Flame-based Aerosol Synthesis of Metal Nanoparticles and Supported-Metal Nanostructures & Solution-Phase Synthesis of Transition-Metal Chalcogenide Nanostructures

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This first part of this lecture will describe a nanomaterial synthesis method that we call the High-Temperature Reducing Jet (HTRJ) process, describe some of the materials generated by this process, and discuss their applications. Flame-based processes are the dominant commercial route to large-volume nanomaterials such as carbon black, fumed silica, and titania nanoparticles. However, flame-based synthesis of metal nanoparticles is not usually possible. In our HTRJ process, hot combustion products of a fuel-rich hydrogen flame pass through a converging-diverging nozzle to accelerate them to sonic or supersonic velocity. An aqueous metal precursor solution injected at the throat section of the nozzle is atomized by the high velocity gas stream, providing exceptionally rapid heating and mixing. The droplets evaporate and the precursor decomposes, initiating nucleation of particles in a reducing environment containing excess H_2. This approach separates combustion chemistry from particle formation chemistry, allowing use of aqueous precursors. Metals that can be reduced by hydrogen in the presence of water are thus generated as metallic nanoparticles. Our recent and current efforts include single-step synthesis of supported metal-alloy particles on metal oxides or reduced graphene oxide (RGO), single-step synthesis and surface passivation, and applications of these materials in conductive inks, membranes for hydrogen/CO_2 separation, and catalysis.

The second part of this lecture will introduce our work on the solution-phase synthesis of transition metal chalcogenides, mainly working with copper sulfide as a template material. Nanostructures of copper-deficient copper chalcogenides ($Cu_{2-x}E$, where E is S, Se, or Te) have a high concentration of free holes (positive charge carriers) that endow them with localized surface plasmon resonance (LSPR) behavior similar to that of noble metal nanostructures, but at near-infrared wavelengths. We have developed new synthesis methods for these materials, and demonstrated their application in photoacoustic imaging and photothermal therapy. We have also used them, particularly covellite CuS, as a template for producing numerous other materials by cation exchange processes. The high mobility of copper ions in CuS makes it a particularly useful template for these processes, which have allowed us to both create new nanostructures, such as biconcave nanoplatelets, that were not previously accessible and to derive mechanistic insights into cation exchange processes.

Biosketch:

Mark T. Swihart earned a B.S. from Rice University in 1992, and a Ph.D. in 1997 from the University of Minnesota, both in Chemical Engineering, then spent one year as a post-doctoral researcher in Mechanical Engineering at the University of Minnesota. Professor Swihart joined the faculty of the department of Chemical and Biological Engineering at the University at Buffalo (SUNY) in 1998, has been a full professor since 2008, and was named a UB Distinguished Professor in 2014. He currently serves as Department Chair, since 2018 when he was also named an Empire Innovation Professor in UB's RENEW Institute. His research interests include synthesis, processing, and applications of nanoparticles and other nanomaterials. He has co-authored over 250 peer-reviewed journal papers, which have been cited more than 15,000 times. Swihart has received the Kenneth Whitby award from the

American Association for Aerosol Research, the Schoellkopf medal from the American Chemical Society, and the J.B. Wagner award from the Electrochemical Society, along with university awards for research, teaching, and mentoring of undergraduate researchers. He is a fellow of the American Association for the Advancement of Science and the American Institute of Chemical Engineers. Swihart currently serves as an editor for Aerosol Science and Technology, and on the Board of Consulting Editors of AIChE Journal. He has served as research advisor to more than seventy current and former graduate students and more than 100 undergraduate researchers at UB.