Nanocomposite Materials—Leading the Way in Novel Materials Design

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Note: A nanocomposite is defined as a multiphase solid material where one of the phases has one, two, or three dimensions of less than 100 nm, or structures having nanoscale repeat distances between the different phases that make up the material.¹

The Nanocomposite Materials symposium which was held at the TMS 2009

Annual Meeting comprised around 70 technical presentations submitted from more than a dozen different countries. The resulting special emphasis topic should

convey to *JOM* readers the breadth and depth of the technical efforts currently underway in this rapidly developing field. Included are three papers that represent this diversity both in material systems (metallic, polymeric, and ceramic) and applications (structural and/or multifunctional).

As the field of nanomaterials has matured, nanocomposites have emerged as a promising and practical path for novel materials design. Although the ability to combine different material classes to provide a useful balance of properties is nothing new—this is the basis of all rational composite materials design—the ability to combine disparate materials at the nanometer scale has led to a plethora of new materials with increased functionality beyond that predicted by the “rule of mixtures.” These effects can be attributed primarily to the size scale of the phases. At the nanometric scale—where surface and interfacial phenomena dominate over volume effects—material designers need to be aware of such quantities as specific surface area, surface energy, particle morphology, and particle spatial distribution. Accordingly, there has been a steady maturation in

the processing science needed to take full advantage of the continually widening materials design space. For example, two of the papers describe a promising emerging technique for nanocomposite material processing: spark-plasma sintering. The technique uses a combination of electric field, direct and/or indirect heating, and pressure to densify the material to increased levels compared with conventional sintering. Likewise, additional advances continue to be made in the area of materials characterization, both in terms of understanding of the underlying physics of nanoscale phenomena, and in the development of new experimental techniques. Scanning probe microscopy and high-resolution (scanning) transmission electron microscopy (TEM) are rapidly becoming the tools of choice for microstructural characterization, along with focused ion beam (FIB) milling for specimen preparation and micro-machining.

The first paper, “Fatigue and Fracture Toughness of Epoxy Nanocomposites,” by I. Srivastava and N. Koratkar provides a thorough overview and introduction to the major issues affecting fatigue and fracture toughness in a major class of structural nanocomposite materials. The addition of nanofillers to existing epoxy systems has been shown to enhance fatigue and fracture behavior, even at relatively low levels of reinforcement. The article reviews the major technological developments in the field, while describing the underlying, inter-related mechanisms responsible for the improvements in performance.

The second paper, “The Current Activated Pressure Assisted Densification Technique for Producing Nanocrystalline Materials” by J.E. Alaniz, J.R. Morales, and J.E. Garay, highlights some of their group’s ongoing work in tailoring

properties via control of nanocrystalline structure, through the successful use of an emerging processing technique. The materials of interest are oxide nanocomposites, designed to exhibit very different functional behaviors—magnetic and optical—therefore emphasizing the broad applicability of nanocomposites beyond structural materials.

The third paper, “Nanostructured Metal Composites Reinforced with Fullerenes” by F.C. Robles-Hernández and H.A. Calderon is an in-depth investigation of the synthesis and characterization of metallic-matrix structural nanocomposites. The paper gives insight into the application of standard techniques such as TEM, x-ray diffraction, and micro-indentation for characterizing microstructure–property relationships.

The future certainly looks bright for nanocomposite materials, with the joint ASM/TMS Composite Materials Committee of the Structural Materials Division of TMS recently deciding to organize biennial symposia along the same theme. However, one outstanding issue is raw material cost, which is related to quality and reliability of supply for large-scale synthesis. It is hoped that future TMS symposia will address these issues as well as emphasizing the technical aspects of nanocomposite materials research. Stay tuned.

Reference

1. P.M. Ajayan, L.S. Schadler, and P.V. Braun, *Nanocomposite Science and Technology* (Weinheim, Germany: Wiley VCH, 2003).

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