followed by a continuous increase in resistance, signifying recovery of the protective properties of the film as well as slow release of inhibitor in the nanoreservoirs. The release of inhibitor was triggered by an increase of pH as a result of the chemical reaction between the Al_2CuMg intermetallic contained in the AA2420 alloy when dissolved in the corrosive medium.

The researchers said that the results of this investigation demonstrated that the ZrO_2/nanoreservoir-SiO_2 film provides the best corrosion protection when the SiO_2 nanoreservoirs contain two sets of PSS/inhibitor layers, ensuring stability of the film with a uniform particle distribution and self-healing capabilities. The researchers said that their future plans include controlling the rate of inhibitor release and expanding the applicability of this type of coating system using other compounds more compatible with different industrial materials.

SIARI SOSA

Composite Materials Fabricated through Face-Selective Adhesion of Gold Nanoparticles on L-Cystine Single Crystals

Y. Fujiki and colleagues at Kyushu University, Japan, have produced a method to form composite materials by using transparent hexagonal prisms of L-cystine decorated anisotropically with gold nanoparticles. They reported their findings in the July 17 issue of the *Angewandte Chemie International Edition* (p. 4732; DOI: 10.1002/anie. 200504212).

L-cystine single crystals, recrystallized from a 0.5% hydrochloric acid solution, were immersed in a solution of gold nanoparticles 20 nm in diameter. The researchers used a batch method and a mounted method, consisting of mounting a crystal in a glass capillary prior to immersion, to ensure all the faces of the crystals were equally exposed to the solution of gold nanoparticles. After washing the crystals with water, the researchers observed that only the two hexagonal faces of the prisms were stained purple, due to peaking of the surface-plasmon band of the aggregated gold nanoparticles at 700 nm. Further characterization by electron and atomic force microscopies confirmed that gold nanoparticles were deposited only on the hexagonal surfaces of the prisms, while the rectangular faces remained smooth. The researchers attributed this anisotropic decoration to the arrangement of the L-cystine molecules in the crystals. Layered structures were formed with the zwitterionic groups exposed on the surface of the hexagonal {001} faces. The higher density of polar residues on the hexagonal faces than on the rectangular ones enabled the gold nanoparticles to attach onto these surfaces.

The researchers concluded that with different functional groups exposed on the faces of organic single crystals, other materials could be anisotropically decorated by these or other intermolecular interactions. This may allow the preparation of a wide variety of composite materials with an organic crystal core and an anisotropic aggregation of other crystals due to attractive or repulsive interactions with the uncoated or coated faces, the researchers said.

JOAN J. CARVAJAL

Micromachining of 10 μM Al–0.5 wt% Cu Films Achieved through Porous Anodization Technique with Reduced Undercutting

Subtractive etching is a technique used in microelectronics fabrication to pattern wide metallic lines in film substrates. Wet (chemical or electrochemical) approaches to subtractive etching are economically attractive. A mask barrier is first placed in the desired configuration, and afterwards the selected etching procedure consumes the unprotected metal. However, this method has the disadvantage of undercutting or consuming some of the metal under the masking barrier. Thus, depending on the degree of isotropy of the etching process, the desired metallic feature could completely disappear.

One approach to overcoming this isotropic effect involves anodization of aluminum-patterned films to form porous alumina outside the protected regions. Still, this approach has also been limited by undercutting as a result of lateral pore growth, which consumes part of the desired metallic material. A group of researchers from the Center of Micro-Engineered Materials, University of New Mexico led by D.A. Brevnov, in collaboration with G.P. Lopez and P. Atanassov, teamed with researchers from Sandia National Laboratories (Albuquerque, NM), Intel (Rio Rancho, NM), and with support from Intel (Santa Clara, CA) to determine the optimal conditions of aluminum anodization and reported their work in the August issue of *Electrochemical and Solid-State Letters* (p. B35; DOI: 10.1149/1.2206007).

The researchers used Si wafers, which were covered by 600 nm of SiO_2, on which they deposited a 9.5-μm-thick layer of Al–0.5wt% Cu film. The first step to create the desired pattern was to apply a 2.2-μm layer of Shipley 1818 photoresist, then grow a mask of dense barrier alumina in an aqueous solution. The wafers were then anodized at 100 V for 2 min, followed by the removal of the photoresist using acetone and an oxygen plasma. The configurations patterned this way resulted in 1-mm-long, 10-μm-wide trenches set 15 μm and 20 μm apart (center to center), respectively, as well as 1-mm-long and 3-μm-wide trenches set 6 μm and 18 μm apart, respectively. At this point, the researchers anodized all films in a 3% weight/volume oxalic acid solution (1.5 pH) at 40°C and 25 V, conditions previously determined to be optimal.

Scanning electron microscopy observations of cross sections of the patterned films showed that metallic pillars formed under the masking barrier that were narrower at the top with concave slopes. The increased consumption of the metallic film immediately under the mask barrier demonstrated that lateral porous expansion was time-dependent, said the researchers. Porous alumina formed in the unprotected areas, with a volumetric expansion limited to 20%, inhibiting the appearance of cracks that are produced under conditions of higher volumetric expansion. The etch factor (i.e., the ratio of the depth of the etch to the amount of the undercut) was determined to be 2, since the undercut of material consumed under the mask barrier was half the depth of film consumed. The researchers said that this is an improvement with respect to the standard wet chemical etching technique, which gives an etch factor of about 1.2. The researchers concluded that their technique is successful for patterning Al–0.5 wt% Cu films. The advantages of using an economical etchant method on an industry-standard metallic film can facilitate the optimization of processes for industrial electrochemical micromachining.

SIARI SOSA