faces between different-handed materials regardless of the medium in which the beams are propagating.

ANDY FRANCIS

Layered ZnDS Nanocomposites Formed with Assistance of PLA

Researchers have paid considerable attention recently to the family of layered metal hydroxide materials, such as layered double hydroxides (LDHs), hydroxide double salts (HDSs), and single-metal hydroxides because of their pronounced anion exchange capacity. N. Koshizaki and colleagues from Nanoarchitectonics Research Center, Japan, formed layered zinc hydroxide/dodecyl sulfate (ZnDS) nanocomposites in a special solution environment created by pulsed laser ablation (PLA) of a zinc plate in an aqueous solution of sodium dodecyl sulfate (SDS). As reported in the February 24 issue of *Chemistry of Materials*, the researchers made the preparation of ZnDS a simple process, directly triggered by metal species without any chemical modifications.

Other methods for the synthesis of layered composites—for example, zinc hydroxide salts (LHS-Zn)—are coprecipitation or organo-derivatization reaction methods, but such LHS-Zn composites are generally poorly crystallized and exhibit turbostratic disorder.

In contrast, the researchers obtained a ZnDS composite platelet that presents highly ordered single-crystalline layered structures with well-defined octagonal shapes.

The scientists conducted PLA experiments in deionized water with dilute (0.001 M) and more concentrated (0.1 M) SDS solutions. X-ray diffraction of the resultant ZnDS composite showed the formation of layered structures: ZnDS products with long-range order and with no turbostratic faults revealed in products from either SDS solution and some stacking disorder indicated in products from the 0.1 M SDS solution. Products by PLA of Zn in deionized water revealed typical reflections of wurtzite ZnO, also confirmed by transmission electron microscopy (TEM) observation.

TEM images of products in 0.001 M or 0.01 M SDS solutions revealed numerous lamellar thin platelets with irregular octagonal shapes and an average diameter of 1.5 μm preferentially lying on the grid. Electron diffraction patterns showed that the octagonal platelets were monocrystals lying naturally on the plane with clear hexagonal crystal symmetry.

In the composite formation processes, the researchers produced charged inorganic zinc hydroxide species step-by-step by the strong reaction between the ablated Zn species and the water molecules. The preferred coordination of hydrophilic head groups with zinc coordination sites prevents further reaction from forming ZnO nanoparticles.

The researchers said their simple method of forming layered ZnDS nanocomposites enables the development of new types of hybrid composites by using other applicable metal targets and surfactants.

EKATERINA A. LITVINOVA

Carbon-Nanotube Formation Observed *In Situ*

Due to their magnetic, electronic, and mechanical properties, carbon nanotubes (CNTs) are excellent candidates for a variety of emerging nanotechnology applications. Exploitation of any of these properties requires either the production or the

https://doi.org/10.1557/mrs2004.92 Published online by Cambridge University Press

isolation of a single CNT phase. However, the products of current synthetic schemes are either pure multiwalled CNTs (MWNTs) with a range of outer diameters or a mixture of single-walled CNTs (SWNTs) with different diameters and chirality. A detailed knowledge of the growth mechanisms for CNTs is currently lacking, although it has been found recently that catalytic chemical vapor deposition (CVD) provides a near-equilibrium route to both MWNTs and SWNTs. In order to gain a detailed understanding of the CNT growth process, which might lead to the ability to control the type of CNTs produced, R. Sharma of Arizona State University and Z. Iqbal of the New Jersey Institute of Technology, Newark, have used an environmental transmission electron microscope (ETEM) to observe *in situ* the growth of CNTs in various reaction conditions.

As reported in the February 9 issue of *Applied Physics Letters*, Sharma and Iqbal used CVD to produce CNTs by flowing propylene or acetylene gas over Ni or Co catalysts. While the researchers observed only growth of graphitic filaments as propylene flowed over Ni-SiO_2 at 400°C, the growth of well-defined CNT structures was observed as acetylene flowed over Ni-SO_2 at 450°C. Sharma and Iqbal observed Ni particles at the tips of the CNTs as well as in the middle of the tubes. In addition, the researchers said that these CNTs grew in a zigzag manner, with cumulative turns of up to 360°. After finding that CNTs had formed all over the sample area, the researchers concluded that the electron beam did not induce the CNT growth process and, therefore, the observations *in situ* are directly comparable to the bulk synthesis conditions.

