Infrared Transparency and Copperlike Conductivity Combined in Polymer Coatings

Infrared-transparent polymer coatings that have the conductivity of copper have been developed by Fractal Systems Inc. The development of durable, mid-infrared-transparent, electrically conductive coatings is of importance for applications such as solid-state lighting, coatings for optical devices, and electromagnetic shielding, as well as the windows and domes of forward-looking IR sensors, IR search and track sensors, IR transmitting seekers, and space-based IR systems. The mid-IR spectral region of interest is 1–1.5 μm, 3–5 μm, and 8–12 μm, with a desired transparency of >80%.

No materials have satisfied both the optical and the electrical requirements for these applications. Existing conductive, visibly transparent materials such as indium tin oxide (ITO) are not sufficiently transparent in the IR region. They break down in the IR above 1 μm at the thickness needed for providing the high conductivity for electromagnetic interference (EMI) shielding. A metallic mesh degrades the optical signal passing through the window, particularly with respect to off-axis optical characteristics of the detector. The mesh needs to filter out the electromagnetic energy and also should pass through the appropriate IR energy without distortion. Doped semiconductors tend to oxidize with time, resulting in degradation of IR characteristics (i.e., reduced transparency and increased reflection) and are difficult to manufacture.

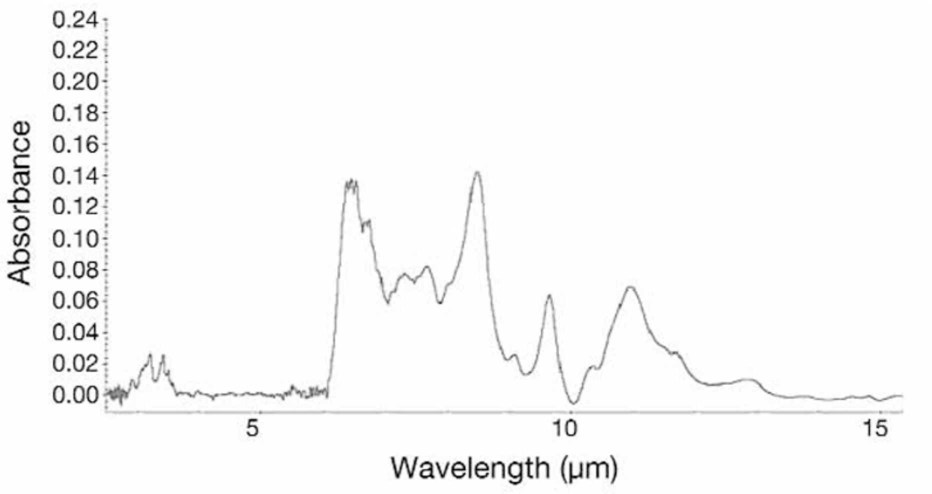

Figure 2. Fourier transform infrared spectrum of a polypyrrole film.

The Fractal Systems coatings are based on the use of intrinsically conductive polymers (ICPs) processed using a modified electrophoretic technique. High copperlike conductivity and high visible and IR transparency have been achieved with some of these polymers through both processing and bandgap tuning. The polymers are stable for several weeks; steps have not yet been taken to assess their long-term stability. The ICP thin-film coatings of submicron thickness are pinhole-free and very homogeneous. Because of their high conductivity, their EMI shielding effectiveness is sufficient to provide protection. The coatings are prepared by electrochemical polymerization of the monomer(s) or by processing of already synthesized polymers. They are applied using traditional chemical processes at atmospheric conditions. The result is an increase in conductivity of four orders of magnitude (shown in Figure 1) relative to that of conventionally synthesized ICPs by chemical or electrochemical means, which is typically in the range of 10^{-2}–10^{2} S/cm. Figure 2 shows that IR transmission for one of the polymers (polypyrrole) exists throughout most (>85%) of the spectral range of interest.

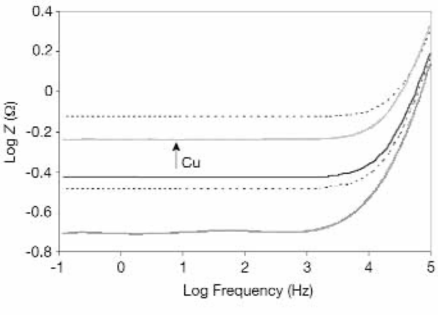

Figure 1. Impedance (Z) plots of various high-conductivity polymers with copper as a reference (second curve from the top). Negative impedance means metallic conductivity; lower impedance, more negative on the log scale, means higher conductivity. Other curves are polyaniline (top), polypyrrole perpendicular to the orientation (two curves immediately below the Cu reference), and polypyrrole parallel to the orientation direction (bottom).

Opportunities

Fractal Systems is working with several contractors from the Department of Defense who are evaluating the materials, and a patent application has been filed on the materials, processes, and several end uses. The company welcomes inquiries about collaboration for commercializing the technology.

