

Advanced Nanoscale Anode Fabrication for High-Performance Solid Oxide Fuel Cells

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Dramatic breakthroughs in the materials for solid oxide fuel cells (SOFCs) have been reported in recent years. The power outputs of SOFCs, however, have not kept pace with these materials developments, indicating the potential for large gains in performance from optimized electrode architectures which provide ready access to catalytic sites and rapid transport of gaseous species. Typical fuel cell electrodes are three-dimensional structures with ill-defined geometries that cannot be easily tuned and do not permit ready deconvolution of effects due to catalysis and those due to gas phase transport. To address these factors, it is essential to engineer reproducible and tunable electrode structures.

As a first step towards optimized 3-D structures, we examine well-defined, two-dimensional electrode structures with tunable features including pore size, porosity, and wall thickness. Here, we utilize a facile sacrificial templating method¹, known as nanosphere lithography, to deposit a fully connected, yet fully porous metallic thin-film on fuel cell electrolyte materials. In short, an ordered monolayer of monodisperse polystyrene beads is applied to the surface of the substrate, the beads are etched in an oxygen plasma to create vias between them, a line-of-site thermal evaporation is used to deposit a thin-layer of the metal of choice, and, finally, the beads are removed (Figure 1). Specifically, porous metal films of nickel, gold/titanium, copper, and aluminum have been deposited on yttria-stabilized zirconia (YSZ) and samaria-doped ceria (SDC) single crystals. Starting beads of diameters 0.5 – 2 μm are used, yielding pore and interpore feature sizes of 0.3 – 1.5 μm .

In general, the metal film thickness must be greater than 200 nm to achieve sufficient in-plane conductivity, but cannot be so thick as to inhibit the eventual bead removal. This upper limit is equal to roughly half the diameter of the etched bead. In addition, it is found that during the oxygen plasma etching process, significant necking occurs between neighboring beads until half of the original diameter is etched away. These considerations imply that the starting bead size should be relatively large in order to produce the desired structure. Typical polystyrene monolayer application methods are difficult to employ for bead diameters larger than 1 μm . However, using a combination of evaporative and spin coating methods, we have achieved exhaustive substrate coverage with bead sizes as large as 2 μm .

Ideally, this two-dimensional metallic network ensures gas access to reaction sites and will serve as the backbone for subsequent nanowire depositions to dramatically increase the surface area and thereby accessible reaction sites.

¹C. Haginoya, M. Ishibashi, and K. Koike, *Appl. Phys. Lett.* **71**, 2934 (1997)

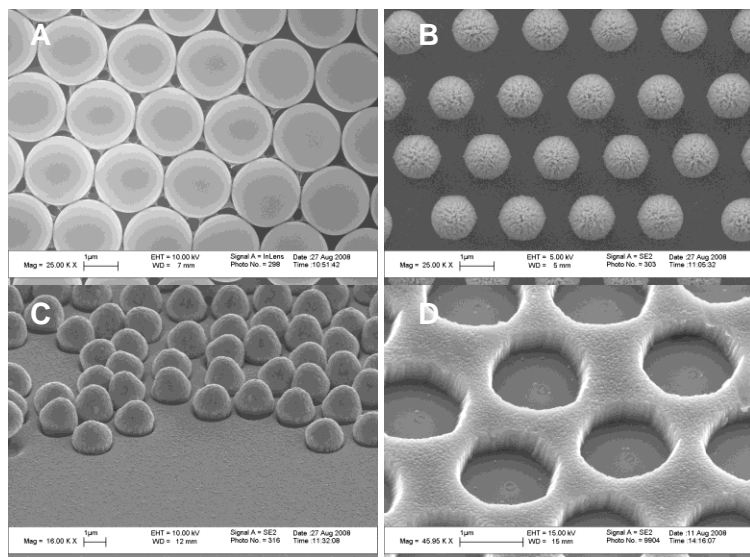


Figure 1. Sacrificial templating process: (A) PS bead monolayer on single crystal YSZ (yttria stabilized zirconia), (B) diameter reduced via oxygen plasma etching, (C) metal (Cu) thermally evaporated, (D) PS beads removed.