Sharma and Iqbal said that *ex situ*, high-resolution electron micrographs confirmed that MWNT growth is favored at 450°C. The inner diameters of these tubes ranged over 2–8 nm, while the outer diameters ranged over 8–17 nm. The researchers also observed several graphene sheets perpendicular to the length of a tube and said that a bubble seen within the wall of a tube indicates that the CNT was in the process of development.

Sharma and Iqbal found that at 700–800°C, single- and double-walled CNTs formed predominantly but occasionally very thin graphene filaments were observed. They also often observed bundles of SWNT sheets forming. The researchers said that, in contrast to MWNT growth, the SWNTs grew straight out from the catalyst with very uniform diameters, varying between 1 nm and 1.5 nm for different tubes. In addition, the researchers observed no catalyst at the tube tips or in the middle of the tubes, which is consistent with the proposal that SWNTs grow from the catalyst that is present at the tube root, although they admit that the roots of their SWNTs are hidden from view. Sharma and Iqbal used confocal micro-Raman spectroscopy to confirm that samples prepared with acetylene at 700°C were indeed SWNTs. They said that the diameters calculated from the Raman data agree well with the diameters measured from the ETEM images.

In future work, Sharma plans to "observe the effects of temperature and pressure on the mechanism, growth rate, and structure (chirality and diameter) of CNTs using ETEM for controlled CNT synthesis," while Iqbal will "use this information for large-scale synthesis of SWNTs with desired structure."

STEVEN TROHALAKI

Microwave Technique Allows Selective Drilling of Thermal Barrier Coatings

Some gas-turbine engine components are exposed to temperatures exceeding the melting point of the most common superalloys used for this application. These components typically have internal cooling holes that allow a local reduction in temperature while in operation. Additionally, the use of thermal-barrier coatings (TBCs) extends the service life of these components. A TBC is applied in a two-step process including a first layer of a metallic coating, or bond coat, and a second layer of ceramic coating, or top coat. The ceramic of choice is usually yttria-stabilized zirconia (YSZ) and is typically deposited by air plasma spray or electron-beam physical vapor deposition. After a plasma-sprayed coating is deposited, the cooling holes are reopened with, for example, a laser drill. This is a laborious process, since the laser, not able to distinguish between the metal substrate and the ceramic coating, has to be perfectly aligned with the covered hole. However, an alternative technique using a microwave drill is currently under development by E. Jerby from Tel Aviv University in Israel and A.M. Thompson from General Electric Global Research in New York, as these researchers explain in the February issue of the *Journal of the American Ceramic Society*. Jerby and Thompson said the advantage of the microwave drill is the materials selectivity of the microwave energy. When a coaxial open-end applicator comes into contact with a ceramic material, the power density is concentrated at the contact point, increasing the temperature locally up to the melting point of the ceramic; but contact with a metal reflects the microwave energy and produces no localized heating.

The investigators built a microwave drill using a power-tuned magnetron (2.45 GHz) and a coaxial microwave structure with a movable tungsten center electrode that worked as a drilling bit when pushed through the molten ceramic material, along with a gas inlet for cooling the coaxial structure. The cooling gas could be argon or air. The electrode worked as a near-field monopole antenna that allowed drilling holes with a diameter 10^{-2} times smaller than the microwave wavelength. Experiments were conducted on plates with a thickness of 3.2 mm containing predrilled holes of 0.76 mm, 1.02 mm, and 1.27 mm diameters. Two different TBCs were deposited. One had a NiCrAlY base coat, 0.25 mm thick, and a porous YSZ top coat, 0.76 mm thick; the other had a NiCrAlY base coat, 0.35 mm thick, and a dense YSZ top coat, 0.76 mm thick. Holes were drilled in less than 5 s using a power level of 0.5 kW or less, and resulting holes showed a smooth round edge. Cross-sectional observations around the holes revealed that the ceramic material around the edge became denser and developed cracks, and that the TBC deposits inside the hole are not removed. The base metal was unaffected by the process. Success rate was above 70% for the more than 50 drilling attempts conducted, with the porous TBC giving the best results. The researchers said that failure was mostly due to mechanical flaws rather than a defect inherent in the process itself. The researchers are now looking into the possibility of using the information in the reflected wave to direct the drilling process.

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https://doi.org/10.1557/mrs2004.92 Published online by Cambridge University Press