more reactive than molecular oxygen) triggers a fast degradation. We report on the physical properties of composites based on polyaniline (PANI) and polypyrrole (PPY) dispersed in various conducting matrices such as polystyrene and polystyryl chloride. Various experimental data were used to analyze conducting polymers (PANI and PPY) and their composites. Electron spin resonance (ESR) was used to monitor the concentration and the temperature dependence of conducting electrons. The resonance line shape was used to analyze the mesoscopic nature of the conduction. The resonance line position and amplitude revealed the absence of high spin biliporobinoids and indicated that the charge transport is dominated by polaron. The temperature dependence of the resonance line width was correlated with polaron mobility. DC electrical conductivity measurements, at low temperatures, revealed a dominating one-dimensional variable range hopping in both CP and composites above the percolation threshold. The dependence of the DC conductivity on the dispersed within the polymeric matrix showed that the conductivity percolation threshold is at relatively large fillings. Mechanical testing (elongation at break and tensile strength) on polymeric matrices loaded with various fractions of conducting polymers revealed a close connection between electrical and mechanical properties. The data are compared with the results obtained by dispersing metallic fibers within polymeric matrices. The radiation stability of CP and of composites based on conducting polymers is tentatively discussed. The tuning of mechanical and electrical properties of the composites...
is realized by adjusting the amount of conducting filler introduced in system and by controlling the conductivity of CP through the doping level. The effect of doping on polyaniline, as revealed by ESR spectroscopy is discussed.

11:45 AM N9N.12
Raman Spectroscopy of Graphitic Foams. Eduardo Bde Barros1, N. S. Demir1, G. Dresselhaus2 and M. S. Dresselhaus3; 1Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts; 2Departamento de Fisica, Universidade Federal do Ceara, Fortaleza, Ceara, Brazil.

The pitch based graphitic foams recently developed by J. Klett of the Oak Ridge National Laboratory (ORNL) have been found to have a very high thermal conductivity to weight ratio. Several thermal management applications to this novel material are expected to be found in the aeronautics and aerospace industries. The heat transfer in solids is mainly governed by the phonon propagation properties.

Therefore, Raman spectroscopy should prove to be a key technique to probe the thermal properties of graphitic foams. The pitch based graphitic foams are distributed on a tetragonal pattern and the graphene planes are found to have different orientations throughout the structure surrounding the pores. Raman spectroscopy studies were performed on the different regions of the foam. The D band intensity, which indicates the presence of defects in the graphene structure, is observed to change relative to the G band-intensity for regions of the foam with different types of microstructure. Also, the two peak structure related to the stacking of graphene layers of the double resonance feature known as G' band was studied yielding interesting correlations between structural features and characteristics of the Raman feature. The authors thank Dr. J. Klett of the ORNL for providing the samples and the Intel Corporation for their support.

SESSION N9: Space-Induced Degradation of Materials
Chair: Kenneth Label
Thursday Afternoon, December 2, 2004
Room 207 (Hynes)

1:30 PM *N9N.1

Polyimides such as Kapton are used extensively in spacecraft thermal blankets, solar concentrators, and space inflatable structures. Atomic oxygen (AO) in lower earth orbit (LEO) causes severe degradation in Kapton resulting in reduced spacecraft lifetimes. One solution is that SiO2 coatings impart remarkable oxidation resistance and have been widely used to protect Kapton. Imperfections in the SiO2 application process and micrometeoroid / debris impact in orbit damage the SiO2 coating leading to erosion of Kapton. A self passivating, self healing silica layer protecting underlying Kapton upon exposure to AO may result from the nanodispersion of silicon and oxygen within the polymer matrix. Polyhedral oligomeric silsesquioxane (POSS) composed of a morganic cage structure with a 2:3 SiO ratio surrounded by tailorable organic groups is a possible delivery system for nanodispersed silica. A POSS diamine was copolymerized with pyromellitic dihydride and 4,4'oxydianiline resulting in POSS Kapton Polyimide. The glass transition temperature (Tg) of 5 to 20 weight % POSS Polyimide was determined to be 5 – 10 °C lower than that of unmodified polyimides (414 °C). Furthermore the room temperature modulus of polyimide is unaffected by POSS, and the modulus at temperatures greater than the Tg of the polyimide is doubled by the addition of 20 % POSS.

To simulate LEO conditions, POSS Polyimide films were exposed to a hyperthermal O-atom beam. Surface analysis of exposed and unexposed films conducted with X-ray photoelectron spectroscopy, atomic force microscopy, and surface profilometry support the formation of a SiO2 self healing passivation layer upon AO exposure. This is exemplified by erosion yields of 10 and 20 weight % POSS Polyimide samples which were 3.7 and 0.98 percent, respectively, of the erosion yield for Kapton H at a fluence of 8.5 x 10^15 O atoms cm^-2.

