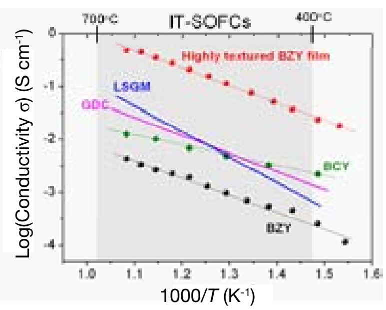
Energy Focus

Epitaxially grown BZY films display high ionic conductivity

Research in the field of solid oxide fuel cells (SOFC) spans more than 20 years in an attempt to synthesize a cost-effective oxide material with high ionic conductivity at intermediate-to-low temperatures and good chemical stability, for a wide range of applications such as SOFCs for portable power supply in small electronic devices. High-temperature proton conductors, like yttrium-doped barium zirconate, are now considered as alternatives to the oxygen-ion conductor electrolytes conventionally used in SOFCs, which have been proven to be environmentally benign and efficient energy production devices. D. Pergolesi, E. Fabbri, and E. Traversa of the University of Rome 'Tor Vergata', Italy and the National Institute for Materials Science, Japan and their co-workers, fabricated grain-boundary–free thin films of yttrium-doped barium zirconate ($BaZr_{0.8}Y_{0.2}O_{3-\delta}$; BZY) that showed the highest proton conductivity ever reported under such a low temperature (350°C) for any oxide material.

As reported in the September 19th issue of *Nature Materials* (DOI:10.1038/NMAT2837; p. 846), the researchers used pulsed laser deposition (PLD) to fabricate highly textured, epitaxially grown BZY films (1 μm thickness) deposited on (100)-oriented MgO substrates and achieved proton conductivity values of 0.11 S/cm at 500°C.

The researchers achieved a proton conductivity value of 0.01 S/cm, which is considered as the minimum conductivity value for practical applications in fuel cells, at a temperature as low as 350°C (see figure). As seen in the figure, BZY film conductivity is significantly larger than best performing, stable oxygen-ion conductors used for SOFC applications in the intermediate temperature range. The researchers carried out an extensive in-plane x-ray diffraction analysis to confirm the crystalline nature of epitaxially grown BZY films and to obtain reciprocal space maps.



Comparison between the electrical conductivity of the BZY films grown on MgO with that of BZY and BCY (Y-doped barium cerate) sintered pellets, measured in the intermediate temperature range. Conductivity values of the oxygen-ion conducting electrolytes ($La_{0.8}Sr_{0.2}Ga_{0.8}Mg_{0.2}O_3$; LSGM and $Ce_{0.8}Gd_{0.2}O_{1.9-\delta}$; GDC) are also reported.Reproduced with permission from *Nature Materials* **9** (10) (2010) 846; DOI: 10.1038/NMAT2837. © 2010 Nature Publishing group.

The researchers used electrochemical impedance spectroscopy to carry out electrical analysis of BZY films grown on MgO substrate in the temperature range of 350°C to 650°C, in a humid atmosphere of 5% H_2 in Ar. The proton conductivity of the BZY films grown on MgO substrate was measured to be about two orders of magnitude higher than sintered pellet of the same material. The researchers attribute the large proton conductivity observed in epitaxial films to the high crystalline nature of epitaxial films which minimizes nonconducting grain boundary regions. According to the researchers, the results from this study may open new perspectives in the development of miniaturized SOFCs for portable and low power-demanding applications.

Rohit Khanna

Nano Focus

Novel fabrication approaches yield continuous nanocomposite and nanoceramic fibers

Nanoscale composite materials are being increasingly used as biomaterials, catalysts, sensors, energy-storage materials, filters, and in many other applications. There is need for improved methods to fabricate nanocomposites with better control and reproducibility of material properties including microstructure, chemistry, and dimensions that can also be applied to a wide variety of materials. Y. de Hazan of the Swiss Federal Laboratories for Materials Testing and Research (Empa), T. Graule of Empa and Technische Universitat Freiberg, and their colleagues have developed a versatile spinning technique to fabricate continuous fibers of ceramic/polymer nanocomposites and nanoceramics.

As reported in the September issue of the *Journal of the American Ceramic Society* (DOI: 10.1111/j.1551-2916.2010.03802.x; p. 2456), the researchers developed a spinning process in which the feedstock consists of colloidal particles dispersed in a radiation-curable monomer. A number of techniques have been developed previously to fabricate ceramic and polymer/ceramic composite fibers. One class of techniques involves extrusion and spinning such as melt spinning, wet and dry spinning, and electrospinning. Another class involves direct writing or a free-form fabrication method of colloidal inks to form well-defined shapes. Most of these techniques to fabricate elongated structures use extrusion and drawing methods that utilize different variations of applied tension and elongation of the extruded filament, and are limited by the range of usable viscosity of the dispensed solution.