Source: Matt Aldissi, President, Fractal Systems, Inc., 200 9th Avenue North, Suite 100, Safety Harbor, FL 34695, USA; tel. 727-723-3006, fax 727-723-3007, and e-mail maldissi@fractalsystemsinc.com.

Technology Advances provides up-to-date reports of materials developments that show potential to bridge the gap between research innovation and application of advanced materials technologies. If you encounter or are involved with materials research that shows potential for commercialization and would like to present these developments, contact Renée G. Ford, PDS Communications, Inc., tel. 914-967-0955; fax 914-967-7927; or e-mail renford@compuserve.com.

Quaternary Metal Oxide Compositions Preserved by Depositing with Pulsed-Laser Deposition

Researchers at Lawrence Berkeley National Laboratory (LBNL) have been using pulsed laser deposition (PLD) to develop quaternary metal oxide thin films that include alkali metal oxides, alkaline earth oxides, and transition-metal oxides. By using PLD, materials with widely different boiling points are incorporated into a single film, a process that cannot be effected by traditional thermal techniques. The PLD method enables the creation of thin films of unique structure and composition by preserving phases that are otherwise too transient to capture, and it eliminates the use of a straightforward evaporative coating approach that is often necessary in the traditional thermal method of making films.

Along with control of chemical composition to create novel thin-film materials, control of structure in creating crystalline and amorphous films, and the ability to create thin films with any desired stoichiometry, this PLD approach offers several more advantages. It allows variable dopant levels by preserving metastable states. Films can be made that are comprised of phases that represent combinations of elemental composition and structure, that is, that are new and have not previously been reported. Most importantly, it allows the preparation of film phases involving the introduction of metal oxides into the system that have highly disparate boiling points. Because of this disparity, classical thermal techniques for preparation of such phases are complicated by premature boiling off of low-temperature boiling components before the final phase is formed.

The deposition process involves the interaction of a pulsed laser beam with a solid target of the material for which a thin film is sought. The interaction creates a plasma plume consisting of the elements of interest, and the subsequent deposition of the plume onto a heated surface. Figure 1 shows a typical plume that is formed from the interaction of the laser with a YBCO target material. The plume contains the gaseous species that subsequently condense on the substrate on which a desired film is to be deposited. The substrate-laden film exhibits a different composition based on several experimental parameters, including the temperature of the substrate during the deposition process and the initial composition of the target material with which the laser has interacted.

Calcium nickel potassium oxide films exemplify the use of this technique for making films of components with disparate (high and low) boiling points, starting with films of the main $Ca_{(1-x)}Ni_xO$ host into which potassium can be co-condensed. Of the three metal oxide components, calcium and nickel oxide have high boiling points, while potassium oxide has a relatively low boiling point. For example, Figure 2 shows the diffractograms of the range of compositions that can be obtained for the calcium nickel oxide parent-host matrix that have been deposited on a single-crystal MgO substrate using this technique. The potassium can be co-deposited with the calcium and nickel oxides at different concentration levels.

Figure 1. Typical plume emitted from the interaction of a laser with a YBCO target material in the pulsed laser deposition process.

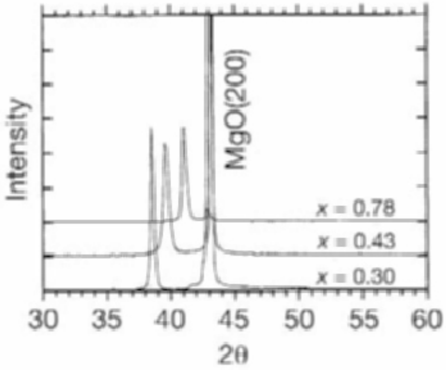

Figure 2. Diffraction patterns in the 30°–60° range from $Ca_{(1-x)}Ni_xO$ films fabricated from different Ca-Ni-K targets. The substrate is single-crystal MgO.

These thin films produced by PLD also can be used as substrates for detailed studies of reaction mechanisms and kinetics with gases involved in catalyzed reactions such as methane coupling and coal gasification, as coatings on catalytic reactor components and catalytic supports, as optical coatings, as semiconductors and related electronic materials, and as materials for environmental remediation. Additional potential uses include broader applications to other catalysis systems, optical coatings, composite materials, modifications of electronically important materials such as semiconductors and superconductors, development of sensors for chemical and biological agents, alternative fuels research, and hydrogen gas generation and containment.

Opportunities

Lawrence Berkeley National Laboratory is interested in extending the application of the technique to new areas of technology, pursuing joint application of research and development in the field, and licensing any products that result. The patented process (U.S. Patent No. 5,427,993) is also available for licensing.

Source: Dr. Dale L. Perry, Lawrence Berkeley National Laboratory, MS 70A1150, Berkeley, CA 94720 USA; tel. 510-486-4819, fax 510-486-5799, and e-mail dlperry@lbl.gov. For technology transfer and licensing: Pam Seidenman, Marketing Manager, Technology Transfer Department, Lawrence Berkeley National Laboratory, One Cyclotron Road, MS 90R1070, Berkeley, CA 94720 USA; tel. 510-486-6461, fax 510-486-6457, and e-mail ttd@lbl.gov.

