Materials by Design: Heterostructures with Targeted Nanoarchitecture and Tunable Properties

We have shown that by controlling the local composition of an amorphous intermediate on the nanoscale it is possible to kinetically control the self-assembly of new nanostructured compounds consisting of two or more compounds with different crystal structures that are precisely interleaved on the nanoscale. We have used this approach to synthesize hundreds of new metastable compounds with designed nanostructure, including structural isomers. Many of these materials have unprecedented physical properties, including the lowest thermal conductivities ever reported for a fully dense solid, systematic structural changes dependent on nanostructure, and charge density wave transitions. The designed precursors enable diffusion to be followed and quantified over distances of less than a nanometer, providing insights to the mechanism that gives control of the nanoarchitecture of the final product. We believe the ability to prepare entire families of new nanostructured compounds and equilibrating them to control carrier concentrations permits a new "thin film metallurgy" or “nanochemistry” in which nanostructure and composition can both be used to tailor physical properties, interfacial structures can be determined for precisely defined constituent thicknesses, and interfacial phenomena and modulation doping can be systematically exploited.