2:00 PM N9N.2

Fluoropolymers, like Teflon®PTFE (polytetrafluoroethylene), FEP (fluorinated ethylene-propylene co-polymer) and PFA (polytetrafluoroethylene-co-perfluoroalkyl vinyl ether) have been extensively used in space applications, protective coatings, microelectronic packaging and biotechnology. However, their low surface energy properties present significant challenges for adhesion and wettability when bonding to other materials, such as, the conductor copper. Therefore, surface modification processes, that allow wettability or enhance the adhesion of copper to Teflon, are of considerable interest. PFA was modified with vacuum UV (VUV) radiation downstream from an argon microwave plasma. During most of the experiments, oxygen flowed over the VUV exposed samples. Surface modification was investigated by water contact angle, X-ray photoelectron spectroscopy (XPS), and scanning electron microscopy (SEM). Copper was sputter coated onto the modified surfaces. The adhesion of copper to the modified surfaces was monitored by use of a tape test. The results for PFA will be compared to the earlier reports on the adhesion of copper to VUV modified PTFE. [2] H. Desai, L. Xiaolu, A. Entenberg, B. Kahn, F. D. Egito, L. J. Matienzo, N. S. Demir, M. S. Dresselhaus, and G. A. Takacs, in: Polymer Surface Modification: Relevance to Adhesion, K. L. Mittal (Ed.), Vol. 3, in press, VSP, Utrecht (2004).

2:15 PM N9N.3
Degradation and Oxidation of Silver due to Hyperthermal Atomic Oxygen. Long Li1, Liang Wang1, Timothy K. Minton2 and Judith C. Yang1; 1Materials Science and Engineering Department, University of Pittsburgh, Pittsburgh, Pennsylvania; 2Department of Chemistry and Biochemistry, Montana State University, Bozeman, Montana.

Atomic oxygen (AO) formed by the photodissociation of molecular oxygen is the primary species of oxygen in the low-Earth orbit (LEO), ranging from approximately 200 to 700 km above the earth. The high relative velocity between space vehicles and ambient atomic oxygen leads to hyperthermal collisions of O-atoms with spacecraft materials. These collisions, which are equivalent to e-atom with 3 eV of translational energy striking a surface, may cause rapid degradation and/or oxidation of materials. Silver is used as a mirror material on spacecraft and as a sensor material to monitor atomic oxygen fluence. We have chosen silver as a typical model metal to gain insights into degradation and passivation mechanisms of metals exposed to atomic oxygen. In this work single crystal silver bulk crystals, held at a temperature of 220°C, were exposed to a 5 eV atomic oxygen beam created by laser detonation of O2. The O-atm exposure fluence was 8×10^19 atoms/cm². We have characterized the resulting oxide and oxide-metal structures by cross-sectional (scanning) transmission electron microscopy ([S]TEM) and high-resolution TEM. Our results show that a more than 10 micron oxide scale formed on each silver surface that is oxidized by O2. The oxide scale/substrate interface is very rough and detached in some areas. Many defects and large lattice deformations inside the single crystal substrate are observed near the interface. The results suggest a bulk oxidation of silver single crystals with atomic oxygen and a high permeability of atomic oxygen in the silver lattice. These results suggest that atomic oxygen beam with a 5 eV energy should enhance the diffusion of O-atoms into the substrate. For further investigation, an unique Physical Sciences Inc. FASTTM AO laser detonation atomic oxygen source in a UV chamber is employed for ex situ oxidation studies. The system is equipped with a Maxtek Inc. BQCM system, a quartz crystal microbalance with dual-sensor, to dynamically measure the mass change of metals coated onto the sensor crystals when exposing to atomic oxygen, thereby allowing the in situ measurement of mass gain and atomic oxygen flux. Thin films of single crystalline silver will be exposed inside the atomic oxygen source for incremental time periods and then characterized using XPS by transmission electron microscopes in order to observe the evolution of the oxide.

2:30 PM N9N.4
Structural Characterization of Oxide Layers on Aluminum Modified by Exposure to Hyperthermal Atomic Oxygen. Long Li1, Liang Wang1, Timothy K. Minton2 and Judith C. Yang1; 1Materials Science and Engineering Department, University of Pittsburgh, Pittsburgh, Pennsylvania; 2Department of Chemistry and Biochemistry, Montana State University, Bozeman, Montana.
Polyimide is a high glass transition temperature with excellent mechanical properties, high temperature stability even in the presence of oxygen, and high dielectric strength. The polymer is important for space applications mainly due to its reduced weight, low electrical conductivity, and mechanical strength. The high dielectric strength of polyimide (2600 V/mil for Kapton) is preserved up to 400°C. Polyimide has already been used in space for inflatable structures, multi-layer-insulation, flexible circuit boards, thermal blanket, and acoustic fuselage blanket. The transparent polyimide (LaRC) has a high transparency (90%), and a decomposition temperature of about 550°C. The polymer exhibits liquid crystal features and is characterized by a stiff molecular chain. Recent studies revealed that the use of polyimide as insulator has to be considered with caution. High fluence heavy ions as well as short circuit arcs are capable of producing conducting channels in polyimide. The pyrolysis like nature of these modifications that result in the production of graphite like conducting nanostructures, is responsible for the failure of polymide-based insulators. A spectral analysis shows the effect of proton irradiation on polyimide aiming to a better understanding of the molecular basis of polyimide failures is reported. The final goal of this research is to assess the limits of in space application of polyimide. Thin films of polyimide where subjected to irradiation with protons irradiated at 200 MeV, at different fluences. The irradiation has been done in air, at room temperature. Electron spin resonance spectroscopy was used to identify the nature of radicals and to study the effect of temperature on the recombination of free radicals. Additional studies were done by using FTIR and UV-VIS measurements on the same samples. Dynamical mechanical analysis tests revealed the decrease of the glass transition temperature of polyimide upon irradiation. This indicates that chain scissions is the main degradation process of proton irradiated polyimide.

