Vertically Aligned Carbon Nanotube Membrane for Solar Hydrogen Generation

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Principal Investigator(s): Prof. Todd D. Krauss
User(s): Anni Siitonen, Gregory Pilgrim

Affiliation(s): Department of Chemistry, University of Rochester
Primary Research Funding: United States Department of Energy
Contact: krauss@chem.rochester.edu, asiitone@z.rochester.edu, g.pilgrim@rochester.edu

Abstract:
We are developing vertically aligned carbon nanotube (VA-CNT) membranes for an artificial photosynthetic device. To fabricate the membrane, we synthesize VA-CNTs by chemical vapor deposition (CVD). Following nanotube growth, a polymer (either PDMS or PTFE) is deposited to make a chemically resistant membrane.

Summary of Research:
The development of new energy sources is a necessity for satisfying the increasing worldwide demand for energy. Out of the possible energy resources, the sun is the most widely available and most abundant source for long-term carbon free energy, although there are still many challenges in reaching that goal [1,2]. In this project, we are developing vertically aligned carbon nanotube membranes for a bio-inspired device producing hydrogen from solar energy. VA-CNTs will act as linkage between the light harvesting bio-molecule and the H₂ producing catalyst. Due to their exceptional electrical properties NTs can efficiently accept and separate electrons from the excited donor and transport to the catalyst even at long ranges. At the same time impermeable VA-CNT membranes can provide a physical distance between the light harvesting and H₂ producing components as well as separating them with different environments.

Dense forests of vertically aligned carbon nanotubes are synthesized by a chemical vapor deposition (CVD). A catalyst layer of 20-30 nm of Al₂O₃ and 1-3 nm of Fe are deposited on a Si wafer by e-beam evaporation. The thin metal layer is annealed at 800°C under hydrogen flow [3]. Al₂O₃/Fe form catalyst particles that are 8-12 nm as analyzed with atomic force microscopy (AFM). The CNTs are synthesized at 750-800°C with ethylene as the carbon source and argon as carrier gas. A small amount of water vapor is introduced to the carrier gas to weakly oxidize and remove the excess amorphous carbon to increase the catalyst lifetime [4]. With appropriate proportion of water, the growth rate of CNTs can be significantly improved and CNTs of a few mm can be synthesized. This length is appropriate for easy handling and an adequate thickness for formation of the impermeable membrane. Polymer membranes will be composed of either PDMS, which has already been used in similar Si nanowire systems [5] or polymerized PTFE, another novel and highly chemically resistant option [6].

References:
Figure 1: Scanning electron microscope images of vertically aligned carbon nanotubes.