Photoadaptive Fibers for Textile Materials M98-A10

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Goal:

Photoadaptive fibers and films, which experience photo induced reversible optical and heat reflectivity changes, are being developed. Our initial goal of producing fibers and films that are metallized exclusively at high light intensities has been accomplished.

Research:

Adaptive systems that exhibit desirable and predictable reversible alterations of their properties in response to external stimuli are very attractive, and are usually called "smart" systems. Important classes of responsive systems are those that are photoadaptive, that is, systems experiencing reversible changes upon exposure to light. A simple example are photo-chromic glasses, where photoreduction of silver halides yields Ag particles that decay in a dark reaction with Cu2+ ions to reform the starting silver halides. This research is centered on the development of photoadaptive fibers that undergo reversible changes in their optical, heat reflectivity, and electrical properties. Potential applications for these fibers include selective reflection of high intensity infrared radiation, shielding of electromagnetic radiation, and as recording media for optical storage of data. Specific textile applications are their use in protective garments for firefighters and clothing against high intensity sunlight. Nanometer-sized metal particles of silver and gold in high concentrations reflect infrared radiation and are, therefore, employed in the photoadaptive fibers as active reflectors. The particles are formed only under high fluxes of photons, that is, under conditions where heat reflection is required. Improved charge transport is expected for fibers containing metal particles, minimizing the charge accumulation effects typical of environments with high light intensity. Manipulation of the electromagnetic properties of flexible textiles can also be achieved by generation of metal particles inside fibers. Applications for such materials include enclosures for electromagnetic radiation and garments containing resistive heating elements. The "metallized" fibers can, in principle, be used as recording media for 3D storage of optical data as well. For this purpose metal crystallites would be generated as layers in sequential fashion within structural anisotropies that are regularly spaced in the fibers.

Preparation of crosslinked films has been studied for their effect on the formation of silver particles. It has been determined that crosslinking PVA with glutaraldehyde yields the best films with acceptable kinetics. The temperature at which the films are crosslinked determines the rate at which the silver particles form. The formation of silver in PVA crosslinked gels occurs within 5 seconds of illumination with 350 nm light. Efforts are underway to duplicate the kinetics of the gel system in the film and fiber systems which require 2-3 minutes of illumination to form silver particles.

Preliminary results indicate that Ag particles present in the PVA films can be oxidized with the addition of peroxides into the films. The formation-decay, formation-decay, formation-decay cycles have been observed for these films and the rate of each formation and decay cycle calculated. The rates of formation increased after each cycle and the rates of decay decreased with each cycle. The increase in the formation is believed to be a result of the incomplete oxidation of the formed particles form the previous decay. These remaining particles then act as catalysts for the reduction of silver ions in the next illumination cycle. The decreasing rate of oxidation is expected to be a result of the consumption of the added peroxide or the deterioration of the polymer. Therefore, illumination of polymer films in controlled atmospheres is being studied. The addition of pure oxygen results in an increased decay rate. It is expected that an Argon atmosphere will yield much faster formation kinetics.

It has been determined that the formation of silver particles in these films occurs via a multiphotonic process as postulated. The characterization of the particles has been completed and determined to be crystalline and of 15-25 nm in size.

Graduate Students: 2
Undergraduate Students: 4

Publications: 1
G. A. Gaddy, J. L. McLain, S. Ruggs, E. S. Steigerwalt, B. L. Slaten, and G. Mills. "Kinetic Study of Silver Nanoparticle Formation in Polymer Films."
Manuscript accepted to The Journal of Cluster Science, January 2001

Presentations: 4
Gaddy, G. A., McLain, J. L., Ruggs, S. V., Slaten, B. L., and Mills, G., "Characterization and Kinetics of the Photo-Induced Formation of Silver Particles, 221st ACS National Meeting, San Diego, CA, April 1-5, 2001.

Gaddy, G. A., McLain, J. L., Slaten, B. L., and Mills, G., Reversible Formation of Nanometer-sized Silver Particles in Vycor Glass. Joint Southeast-Southwest Regional Meeting of the American Chemical Society, New Orleans, LA. December 2000.

Gaddy, G. A., McLain, J. L., Slaten, B. L., and Mills, G., "A Kinetic Study of the Photo-reduction of Silver Ions and the Oxidation of Silver Particles in Polymer Films." 67th Annual Meeting on the Southeastern Section of the American Physical Society, Starkville, MS. November 2000.

Gaddy, Mclain, Huang, Slaten, and Mills, "Kinetics of Ag Nanoparticle Formation in Polymer Films", Consortium on Nanostructured Materials, Richmond, VA , September 2000.

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