The present work reports phase transformations of thin films of C60 irradiated with 100 MeV Au ions. The present work is in continuation with our earlier work using 59Ni++ and 150O++ ions to study the modification in C60 thin films. The study of C60 thin films using Au++ ions, provides us enough additional information to investigate the role of C60 thin film phase transformation due to different ion fluences. Thin films of C60 (230 nm) were deposited on Si(100) and quartz substrates and then irradiated using 197Au++ ions of 100 MeV energy. The Sα and SΔ values for these ions incident on C60 solid were obtained to be 1.292 X 10^3 eV/Å and 1.895 X 10^3 eV/Å, respectively. The Sα value being about 2 orders of magnitude more than the SΔ value, shows that the electronic energy loss is dominant for the irradiation of 197Au++ ion at 100 MeV. The irradiated films of C60 were characterized using Raman spectroscopy measurements and optical absorption measurements. However, only results of Raman measurements have been presented here. Raman spectra of the films were measured using LABRAM Raman spectroscopy. The Raman spectra were recorded at room temperature with Ar ion laser excitation 514.5nm (10X objective) at Universitaet Wuerzburg, in a range of 750 - 2150 cm^-1. Power and exposure time was so adjusted as to avoid any phototransformed polymer peak. The Raman spectra indicate that swift heavy ion (SHI) irradiation results in transformation of crystalline C60. At low fluences along with the fragmentation of C60 there is dimer/polymer formation. As fluence increases the dimer/polymer content first rises, optimizes, decreases and finally vanishes at very high fluences. At high fluences, all the C60 molecules as well as the polymeric C60 fragment absorbing in nano-crystalline graphite1,2 embedded in amorphous carbon (a-C). A comparison Raman spectra of Au, Ni and O irradiated C60 thin films indicates that the decrease of all the modes (A2g and E2g modes) is steepest for the Au ion fluences. However, the decrease of all the modes is steepest for the Au ion fluences. For the Au ion fluences, the decrease of all the modes is steepest for the Au ion fluences.
fluence values for different ions used are strongly correlated with the $S_2$ value of the ion. Thus lower the $S_2$, the larger the range of fluence for which $C_{60}$ to polymeric $C_{60}$ as well as amorphous carbon is dependent mainly on the total energy deposited in the film. A critical energy value is responsible for onset and the vanishing of $C_{60}$. REFERENCE F.1. Naveed Bajwa, Alka Ingole, D.K Avasthi, Ravi Kumar, A Tripathi, K Dharmavir and V.K Jindal J. Appl. Phys. 94, 326 (2002). 2 Naveed Bajwa, Alka Ingole, D.K Avasthi, Ravi Kumar, K Dharmavir and V.K Jindal, Radiotis measurements 90, 737 (2000).

3:45 PM NN9.8 TEM Studies of the Protective AI Coatings on Kapton. Judith C. Yang, Huiping Xu, Long Li, Bruce Banks; Materials Science & Engineering, University of Pittsburgh, Pittsburgh, Pennsylvania; 3 John H. Glenn Research Center at Lewis Field, NASA, Cleveland, Ohio.

Polymeric materials undergo rapid erosion when exposed to the harsh low-earth-orbit (LEO) environment. Coatings can reduce the erosion rate of polyimide Kapton from atomic oxygen (AO) attack. Specifically, we are investigating how thin AI coatings can protect Kapton. Protective AI layers with variations in layer thickness and growth conditions were deposited on circular plates of Kapton with 1" diameter and 0.003" thickness. The quality of these protective coatings are being evaluated by mass loss measurement as a function of AO fluence within oxygen plasma and compared to Kapton alone, where dramatically decreased erosion rate has been noted. To understand how these coatings protect Kapton as well as how the AO interacts with the coatings, we are investigating the microstructure of these coated materials by plane view and cross-sectional transmission electron microscopy (TEM) methods. TEM samples were prepared by Ultramicrotomy. Special attention is focused on defects, cavities and grain size of the protective layer as well as interfaces between this layer and Kapton.


4:15 PM NN9.10 Be Ion and Electron Irradiation Effects on Compositionally Tuned MgZnO Based UV Detectors. Shiva Hullavarad, R. D. Vispute, S. Dhar, T. Venkatesan and I. Tukucz; 1Center for Superconductor Research, University of Maryland, College Park, Maryland; 2Bluewave Semiconductors, Baltimore, Maryland.

