Solid-State Electrochemical Micromachining Enables Direct Surface Patterning

Electrochemical micromachining (EM) has been used as a "shaving off" method to fabricate textured or patterned surfaces. It has become one of the most widely used methods because it requires simple equipment and enables more rapid etching than techniques such as ion-beam milling and laser abrasion. However, during the EM process, a liquid electrolyte, which can be difficult to handle, is required as a conducting medium between the two electrodes. Furthermore, high-resolution patterning processes require masking or the use of focused laser writing or focused ion-beam writing of patterns. Now, K. Kamada of Kyushu University, K. Izawa of Kumamoto University, and their colleagues have proposed an electrochemical micromachining procedure that eliminates the need for wet processing and allows fine patterns to be written.

As reported in the April 19 issue of *Chemistry of Materials* (p. 1930; DOI: 10.1021/cm0502929), the researchers describe a route for solid-state micromachining using an anodic electrochemical reaction at the microcontact between an ion-conducting microelectrode and a metal substrate, which they call the solid-state electrochemical micromachining (SSEM) method (schematically shown in Figure 1). During the SSEM process, the metal substrate is locally incorporated into the ion-conducting microelectrode in the form of metal ions through the microcontact under a dc bias. Continuous application of an electric field produces micromachining of the substrate, thereby removing the need for wet processing.

The microelectrode is formed from a pyramid-like (tetrahedral shape) piece of β''-Al_2O_3 (typically, Na-β''-Al_2O_3) with a contact radius of ~10 μm. It is very lightweight (~0.02 g), which reduces the mechanical stress at the microcontact to a minimum and keeps it constant. The solid-state electrochemical cell consists of a Ag plate (cathode)/pyramid-like Na-β''-Al_2O_3 microelectrode/ target metal substrate (thickness, 0.5 mm; M: Ag or Zn; anode) system. The researchers said that since the contact radius at the Na-β''-Al_2O_3/M interface is on the order of 10 μm, a position-selective dissolution occurs at the microcontact, which makes it an excellent tool to pattern the metal surface directly in either a dot or scan-line format. The researchers also said that further work is needed to solve some remaining problems with this technique, including a slow etching rate, low current efficiency, and roughness of the micromachined surface.

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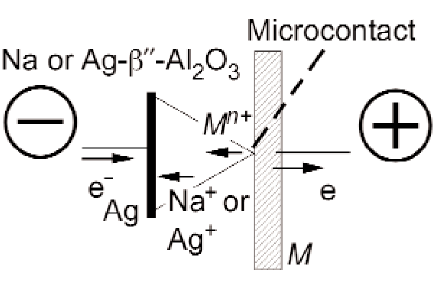

Figure 1. Model for ion migration during solid-state electrochemical micromachining of a metal substrate; M *is the target metal substrate. Reprinted in part with permission from* Chem. Mater. ***17*** *(April 19, 2005) p. 1931. ©2005 American Chemical Society.*

Rethinking the Hydrophobicity of Lotus Leaves

The lotus leaf is a symbol of purity in many cultures due to its ability to remain clean. When water drops fall on the leaves, they exhibit a superhydrophobic contact angle of 160°; the drops promptly roll off the leaves, collecting any dirt along the way. This behavior is believed to be a result of the complex structure of the leaf, which includes a wax layer and a two-level surface structure of micrometer-scale bumps and nanometer-scale hair-like features. In contrast to previous studies that observed the behavior of macroscopic water drops placed on the lotus leaf surface, Y.-T. Cheng from General Motors Research and Development Center and D. Rodak from Ricardo Meda Technical Services conducted experiments to investigate the hydrophobicity of this surface when water condenses on the leaves.

As reported in the April 4 issue of *Applied Physics Letters* (144101; DOI:10.1063/1.1895487), when water condensed on the leaf during exposure to water vapor, the researchers found three types of behavior: some drops would fall off the leaf as expected; some drops formed a high contact angle but would not roll off; and some others spread out, wetting the leaf. The researchers said the behavior arises primarily from the two-level structure. When macroscopic water drops are placed on the leaf in standard studies, they are in contact with the leaf bumps and the air trapped between the bumps and the hair-like structure. The resulting contact angle is a combination of the contact angle of the leaf and air.

However, during condensation, microscopic water drops can form in the nanometer-scale structure, interpenetrating the hair-like structure. When water drops are placed on the leaf surface following condensation treatment, the drop is supported by a composite surface formed by the leaf and water, decreasing the overall contact angle. In the last case, the surface may even be hydrophilic.

According to the researchers, this finding significantly changes the common perception of lotus leaves as superhydrophobic and has important ramifications on how to make and use superhydrophobic surfaces, with potential applications on self-cleaning and low-friction surfaces.

MARIA MARTA FIDALGO

Zeolite-Coated Optical Fibers Demonstrated as Sensitive Chemical Vapor Detectors

From manufacturing to pollution monitoring to homeland security, many applications await the development of fast and accurate chemical-vapor sensors. H. Xiao and a team of researchers from the New Mexico Institute of Mining and Technology have reported constructing just such a sensor based on a cleaved optical fiber coated with a thin zeolite film. The sensor is able to detect isopropanol and other test vapors in a nitrogen atmosphere at concentrations as low as 0.075%. The technology is especially promising for use in the field because it has excellent thermal and chemical stability.

The use of optical-fiber technology in gas sensors is well established, particularly since optical measurements can be made with high precision. Zeolites—crystalline aluminosilicate materials with regular nanometer-scale pores—have also been used in chemical sensing applications, acting as molecular sieves. Until now, however, these technologies have not been combined. As reported in the June 1 issue of *Optics Letters* (p. 1270), the researchers first cleaved a 9 μm (core diameter) single-mode optical fiber and grew a thin-film coating of all-silicon MFI-type zeolite on the exposed fiber face. They then placed the coated fiber end in a nitrogen atmosphere with a controlled flow of isopropanol and directed light at 1539.5 nm down the fiber toward the coated face. The refractive index and thus boundary reflectivity of zeolites depends strongly on the presence of guest molecules in the pores and channels. By measuring the intensity of reflected light from the zeolite coating, the researchers could determine the amount of isopropanol it had adsorbed from the atmosphere. The sensor showed a monotonic reflectivity response to low vapor concentrations and very fast adsorption, taking 1 s to adsorb introduced isopropanol and 3 s to return to the base reflectivity when the isopropanol flow was

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