Photoluminescent Fibers Help Solar Cells Recharge Batteries

Photovoltaic (PV) arrays combined with flexible photoluminescent fibers have been shown by AstroPower Inc. to recharge batteries (see Figure 1), which is especially useful in remote locations with inhomogeneous illumination. The main problem with standard solar cells is that they generate a relatively high current but low voltage (usually <1 V). This voltage is too low to charge standard batteries. To increase the voltage, a series connection of several solar cells is necessary. However, in many practical applications, the illumination of the cell array is not homogenous, and this simple approach is not efficient. Localized shadowing of the array drastically decreases its output power. Moreover, shadowed cells are driven into reverse voltage operation and may be damaged unless bypass diodes are used.

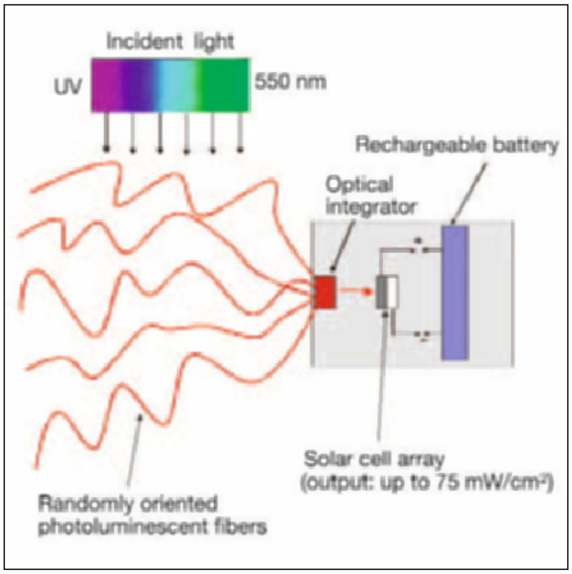

Figure 1. Schematic diagram illustrating the concept of recharging batteries by combining photovoltaic arrays with photoluminescent fibers.

Uniform illumination of the array can be provided by photoluminescent fibers that absorb the short-wavelength part of sunlight (from ultraviolet to green light), omnidirectionally re-emit it at longer wavelength (red or infrared light), and couple it to a miniature PV array. The different refractive indices between the fiber and the air set the conditions for total internal reflection and give the fiber waveguiding properties. Therefore, a large portion (about 50%) of the re-emitted light can propagate in the fiber toward the PV array situated at its end. A bundle of thin (0.25–1 mm diameter) fibers can be arranged and coupled with the PV array in such a way that shadowing of some fibers does not affect the homogeneity of the array illumination. As the light delivered by the fibers is dependent on their length and number, it can have a high intensity, and thus a small PV array can produce relatively large power. Also, it is easier to integrate a smaller PV array in a shock-resistant design, which is important for deployment where devices are difficult to access. Thus, miniature PV arrays with flexible photoluminescent fibers provide light-conversion systems that are small, lightweight, insensitive to orientation and partial shading, and relatively easy to manufacture .

AstroPower has fabricated and tested miniature AlGaAs/GaAs PV arrays designed to operate under a wide range of illumination conditions with a maximum light intensity equivalent to several suns. The arrays consist of six PV cells isolated by etched trenches and connected in series. Multilayer AlGaAs/GaAs structures several micrometers thick were epitaxially grown on semi-insulating GaAs substrates. The total area of the finished cell array is about 20 mm^2. The arrays are integrated with photoluminescent fiber bundles consisting of polystyrene (PS) or polycarbonate (PC) fibers with different diameters (0.25–1.00 mm) and length (0.3–0.9 m).

Testing has shown that commercially available polycarbonate (PC) and polystyrene (PS) fibers do not totally meet requirements for the photoluminescent fibers: PS fibers show good photoluminescent properties but do not have sufficient ultraviolet stability, while the opposite is true for PC fibers. However, the UV stability of PS fibers can be improved to a level typical for commercially available PC fibers by introducing modifiers (light stabilizers and antioxidants).

AlGaAs/GaAs PV cell arrays integrated with photoluminescent PS fibers demonstrated high performance in operation. An output electric power density as high as 75 mW/cm^2 was measured outdoors for a six-cell array integrated with a 0.9-m-long fiber bundle. The power density achieved is sufficient for many applications.

Opportunities

AstroPower Inc. is seeking developers of photoluminescent fibers with high-UV stability and good photoluminescent properties. It also welcomes inquiries about joint applications development.

Source: Dr. Oleg V. Sulima, AstroPower Inc., Solar Park, Newark, DE 19716 USA; tel. 302-366-0400 ext. 3031, fax 302-283-0162, and e-mail sulima@astropower.com.

MRS Future Meetings

2004 SPRING MEETING
April 12-16
Exhibit: April 13-15
San Francisco, CA

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2004 FALL MEETING
Nov. 29-Dec. 3
Exhibit: Nov. 30-Dec. 2
Boston, MA

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