MgZnO is a novel oxide based UV sensitive material. The band gap of Mg$_x$Zn$_{1-x}$O can be tuned by varying the composition of Mg to achieve band gaps corresponding to UV-A, UV-B, UV-C regions of UV spectrum. This material is of significant importance for various applications in flame sensors, UV index monitors and missile plume detection. The interesting property that makes this material unique is its existence in multiple phases for different Mg compositions. This allows picking up desired Mg composition corresponding to suitable UV sensitive window and growing on lattice matched substrate. In the present work we have studied the effect of 1 MeV He ion and 100 keV electron irradiation on M-S-M Photoconductors fabricated on MgZnO. The Mg$_x$Zn$_{1-x}$O films are synthesized by Pulse Electron Deposition. X-Ray Diffraction and Rutherford Back Scattering-channeling techniques are used to characterize the crystalline quality and composition of the samples respectively. We also measure the change in optical transmission of the absorption edge at the band gap as a function of irradiation dose. The leakage current, sharpness of photoresponse under proper UV light illumination are also studied as a function of ion dose.


Polymer based adaptive optic mirrors have been identified as an alternative approach to overcome weight limitations in large aperture spaced-based telescopes. Dimensional adjustments using electron beams have been successfully demonstrated but are dependent on reliable piezoelectric properties and responses of thin films. While polyvinylidene fluoride (PVDF) as a generic polymer type has been identified as a suitable piezoelectric material for control purposes, it is also well known that fluorinated polymers are highly radiation-sensitive materials. Mechanical properties will change under various types of radiation ($\gamma$, x-ray, c-beam, ion-beam, strong vacuum UV). Extreme temperature fluctuations with annealing effects and cyclic stresses are of similar concern. As part of our work, we have studied the degradation of PVDF and related copolymers under a range of stress environments and specifically investigated the impact of these environments on the piezoelectric properties necessary for reliable operation of thin film mirrors in space. We have established fundamental correlations between chemical and physical features of various PVDF copolymers and their piezoelectric properties. Among the techniques used were x-ray diffraction, 19F NMR with high speed spinning, DSC, tensile strength measurements of GSR and measurement of D-E hysteresis loops. Material performance was found most significantly to depend on crystallinity, processing history, moduli, and net polarization. For example, high temperature properties are severely impacted by mechanical relaxation phenomena in highly oriented materials. Conversely, at low temperature materials with limited Tg-moduli transitions showed more consistent responses.

Therefore, physical property changes appear to be the dominant factor controlling performance rather than radiation induced chemical changes. A framework for material qualification issues and overall system survivability predictions in low earth orbit conditions has been developed. It will allow for improved material selection approaches, feedback for manufacturing and processing technologies, avenues for material optimization/stabilization strategies and provide the necessary guidance on alternative materials. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy’s National Nuclear Security Administration under Contract DE-AC04-94AL85000.

SESSION NN10: Magnetic Materials for Space Applications
Chair: Ralph Skomski
Thursday, December 2, 2004
Room 206 (Hynes)

7:00 PM NN10.1 Laser and Particle Beam Irradiation Effects in Amorphous MgZnO. Monica Sorace, Physics, Duquesne University, Pittsburgh, Pennsylvania.

This work presents a comparison between laser and particle beam
Fabrication of LBMO/YBCO Double Layers for Tunable Microwave Filters

Tarno Endo,1,2 Michi Ogata,1 Yoshika Sakurada,1 Hidetaka Nakashima,1 Hirofumi Yamasaki,1 Akira Onzomo,2 Yasuyuki Nakamura,5 Atsushi Ochi,2 Sumitsuka Tachikawa,4 and Akira Ohnishi,1

1Institute for Chemical Research, Kyoto University, Uji, Kyoto, Japan; 2NEC Corporation, Tokyo, Japan; 3NEC TOSHIBA Space Systems, Ltd., Yokohama, Japan; 4Japanese Aerospace Exploration Agency, Sagamihara, Japan.

A variable emittance radiator for a spacecraft, named SRF (Smart Radiation Device), which uses a metal-insulator transition of (La,Ca,Sr)MnO3, was developed. The emittance property of this material significantly changes at the metal-insulator transition temperature (close to room temperature); that is, (La,Ca,Sr)MnO3 is a highly emissive insulator above room temperature and a less emissive metal below room temperature. Therefore, the (La,Ca,Sr)MnO3 material installed on spacecraft surfaces can automatically control the radiation heat transfer from the spacecraft to space without requiring any electrical power. The developed radiator can greatly improve the weight of the propulsion system over the conventional thermal control layers. Several forms of the device, which include ceramic tiles and thin films, have been developed. After undergoing simultaneous ion beam irradiation, the film on the thin film developed device is indeed employed on the JAXA’s asteroid sample return spacecraft MUSES-C (Hayabusa), which was launched on May 9, 2003. The emittance property of the material will be discussed from a physical point of view. The outstanding device performance will also be reported.

7:45 PM *NN10.3

Fabrication of LBMO/YBCO Double Layers for Tunable Microwave Filters

Tarno Endo,1,2 Michi Ogata,1 Yoshika Sakurada,1 Hidetaka Nakashima,1 Hirofumi Yamasaki,1 Akira Onzomo,2 Yasuyuki Nakamura,5 Atsushi Ochi,2 Sumitsuka Tachikawa,4 and Akira Ohnishi,1

1Institute for Chemical Research, Kyoto University, Uji, Kyoto, Japan; 2NEC Corporation, Tokyo, Japan; 3NEC TOSHIBA Space Systems, Ltd., Yokohama, Japan; 4Japanese Aerospace Exploration Agency, Sagamihara, Japan.