In the new method developed in this study, the curable dispersion is extruded through an extrusion/spinning die and cured using UV or heat immediately to a solid fiber and thus there is no lower limit of the feedstock viscosity. The method is versatile and can be applied for a wide variety of nanocomposites, including feedstock with high particle

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content. Furthermore, the researchers demonstrated that the basic design can be suitably adapted to vary fiber elongation with concomitant change in diameter using a mechanical tensioning device or a sheathing fluid. They also prepared co-extruded fibers using another adaptation of this technique.

The researchers said that this new fabrication method will find increasing use to prepare ceramic and highly loaded ceramic/polymer nanocomposite fibers from a variety of material combinations at low temperature and pressure with dimensions of 15–500 μm and controlled composition and microstructure.

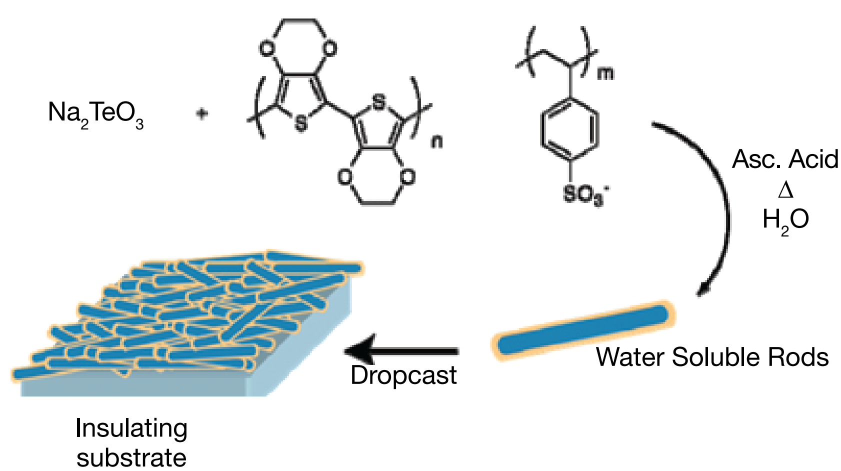
Kaushik Chatterjee

Nano Focus

High thermoelectric efficiency achieved in polymer-nanocomposites

Researchers R.A. Segalman (University of California, Berkeley and Lawrence Berkeley National Laboratories), J.J. Urban (Lawrence Berkeley National Laboratories), A. Majumdar (Advanced Research Projects Agency–Energy), and their co-workers have reported the highest thermoelectric figure of merit for an organic–inorganic hybrid or aqueously processed material to date. Thermoelectric efficiency is related to a combination of high thermopower (or Seebeck coefficient, S, V/K), high electrical conductivity (σ, S/cm), and low thermal conductivity (κ, W/m K). To date the best materials available have been inorganic compounds with relatively low earth abundance and highly complex processing routes (and hence greater expense), such as Bi_2Te_3.

In the last decade, polymers with much enhanced electrical conductivities (>100 S/cm) have become common, and work on molecular junctions indicate that the organic–inorganic interface can provide a boost to Seebeck coefficient. As reported in the October 5th online edition of *Nano Letters* (DOI: 10.1021/nl102880k), the researchers combine a high electrical conductivity, low thermal conductivity polymer with a nanoparticle that contributes high thermopower. Additionally, the work functions of the two materials could be well aligned which opens the possibility of thermionic filtering at the interface and an additional boost to the power factor. In this case, the nanoparticle is composed of tellurium with a very high thermopower



(a) Synthesis of PEDOT:PSS passivated Te nanorods and (b) dropcast composite film on a 1 cm² quartz substrate, showing excellent film uniformity. Reproduced with permission from *Nano Letters* (2010) DOI: 10.1021/nl102880k. © 2010 American Chemical Society.

(~400 μV/K), but relatively low electrical conductivity and high thermal conductivity. The research team has shown that Te nanorods can be synthesized *in situ* into a highly electrically conductive, thermally insulating polymer (PEDOT:PSS, σ >100 S/cm, κ ~ 0.2W/m² K) in a water solution (see figure).

Suspended polymer coated rods can then be dropcast to form a smooth, conformal film. This film has an electrical conductivity two orders of magnitude higher than the Te nanowires and similar to a pure sample of the polymeric component at greater than 10 S/cm. The thermal conductivity for the hybrid is on the order of 0.2 W/(m K), comparable to the polymeric component. The Seebeck coefficient of the hybrid was 163 μV/K.

Thermoelectric efficiency is normally reported as a figure of merit ($ZT = S^2\sigma T/\kappa$). A combination of these factors yield ZT values of ~0.1, which is the largest reported value for an aqueous processed material and the largest reported in an organic or organic–inorganic hybrid to date. This value represents a four order of magnitude increase over the pure polymer or Te nanowires. According to the researchers, these materials could find an important role in spot cooling of microelectronics and scavenging of low grade waste heat.

Jean L.W. Njoroge

Correction

In *MRS Bulletin* **35** (11)(2010) pp. 909, 910, the photo captions should be "E-MRS 2010 Spring Meeting."

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