FINAL REPORT

NASA COOPERATIVE AGREEMENT NCC3-740

"PHYSICAL PROPERTIES AND DURABILITY OF NEW MATERIALS FOR SPACE AND COMMERCIAL APPLICATIONS"

June 3, 2003

PRINCIPAL INVESTIGATOR:

Dr. Paul D. Hambourger

INSTITUTION:

Cleveland State University
2121 Euclid Avenue
Cleveland, OH 44115
(216) 687-2439
p.hambourger@csuohio.edu

PERIOD:

December 3, 1999 – March 31, 2003

I. GOALS AND OBJECTIVES

To develop and test new materials for use in space power systems and related space and commercial applications, to assist industry in the application of these materials, and to achieve an adequate understanding of the mechanisms by which the materials perform in their intended applications.

II. ACCOMPLISHMENTS vs GOALS AND OBJECTIVES

Useful and informative results were obtained on virtually all materials investigated. The results were presented in a large number of technical papers and NASA Technical Memoranda (see attached bibliography). Much of the research was done in consultation with representatives of future NASA projects (e.g. PowerSphere and NGST). In some cases, we collaborated with industry on commercial applications of these materials.

Our work on transparent arcproof spacecraft coatings generated a substantial amount of interest from prospective customers including the team developing the PowerSphere constellation of microsatellites. We therefore devoted more effort to these materials than originally planned. Most of this work was on co-deposited indium tin oxide (ITO) and MgF_2. Dependence of electrical properties on ambient light and film thickness was studied in some detail to provide valuable information for successful use of these coatings. These experiments led to the discovery of a photoconductive effect in short-wavelength visible light that may have to be considered for some applications. Some additional coatings were investigated in an attempt to reduce the photoconductivity, but none had optical properties as good as ITO-MgF_2.

During Year 3 some of the ITO-MgF_2 work was done in collaboration with the PowerSphere team with funding from this Cooperative Agreement and from Cooperative Agreement NCC3-1023. We prepared samples of ITO-MgF_2 for radiation-exposure studies to be done by members of the

PowerSphere team. Other experiments showed that UV and visible radiation from small magnetron sputter guns did not affect the UV-curing resin proposed for PowerSphere construction. Possible methods for controlling the deposition of transparent arcproof coatings on full-sized satellite components were identified for future investigation. Results of this work were disseminated to NASA and industrial members of the PowerSphere team. This collaboration led to additional funding from PowerSphere to investigate the manufacturability of the transparent arcproof coatings.

A wide variety of spacecraft materials, with and without protective coatings, were tested for degradation in the space environment. Most testing was done in ground-based facilities; however, thermal blanket materials removed from the Hubble Space Telescope were also tested. Materials proposed for use on the Next Generation Space Telescope (NGST) were evaluated, as was boron nitride intended for use on Hall thruster engines. Computational techniques for predicting on-orbit material lifetimes from ground-based tests were improved. Preparations were made for exposure of materials to the actual space environment during the Materials International Space Station Experiment (MISSE).

Work continued on highly graphitized onion-skin carbon fibers (diameter 3-50 μm) to better understand previous reports that bulk conductivity is smaller in thinner specimens. Analysis of data from our previous magnetoresistance experiments strongly suggested that loss of conductivity in thinner specimens is due to increased crystallographic disorder rather than cracking as suggested by others. However, a more detailed analysis was cancelled in order to increase the effort on transparent arcproof coatings as described on page 1.

Spinoffs of our work were pursued as appropriate. For example, the effect of surface roughness on the interaction of biomedical materials with cells was investigated and research on the restoration of artworks with atomic oxygen continued.

III. COSTS

All work was completed within each year's budget. There were no cost overruns. NASA's costing requirements were successfully met at the close of each fiscal year.

IV. BIBLIOGRAPHY

C. T. Alexander, T. L. Blanchard, A. M. Pal, S. H. Ubaid, and P. D. Hambourger, "Diameter Dependent Electron Scattering in Vapor-Grown Graphite Fibers," Bulletin of the American Physical Society, Vol. 45, p. 311 (2000).

S. H. Ubaid, C. T. Alexander, T. L. Blanchard, A. M. Pal, and P. D. Hambourger, "Size Dependent Carrier Mobility in Vapor-Grown Graphite Fibers," American Physical Society, Ohio Section, Cincinnati, OH (2000).

Rutledge, S.K.; Banks, B.A.; Chichernea, V.A.; Haytas, C.A.; "Cleaning of Fire Damaged Watercolor and Textiles Using Atomic Oxygen"; Prepared for the 18th International Congress of the International Institute for Conservation of Historic and Artistic Works, Melbourne, Australia, October 10-14, 2000. NASA TM-2000-210335.

Bruce Banks, Sharon Rutledge, Edward Sechkar, Thomas Stueber, Aaron Snyder, Kim de Groh, Christy Haytas, David Brinker, "Issues and Effects of Atomic Oxygen Interactions with Silicone Contamination on Spacecraft in Low Earth Orbit", May 2000, NASA TM-2000-210056.

Sharon Rutledge, Bruce Banks, Joyce Dever, William Savage, "International Test Program for Synergistic Atomic Oxygen and VUV Exposure of Spacecraft Materials, May 2000, NASA/TM-2000-210054.

Dever, J. A., de Groh K. K., Banks, B. A., Townsend, J. A., Barth, J. L., Thomson, S., Gregory, T., and Savage, W. "Environmental Exposure Conditions for Teflon Fluorinated Ethylene Propylene and the Hubble Space Telescope degradation and post-retrieval analysis." Journal: High Perform. Polym. 12 (2000) 125—139 (March 2000).

