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The Versatility of CVD to Synthesize 1D and 2D Nanostructures: Carbon Nanotubes and Transition Metal Chalcogenides for Electronic and Electrochemical Applications

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5 July 2023 | 10:30

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Registration Form

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Since the excitement about graphene, a monolayer of graphite, with its 2010 Nobel Prize, there has been extensive research in the synthesis of other non-carbon few/mono-layers exhibiting a variety of bandgaps and semiconducting properties (e.g., n or p type). The main approaches to deposit few/monolayers on a substrate are: (a) bottom-up synthesis from precursors using chemical vapor deposition (CVD) or (b) top-down exfoliation (liquid or mechanical) of bulk layered material.
Here we show a combined bottom-up and top-down approach where (a) we synthesize in one step high yields of bulk layered materials by annealing a metal in the presence of a gas precursor (sublimated selenium from selenium powder) using chemical vapor deposition (CVD) and (b) we exfoliate and dropcasted few/mono-layers on a substrate from a sonicated mixture of our material in a specific solvent. It is interesting to note that, besides the structure being 2D layered, the properties of the nanomaterials synthesized slightly differ from the materials with the same stoichiometry synthesized using conventional chemical methods (e.g., solvothermal).
In the first part of this talk, we will discuss the chemical synthesis, the very extensive characterizations, and the lessons we learned in making multiple metal selenides (Ag-Se, Cu-Se, W-Se, Mo-Se, etc.). We will see how we integrated these new materials into sensors, as functional coatings, and into electrochemical devices.
We produced single atom catalysts on carbon nanofibers (SACs@CNFs) using an innovative one-step CVD synthesis based on temperature-controlled delamination of multilayer mixed metal films from a substrate with concurrent reactions with precursor gases and dopants to obtain a self-standing (no binder), high surface area doped carbon electrode bearing nickel SACs (not-PGM). These electrodes with nickel SACs performed well for water splitting, both in performance (low OER overpotential of 290mV @ 10mAcm-2; low HER overpotential of 230mv @ 10mAcm-2) and durability (over 20,000 cycles).
We will discuss the main phenomena are at play, including nucleation, growth, and doping of the nanocarbons; dewetting of thin metal films on the nanocarbons to form the SACs; thermal detachment of selected weak-adhesion thin films; and multiple gas-solid phase reactions in the CVD reactor. Given the inherent scalability of CVD, this technique could be used industrially with large reactors to produce large area electrodes and become a new benchmark for water splitting and other electrocatalytic reactions.

Prof. Gilbert D. Nessim is an associate professor in the Chemistry department at Bar Ilan University (Israel), Institute for Nanotechnology Advanced Materials.
The Nessim laboratory at Bar Ilan University (Israel) focuses on the synthesis of 1D and 2D nanostructures using state-of-the-art chemical vapor deposition (CVD) equipment. The scientific focus is to better understand the complex growth mechanisms of these nanostructures, to possibly functionalize them to tune their properties, and to integrate them into innovative devices.
Prof. Nessim joined the faculty of chemistry at Bar Ilan University in 2010 as lecturer, was promoted senior lecturer with tenure in 2014, and associate professor in 2018. Since March 2020, he is the president of the Israel Vacuum Society. He received the title of "Cavaliere della Stella d'Italia" by the President of Italy for his work on research collaborations between Italy and Israel.
He holds a Ph.D in Materials Science and Engineering from the Massachusetts Institute of Technology (MIT), an MBA from INSEAD (France), and Masters in Electrical Engineering from the Politecnico di Milano and from the Ecole Centrale Paris (ECP, within the Erasmus/TIME program). Prior to his Ph.D, Dr. Nessim spent a decade in the high-tech industry and consulting across Europe, USA, and Israel.