A variable emittance radiator for a spacecraft, named SRF (Smart Radiation Device), which uses a metal-insulator transition of (La,Ca,Sr)MnO3, was developed. The emittance property of this material significantly changes at the metal-insulator transition temperature (close to room temperature); that is, (La,Ca,Sr)MnO3 is a highly emissive insulator above room temperature and a less emissive metal below room temperature. Therefore, the (La,Ca,Sr)MnO3 material installed on spacecraft surfaces can automatically control the radiation heat transfer from the spacecraft to space without requiring any electrical power. The developed radiator can greatly improve the weight of the propulsion system over the conventional thermal control layers. Several forms of the device, which include ceramic tiles and thin films, have been developed. After undergoing simultaneous ion beam irradiation, the film on the thin film developed device is indeed employed on the JAXA’s asteroid sample return spacecraft MUSES-C (Hayabusa), which was launched on May 9, 2003. The emittance property of the material will be discussed from a physical point of view. The outstanding device performance will also be reported.

8:30 PM *NN10.5

Developing Glassy Magnets from Simulated Composition of Martian Soil for Exploration Applications

Narayanan Ramchandran1,2, Chandra Ray1 and Jan Rogers2,3


The long-term exploration goals of NASA include developing human habitation on Mars and conducting scientific investigations on Mars and other planetary bodies. In situ resource processing is a key objective in this area. We focus on the possibility of making magnetic glasses in situ for potential applications development. The talk will focus on ongoing work at NASA Marshall Space Flight Center on making magnetic glasses from Mars soil simulants and its characterization. Analysis of the glass morphology, strength, chemistry and resulting magnetic properties provides a fundamental understanding of the synthesized material that can be used for potential applications development. In an effort to characterize the magnetic properties of the Mars glasses, a series of tests were performed at NASA MSPC. Preliminary tests indicated that the glasses were attracted to a magnet and also had a small amount of residual magnetism. They were opaque (almost black in color). As the first step, a sample of Mars 1 glass (1 mm x 1 mm x 5 mm length) was machined, weighed and its hysteresis curve was
measured using a Vibration Sample Magnetometer (VSM). Next, a small furnace was designed and built and the sample was baked in a graphite crucible at 800 °C for 3 hours in the presence of a uniform, transverse (transverse to the 5mm length of the sample) magnetic field of 0.37 Tesla. The treated sample showed reddening on the outside and showed substantially increased residual magnetism. This sample was again analyzed in the VSM. The data clearly showed that some chemical change occurred during the heat treatment (color change) and that both the glasses have useful magnetic properties. Although no orientation effects of the magnetic field were observed, the data showed the following: 1. Both glass samples are primarily soft magnets and display ferromagnetic behavior (hysteresis, saturation, etc.) 2. The treated glass has improved saturation magnetization (order of magnitude increase), retentivity (hysteresis area increase) and coercivity (order of magnitude increase) compared to the untreated glass 3. The untreated sample has higher coercivity (50% that of Nickel) than the treated sample 4. Both samples have similar energy density. Results from a recent study to quantify the efficiency of magnetic processing conditions such as heat treatment, atmosphere, containerless processing (by electrostatic levitation), and applications of external magnetic fields of different strengths will be discussed. Efforts on optimizing the magnetic properties of the product and the feasibility of using it for a couple of specific magnetic applications such as heat generation using an ac field and for electro forming will also be covered. The latter is an in-situ manufacturing technique being studied for in-space fabrication applications at MSFC.

Chair: Narayanan Ramachandran

9:00 AM NN11.1 Polymer Degradation From The Thermal Analysis Point Of View


In this work the application of different thermal analysis methods to polymer based materials degradation is considered in two ways: the study of the degradation process itself and the evaluation of the degree of damage of a material as consequence of chemical degradation by thermal or radiation effects. The thermal degradation in different atmospheres is basically studied by TGA in dynamic experiments. The authors have found that the evolution of the sample mass follows a mixture of logistics model, so an overall TGA curve can be fitted by this model. The fitting parameters have important implications related to the kinetics of the different processes involved and to the relative amount of each component in the sample. The method itself implies the separation of overlapping processes. Other improvements made by the authors are related to the noise reduction by smoothing of TGA and DSC data, particularly, the estimation of DTG derivatives using logistic regression for pilot bandwidth estimation. The analysis by TGA of many materials results in more or less complex truces that do not allow a simple parametric fit like the one previously described, since although it reproduces the asymptotic at the latter and beginning of the reaction, sometimes many processes are strongly overlapping giving a complex trace that would need an important number of logarithmic components to be adequately fitted. However, it is possible to use a local polynomial regression model instead, been also applicable to DSC traces, whose shapes are totally different from TGA. The authors propose a model based in a nonparametric estimation, where the goodness of the fit depends very much on the bandwidth selection, especially when the derivatives are concerned. The proposed model gave a satisfactory fitting. This way of fitting smoothes the noise always giving always reliable values different than the obtained by other methods that strongly depend on the user choice. Concerning the evaluation of the degree of damage by thermal analysis methods, dynamic mechanical analysis (DMA) was applied to polyimides. The glass transition temperature was measured before and after the exposure to different doses of proton radiation, that emulates the space environment. Other examples show how the exposure for long times at moderately elevated temperatures results in degradation of some mechanical properties. Additionally, the authors performed a study of different nanofillers on styrene-isoprene-styrene block copolymers was studied. Polyethylene and polyimide are such two typical materials. Effects of heat treatment of Si3N4 filler on the mechanical and thermal properties of particulate-reinforced composites. Sea-Hoon Lee1,2, Fritz Aldinger1, Sung-Churl Choi2 and Keun-Ho Auh1; 1Max-Planck-Institut fur Metallsforschung, Stuttgart, Germany; 2Ceramic processing research center, Hanyang university, Seoul, South Korea.