Dever, J. A., Pietromica, A. J., Stueber, T. J., Sechkar, E. A., Messer, R. K., "Simulated Space Vacuum Ultraviolet (VUV) Exposure Testing for Polymer Films," AIAA Paper No. 2001-1054, American Institute of Aeronautics and Astronautics, January 2001.

S. H. Ubaid, M. Shanbhag, A. M. Pal, L. K. Muhieddine, T. L. Blanchard, C. T. Alexander, and P.

D. Hambourger, "Magnetic Field Dependence of Carrier Mean Free Path in Onion-Skin Graphite Fibers," Bulletin of the American Physical Society, Vol. 46, p. 94 (2001).

Dever, J., Messer, R., Powers, C., Townsend, J., Wooldridge, E., "Effects of Vacuum Ultraviolet Radiation on Thin Polyimide Films," High Performance Polymers, Volume 13, Number 3, September 2001, pp. S391-S399.

Joyce A Dever, Kim K de Groh, Russell K Messer, Mark W McClendon, Michael Viens, L Len Wang and Jonathan D Gummow, "Mechanical properties of Teflon® FEP retrieved from the Hubble Space Telescope," High Performance Polymers, Volume 13, Number 3, September 2001, pp. S373-S390.

Joyce Dever, Sharon Miller, Russell Messer, Edward Sechkar, Greg Tollis, "Exposure of Polymer Film Thermal Control Materials on the Materials International Space Station Experiment (MISSE)," AIAA 2001-4924, American Institute of Aeronautics and Astronautics, October 2001.

de Groh, K., Banks, B, Hammerstrom, A., Youngstrom E., Kaminski, C., Marx, L., Fine, E., Gummow, J., and Wright, D., "MISSE PEACE Polymers: An International Space Station Environmental Exposure Experiment," NASA TM 2001-211211, Proceedings of the Conference and Exhibit on International Space Station Utilization, AIAA paper 2001-4923, Cape Canaveral FL, October 15-18, 2001.

Banks, Bruce A. and Rutledge, Sharon K., de Groh, K., Chan, A., Sahota, M., "The Development of Surface Roughness and Implications for Cellular Attachment in Biomedical Applications," NASA TM 2001-211288, presented at the 2001 Fall Meeting of the Materials Research Society, Boston MA, November 26-30, 2001.

Rutledge, Sharon K., Banks, Bruce A., and Tollis, Greg, " Treatment and Analysis of a Paint Chip From "Water Lillies" a Fire Damaged Monet", NASA TM 2001-211326, presented at the 2001 Fall Meeting of the Materials Research Society, Boston MA, November 26-30, 2001.

Joyce Dever, Sharon Miller, Russell Messer, Edward Sechkar, and Greg Tollis, "Exposure of Polymer Film Thermal Control Materials on the Materials International Space Station Experiment (MISSE)," AIAA 2001-4924, American Institute of Aeronautics and Astronautics, October 2001. Also appears as NASA/TM-2002-211363, National Aeronautics and Space Administration, Glenn Research Center, February 2002.

Joyce Dever, Charles Semmel, David Edwards, Russell Messer, Wanda Peters, Amani Carter and David Puckett, "Radiation Durability of Candidate Polymer Films for the Next Generation Space Telescope Sunshield," AIAA 2002-1564, April 2002. Also appears as NASA/TM-2002-211508, National Aeronautics and Space Administration, Glenn Research Center, April 2002.

Banks, Bruce A., Snyder, Aaron, Miller, Sharon K., and Demko, Rikako, "Issues and Consequences of Atomic Oxygen Undercutting of Protected Polymers in Low Earth Orbit", NASA TM- 2002-211577, Presented at the Sixth International Conference on Protection of Materials and Structures from Space Environment, Toronto Canada, May 1-3, 2002.

T. Cashman, J. Kaur, L. K. Muhieddine, M. Shanbhag, S. H. Ubaid, Bryan Welch, Jyothi Vemulapalli, and P. D. Hambourger, "Photoconductivity in Transparent Arcproof Coatings," 6th International Conference – Protection of Materials from Space Environment, Toronto, Canada; May 1-3, 2002.

Banks, Bruce A. and Demko, Rikako, "Atomic Oxygen Protection of Materials in Low Earth Orbit", NASA TM 2002-211360, February 2002, Presented at the 2002 Symposium and Exhibition sponsored by the Society for the Advancement of Materials and Process Engineering, Long Beach, California, May 12-16, 2002.

de Groh, Kim K., Banks, Bruce A. and Demko, Rikako, "Techniques for Measuring Low Earth Orbital Atomic Oxygen Erosion in Polymers", NASA TM 2002-211479, March 2002, Presented at the 2002 Symposium and Exhibition sponsored by the Society for the Advancement of Materials and Process Engineering, Long Beach, California, May 12-16, 2002.

Britton, M., Waters, D., Messer, R., Sechkar, E. and Banks, B., "Sputtering Erosion Measurement on Boron Nitride as a Hall Thruster Material," NASA TM-2002-211837, September, 2002.

Banks, B., Lenczewski, M., and Demko, R., "Durability Issues for the Protection of Materials from Atomic Oxygen Attack in Low Earth Orbit," NASA TM-2002-211830 August, 2002, Paper IAC-02-1.5.02 presented at the 53 International Astronautical Congress, The World Space Congress – 2002, Houston TX, October 10-19, 2002.