Tailored Anodization Leads to the Formation of Long, High-Aspect-Ratio TiO_2 Nanotube Arrays for Dye-Sensitized Solar Cells

As dye-sensitized solar cells (DSCs) continue to receive significant attention for their potential as low-cost alternatives to crystalline silicon photovoltaics, it appears that arrays of nanotubular TiO_2 may hold the key to their performance. In particular, the use of long, smooth TiO_2 nanotube arrays instead of disordered nanoparticulate TiO_2 can enhance DSC efficiencies by absorbing larger amounts of photosensitizing dye, leading to increased photoelectron generation. Now, work reported in the September issue of the *Journal of the American Ceramic Society* (DOI: 10.1111/j.1551-2916.2008.02546.x; p. 3086) by Y. Yang, X. Wang, and L. Li at Tsinghua University in Beijing demonstrates that careful control of the conditions of anodization can lead to the formation of smooth TiO_2 nanotube arrays as long as 22 μm, with aspect ratios up to 200.

The researchers began the nanotube formation process by potentiostatically anodizing 99.5%-pure titanium foils in a dimethylformamide electrolyte solution containing 0.5 wt% hydrofluoric acid, under an applied voltage of 30 V. This resulted in arrays of TiO_2 nanotubes whose length increased with anodization time, saturating at 22 μm after 40 h, which the researchers identify as the point at which the oxide growth and dissolution rates equalize. The nanotubes' wall smoothness also increased with anodization time, and their aspect ratio was as high as 200, as revealed in field-emission scanning electron microscope images. The researchers next created samples using 50 h of anodization time and different (fixed) applied voltages, finding that the average nanotube diameter increased from 110 nm at 20 V to 130 nm at 30 V. A key observation of these experiments was that the nanotubes were covered by a thick protective oxide layer during the anodization, enabling the long growth.

In order to investigate the effectiveness of these long nanotube arrays in solar cells, the researchers first calcined them at 400°C for 3 h and then used them as photoanodes in DSC devices. Although the devices employed an inexpensive and less-effective dye (Indoline dye D102) than the state of the art, the device's conversion efficiency was as high as 3.4%. In light of these results, long, high-aspect-ratio TiO_2 nanotube arrays may bring the commercial viability of DSCs one step closer to reality.

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Morphology and Optical Response of Butterfly Wing Replicated as an Inorganic Glass

The objective of biomimetics is to take advantage of structures found in nature, which have been optimized over millions of years of evolution, for the design of new materials and devices. Biomimetics researchers have been attracted to structures found in insects because they display characteristics that simultaneously serve several functions. For example, the structure of butterfly wings, in addition to making flight possible, is generally responsible for the great diversity of colors and patterns that exist. In one approach to fabricating replicas of biological structures, actual biological samples serve as templates that are coated with inorganic materials such that the microstructure and nanostructure are captured. Butterfly wings are covered with scales to a density of 200–600 scales/mm^2 arranged in a roof-tile pattern. The replicated scale patterns are complex in structure with stratification, voids, and complex groove shapes that can result in a photonic bandgap structure. A biomimetic

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