Effects of heat treatment of Si3N4 filler on the mechanical and thermal properties of particulate-reinforced composites (2D composite) made by precursor-impregnation and pyrolysis (PIP) method were investigated. The PRC are expected to have enhanced thermal shock resistance due to the similarity of coefficient of thermal expansion (CTE) between filler and Si-C-N matrix. The chemical composition of the filler was controlled by changing the heating conditions and/or using the Si3N4 powder bed. Oxygen content of the filler always decreased after the heat treatment above 1300 degree celsius. Carbon and nitrogen contents of the filler were also affected by the heating condition and powder bed. Mechanical properties such as cutting resistance, strength, Young’s modulus and hardness as well as high temperature mass stability of the PRC were improved by the heat treatment of the filler before the impregnation and pyrolysis of the liquid Si-C-N precursor.

9:15 AM NN11.2 Developing New Refractory Open Cell Metal Foams for Aerospace Applications

Authors: Ussein E. Azni, William Roberts and Afsaneh Rabiei; Dept. of Mechanical, Aerospace Engineering, North Carolina State University, Raleigh, North Carolina.

The thermodynamic efficiency of the Brayton cycle, upon which all gas turbines (aeropropulsion and power generation) are based on scales with the peak operating temperature. However, the peak temperature is limited by the materials (lubricants and the temperature they can withstand). The highest temperatures in the gas turbine obviously occur in the combustor region but these temperatures are often too high and the combustion products must be diluted with relatively cooler air from the compressor to reduce the temperature to

SESSION NN11: Materials in Extreme Environments
Chair: Narayanan Ramachandran
Friday Morning, December 3, 2004
Room 207 (Hynes)
tolerable levels for the turbine blades. Thus, to maximize the thermodynamic efficiency, the amount of dilution air should be minimized. The performance of the engine is affected by the temperature of the fuel. The nozzle guide vane is perfectly uniform and equal to the cold air entering the turbine section and eventually provides a profile factor and moving the profile factor closer to unity. This will not only increase the efficiency of the engine but will also increase the lifetime of the turbine blades that constantly suffer from thermal fatigue cycling. However, current practices yield results that are far from optimal. In our study, an open cell porous material is being placed between the combustor section and the turbine section of the engine. This provides a better temperature and velocity profiles and allows operation at the maximum allowable temperatures. The open cell porous material with its increased surface area mixes the hot and cold air into the engine section and provides required transition that is closer to unity. The main issues in this case will be to control the pressure drop at an acceptable level and finding a porous material with sufficiently low stagnation pressure losses yet able to withstand the thermal and mechanical stresses as well as corrosion and oxidation. This research focuses on studying the thermal and physical properties of various open cell porous materials with different cell sizes, materials, and thicknesses and their behavior at elevated temperatures and pressures. The temperature profile versus pressure drop for various porous media will be experimentally tested and analyzed and the effect of each parameter on the pressure drop and temperature profile is being studied.

9:30 AM NN11.4 Processing and Development of an Ultra-Light High Strength Foam Former Material with Intermetallics, by Mario De Stefano, Mary C. Neville and Afsaneh Rabiei; Department of Mechanical, and Aerospace Engineering, North Carolina State University, Raleigh, North Carolina.

A new closed cell metallic foam that is produced by powder metallurgy is being developed. It is processed by mixing melting hollow spheres with metal powder and sintering them into a solid structure. Although denser than similar foams made entirely by sintered hollow spheres, this new foam will have the advantage of greater strength due to the solid matrix around the spheres, while still maintaining a lower density than that of a bulk metal. The solid matrix can be tailored for different applications through the addition of alloying elements. Additionally, wire reinforcements can be added for even greater strength. This process also has the advantage of being able to control the size and distribution of the cells by controlling the shape of the spheres. Both similar and dissimilar materials have been used for the hollow spheres and the matrix, whereas a casting technique only allows a matrix material of a lower melting point than that of the spheres. In this study, both similar and dissimilar materials have been used for the hollow spheres and the matrix to produce different foams. The material has been reinforced with fiber-reinforced wires to increase the strength of the material. Microstructural, mechanical and physical properties of all reinforced and unreinforced materials have been studied using various techniques, including optical microscopy, SEM, EDX, compression and fatigue tests. The results have been compared with the properties of various metal foams processed using different techniques including those produced using hollow spheres and produced by casting technique.

