Microfabrication of graphitic carbon materials via electrochemical etching

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MICROFABRICATION OF GRAPHITIC CARBON MATERIALS VIA ELECTROCHEMICAL ETCHING

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Microfabrication has had a considerable impact in many areas of chemistry and biology. The application of processes such as metal deposition, lithographic pattern transfer and etching techniques to a variety of materials has enabled, for example, the development of lab-on-a-chip devices, microelectromechanical systems (MEMS), miniaturized sensor systems, and methods to easily and reliably pattern surfaces. It is reasonable to believe that further developments of microfabrication processes and materials will lead to additional useful applications. We report here for the microfabrication of structures in carbon materials, particularly glassy carbon (GC) and thin carbon films.[1] The physical properties of GC such as good electrical conductivity, thermal stability, low gas permeability, low coefficient of thermal expansion, and low density provide a framework for GC as an appealing complementary material to glass and silicon for designing miniature systems. In addition, a number of convenient methods exist to chemically tailor the surface of GC opening pathways for the development of microsensors and microsystems for controlled fluid flow. Micromachined GC structures may also find applications as microbatteries, and microcapacitors.

The procedure we employ combines lithographic pattern transfer and electrochemical etching to microfabricate features in carbon. A mask pattern is transferred into a layer of photoresist that had been deposited on a carbon surface. The substrate is then anodized in 0.1 M NaOH and the photoresist dissolved in an appropriate solvent.

We will discuss the etching mechanism, parameters that control the etching rate and the topography of the resultant etched surface. Due to the nanometer scale size of graphitic crystallites in GC, the electrochemical etching is isotropic.

We are exploring a number of applications of microfabricated carbon materials. One application is that of microfluidic devices. As shown in Figure 1, channels of appropriate dimensions for microfluidic devices can be easily etched into GC. We will discuss the fabrication and function of a GC microfluidic device for electrospray mass spectrometry.[2] The advantage here is the ability to apply the electrospray voltage directly to the chip.

Another area we are pursuing is the fabrication of microelectrode arrays. The starting point for fabricating arrays of graphitic carbon structures that range in size from tens of microns to submicron is a thin (1–3 μm) graphitic carbon film on a conductive silicon substrate. Following lithographic transfer of a mask pattern, the carbon film is etched through to the silicon substrate. Arrays of carbon structures like that shown in Figure 2 can be prepared. We will show that shape and size of the structures can be controlled by mask design and etching conditions. Finally, we will present electrochemical characterizations of microelectrode arrays of various designs.

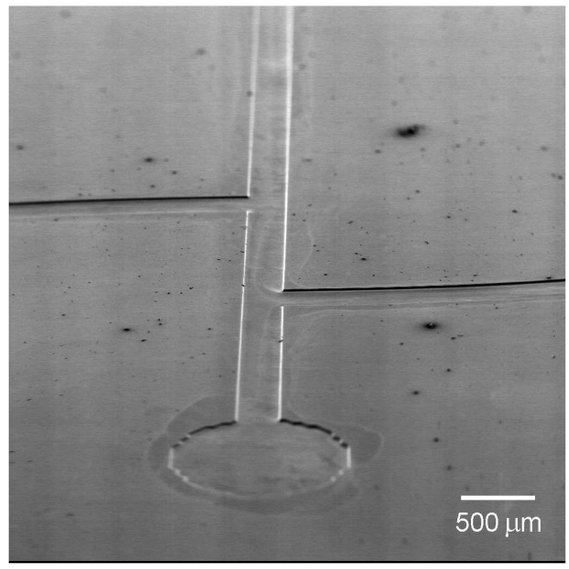

Figure 1: Scanning electron micrograph of channels etched in GC. The channels were etched at 2.0 V vs. Ag/AgCl for 30 min.

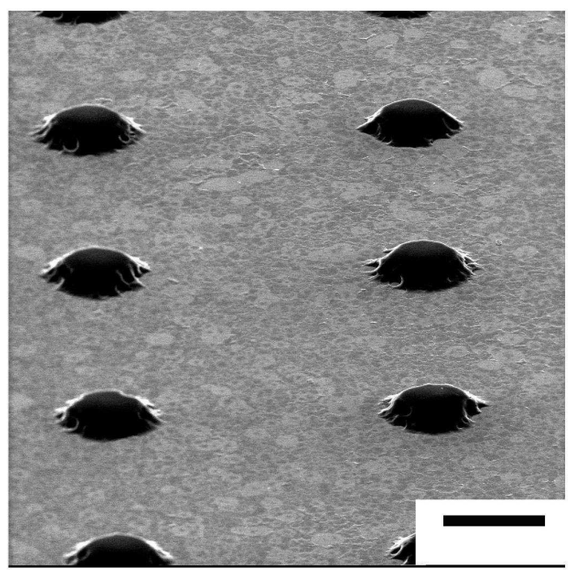

Figure 2: Scanning electron micrograph of an array of carbon structures supported in Si. The initial carbon film was etched for 50 min. at 2.0 V vs. Ag/AgCl. The scale bar corresponds to 30 μm.

References

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2. Ssenyange, S.; Taylor, J.; Harrison, D. J.; McDermott, M. T. *Anal Chem.* **2004**, *76*, 2393-2397.