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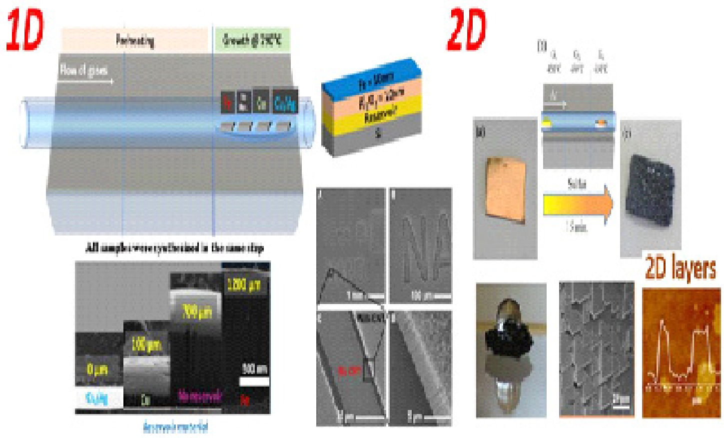
Gilbert Daniel Nessim

Bar Ilan University, Israel

Spaghetti & Lasagne - synthesis of 1D and 2D nanomaterials

Massive research has been done in the past decade on 1-dimensional (1D) and 2-dimensional (2D) nanomaterials, with graphene (2D) winning the Nobel prize in 2010. The interest stems from their original morphologies and structures, which make them attractive for a wide array of applications, including energy, electronic devices, and composites. In our lab, we have focused on developing new processes for the synthesis of 1D and 2D nanomaterials using chemical vapor deposition (CVD). 1D Despite the massive progress achieved in the growth of carbon nanotube (CNT) forests on substrate, apart from lithographic patterning of the catalyst, little has been done to selectively (locally) control CNT height. Varying process parameters, gases, catalysts, or underlayer materials uniformly affects CNT height over the whole substrate surface. We show here how we can locally control CNT height, from no CNTs to up to 4X the nominal CNT height from iron catalyst on alumina underlayer by patterning reservoirs or by using overlayers during annealing or growth. By using different thin film materials as reservoirs, we can locally grow taller CNTs1 (2X with Fe, 4X with Mo), shorter CNTs (with Cu), or completely inhibit CNT growth2 (with Cu/Ag alloy). Additionally, we show how copper3 or nickel4 overlayers (as stencils or bridges) placed above the catalyst surface during pre-annealing or during CNT growth deactivate the catalyst, thus growing patterns of CNT forests without the need for lithography. This modulation of the CNT height using reservoirs and/or overlayers is a significant improvement compared to the "CNTs (one height) / no CNTs" patterning that has been achieved using lithography of the catalyst, and moves us closer to building 3D architectures of CNTs. 2D Most of the recently discovered layered materials such as MoS2 or MoSe2 are n-type, while few materials, such as phosphorene, which suffers from rapid oxidation, are p-type. To form devices such as p–n junctions and heterojunctions, new p-type mono-/few-layers are needed. We developed a one-step synthesis of a 2D layered, crystalline, p-type copper sulfide5 by thermal annealing of a standard copper foil in an inert environment using chemical vapor deposition (CVD). The material synthesized has one stoichiometry (Cu9S5) and exhibits good conductivity despite a bandgap of 2.5 eV. Combined with n-type layered materials, our p-type Cu9S5 opens the door to the fabrication of 2D p–n heterojunctions. We used a similar bottom-up synthesis to synthesize other metal sulfidesand phosphides.

Notes:



Recent Publications

1. Shawat, E.; Mor, V.; Oakes, L.; Fleger, Y.; Pint, C. L.; Nessim, G. D., What Is Below the Support Layer Affects Carbon Nanotube
2. Avraham, E. S.; Westover, A. S.; Itzhak, A.; Shani, L.; Mor, V.; Girshevitz, O.; Pint, C. L.; Nessim, G. D., Patterned Growth of Carbon Nanotube Forests Using Cu and Cu/Ag Thin Film Reservoirs as Growth Inhibitors. Carbon 2018, 130, 273-280.
3. 3Yemini, R.; Muallem, M.; Sharabani, T.; Teblum, E.; Gofer, Y.; Nessim, G. D., Patterning of Forests of Carbon Nanotubes (Cnts) Using Copper Overlayers as Iron Catalyst Deactivators. J Phys Chem C 2016, 120, 12242-12248.
4. Yemini, R.; Itzhak, A.; Gofer, Y.; Sharabani, T.; Drela, M.; Nessim, G. D., Nickel Overlayers Modify Precursor Gases to Pattern Forests of Carbon Nanotubes. J Phys Chem C 2017, 121, 11765-11772.
5. Itzhak, A., et al., Digenite (Cu9s5): Layered P-Type Semiconductor Grown by Reactive Annealing of Copper. Chemistry of Materials 2018, 30, 2379-2388.

Biography

Gilbert Daniel Nessim heads a laboratory at Bar Ilan University (Israel) that focuses on the synthesis of nanostructures using state-of-the-art chemical vapor deposition 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. He joined the Faculty of Chemistry at Bar Ilan University in 2010 as a Lecturer and was promoted to a Senior Lecturer in 2014. He holds a PhD in Materials Science and Engineering from the Massachusetts Institute of Technology (MIT), an MBA from INSEAD (France), and Master's degree in Electrical Engineering from the Politecnico di Milano and from the Ecole Centrale Paris (ECP, within the Erasmus/TIME program.

gdnessim@biu.ac.il