9:45 AM NN11.5 Aerothermal Analysis of an Advanced Hot Structure for Hypersonic Flight Tests, by Raffaele Savino, Mario De Stefano, Engin Ozcivici and Raman P. Singh; Department of Mechanical Engineering, Stony Brook University, Stony Brook, New York.

Closed cell ceramic foams have been fabricated by incorporating hollow ceramic spheres into a silicon carbide matrix using the polymer infiltration and pyrolysis (PIP) technique. The hollow ceramic spheres used in this investigation were preceramic polymers, which are produced as a by-product of coal fly ash, while the silicon carbide matrix was formed by the pyrolysis of a commercially available liquid pre-ceramic polymer. The fabrication process involved physical mixing of the spheres with the liquid pre-ceramic polymer in different quantities. The resulting slurry was compacted into high temperature molds and subsequently subjected to high temperature pyrolysis in an inert atmosphere. In this manner, various closed cell composite foams were fabricated using different grades of carbon fibers, and different levels of infiltration with the preceramic polymer. Foam characteristics that were investigated include density, porosity, mechanical properties (tensile strength, modulus and compressive strength), thermal properties (CTE) and thermal behavior (density and thermal properties). The pyrolysis procedure allows for low-cost and net shape fabrication of complex components with less fabrication time as compared to chemical vapor deposition. It has been demonstrated that these foams can deliver unique mechanical, physical and thermal properties that offer potential for various thermo-mechanical aerospace applications.


Siloxanes have a wide variety of applications throughout the aerospace industry which take advantage of their exceptional insulating and adhesive properties. However, when exposed to the extremes of space, the physical properties of siloxanes can change. This research focuses on studying the thermal and mechanical properties of various siloxane elastomers compared to the properties of various metal foams processed using different techniques such as transverse (T2) relaxation times, cross relaxation rates, and residual dipolar coupling constants provide excellent probes of changes crosslink density and motional dynamics of the polymers caused by ionizing radiation and thermal degradation. The results of NMR studies on aged siloxanes are being used in conjunction with other mechanical tests to provide insight into component failure and degradation kinetics necessary for preliminary lifetime assessments of these materials. Results obtained both from high resolution NMR spectrometers as well as low resolution benchtop NMR screening tools will be presented.

10:30 AM NN11.7 Syntactic Closed-cell Foams Based on Silicon Carbide, by Engin Ozcivici and Raman P. Singh; Department of Mechanical Engineering, Stony Brook University, Stony Brook, New York.

Syntactic closed-cell foams have been studied using various techniques, including optical microscopy, SEM, EDX, compression and fatigue tests. The results have been compared with the properties of various metal foams processed using different techniques including those produced using hollow spheres and produced by casting technique.
Ni-rich NiTi shape memory alloys are the most promising materials for superplasticity due to their high strength and recoverable strains up to 8%. Superelasticity is based on the stress-induced phase transition from cubic B2 austenite to monoclinic B19 martensite and recovery of the B2 phase upon release of stress. In flat specimens of superplastic NiTi, uniaxial tensile stress causes the austenite to martensite transformation, localized in shear transformation bands. We investigated the phase state in flat Ni50.7Ti49.3 tensile specimens by diffraction methods in a space-resolved mode using synchrotron radiation. The specimens were solution annealed at 880°C for 5 min and water quenched; subsequently, the specimens were cold rolled at -150°C with a thickness reduction of 10%. Finally, the samples were aged at 300°C for 6 minutes. Inside the shear band, the transformation to martensite was incomplete even at 8% macroscopic tensile strain. The residual non martensitic grains deform elastically by 1% in the transverse direction as they have to bear an increased load when the neighbouring grains yield forming martensite. The matrix outside the shear band does not show enough strain to be detectable by diffraction. Between the shear band and the adjacent matrix, we observe a boundary region with transitional states of strain. The observed large lattice strain of the residual non martensitic grains can be attributed to a formation of the rhombohedral R-phase state or to stressed austenite. However, a very sharp preferred orientation of R-phase twin domains has to be postulated to get a precise fit of the full diffraction profile.

11:00 AM NN11.9 Template Synthesis of Boron Nitride Nanotubes for Space Applications. Jose Emider Nocues, Arturo Hidalgo Cordova, Joel De Jesus, Rafael Velazquez, Fabrizio Pinzone, and Gerardo Morelli1; 1Dept. of Physical Sciences, University of Puerto Rico, San Juan, PR, Puerto Rico; 2Dept. of Physics, University of Puerto Rico, San Juan, PR, Puerto Rico.

Boron nitride nanotubes (BNNTs) have received increasing attention due to their unique properties that exhibit advantages over carbon nanotubes (CNTNs). BNNTs are semiconductors with a nearly constant bandgap of 5.2 eV, independent of their purity, length, and size. They have a high elastic modulus of 1.2 TPa, and are resistant to oxidation at temperatures up to 900 C in air. Therefore, BNNTs are extremely promising building blocks for emerging technologies and novel systems concepts with high potential payoff. The growth, structure, properties, and purification of BNNTs are not yet well documented due to significant technological difficulties in making them. BNNT-based electronics represent a new generation of mission enabling technologies capable of performing under harsh conditions such as high temperature and ionizing radiation. BNNT nanocircuitry will feature low-power consumption, compactness, and robustness, thus enabling a high degree of redundancy for highly interconnected communication networks, wherein data from multiple modules are shared. Besides their electronic applications, BNNTs are promising materials for reinforcing metals, polymers and ceramics. Once BNNTs are assembled in ropes or bundles, they can be incorporated into structural materials in order to improve their performance. Such materials will show good performance when exposed to shock waves and similar situations. Hence, BNNTs will also help fulfill the goals of lighter, stronger, safer, and more reliable space ships and airplanes. We report on the growth, structure, and purification of BNNTs grown by arc discharge using CNTNs as templates. The arcing conditions are maintained at 20-40 V DC and 50-100 A with a gap spacing nearly constant of around one mm. Scanning electron microscopy, transmission electron microscopy, and electron energy loss spectroscopy were used to investigate the structure of the tubes and the effect of purification treatments.

11:15 AM NN11.10 Modelling of Hydrogen Embrittlement: Combined Continuum Cohesive and Quantum Mechanics Calculations. Santiago A. Serebrinsky, Emily A. Carter, and Michael Ortiz; 1Graduate Aeronautical Laboratories, California Institute of Technology, Pasadena, California; 2Dept. of Chemistry and Biochemistry, UCLA, Los Angeles, California.

Metallic materials are often susceptible to hydrogen embrittlement (HE) when subjected to adequate conditions. In particular, there were several cases along the history of space applications. Despite the long-standing nature of the problem, the mechanism responsible for HE was not elucidated as yet. Such knowledge is central for the prediction and prevention of HE. In this work, we present a model of HE based on a combination of quantum mechanical calculations and cohesive theories of fracture. The latter were successfully applied many times as an engineering tool to study crack propagation under various conditions. Its application depended on some calibration procedure to fit experimental data for specific samples. Here, we point to obtain a more fundamentally based construction to determine fracture properties. We present a model based upon: i) a cohesive law dependent on impurity surface coverage that is calculated from first principles; ii) a stress-assisted diffusion equation for the impurity; iii) a static continuum analysis of crack growth; and iv) the Langmuir equilibrium relation determining the impurity coverage from its bulk concentration. An appealing feature of the model is that it provides quantities readily measured as an output, as opposed to many other models that give only a qualitative picture. We determine crack evolution as affected by several system variables, as yield strength, temperature, etc. Remarkably, crack advancement can be intermittent or smooth, depending on various quantities. We compare calculations for the specific cases of high strength steels and high strength aluminum alloys with experiments. The comparison shows that the proposed model of hydrogen-induced reduction in cohesion is likely the operative mechanism for HE in the former, while for the latter some additional embrittllent factor is required.

11:30 AM NN11.11 Microstructure Development in High-Temperature Mo-Si-B Alloys. Radwan Sakrjudi and John H. Perepezko; MS&E, UW-Madison, Madison, Wisconsin.

Mo-Si-B alloys have been considered as potential high temperature structural materials due to their high melting points (above 2000°C) and excellent oxidation resistance caused by their self-healing principles; ii) a stress-assisted diffusion equation for the impurity; iii) the Langmuir equilibrium relation determining the impurity coverage from its bulk concentration. An appealing feature of the model is that it provides quantities readily measured as an output, as opposed to many other models that give only a qualitative picture. We determine crack evolution as affected by several system variables, as yield strength, temperature, etc. Remarkably, crack advancement can be intermittent or smooth, depending on various quantities. We compare calculations for the specific cases of high strength steels and high strength aluminum alloys with experiments. The comparison shows that the proposed model of hydrogen-induced reduction in cohesion is likely the operative mechanism for HE in the former, while for the latter some additional embritlllement factor is required.


High strain rate compression tests were conducted with columnar ice grown in laboratory. Besides measuring stress and strain to failure we analyzed the size, shape and nature of the fragments, fracture patterns, and effects of end conditions on the failure process. The tests were performed in a split Hopkinson pressure bar at two temperatures, 283 K and 233 K, and a strain rate in the range of 10 to 15 strains/sec. Additional tests were performed on the similarly grown ice at a low rate of 0.001 strain/sec for comparison. The results were further analyzed in terms of the energy absorption and the progressive failure process of the cylindrical specimens. The general observation is that the local failure occurs by splitting, and the final failure by the collapse of the columns, which becomes unstable under the sustained load during the passage of the stress wave through the material. Most failures occurred around a value of 1000 to 1200 microsecond, possibly for the time required for the ejection of the fragments. The temperature effect was evident in the small increase of peak stress when the test temperature was lowered from 260 K to 230 K. Comments are made on some aspects of the microstructural changes typical of high and low rate deformations.