Synthesis of and Structure-Function Relationships in Heterostructures of Quazi-2D Materials

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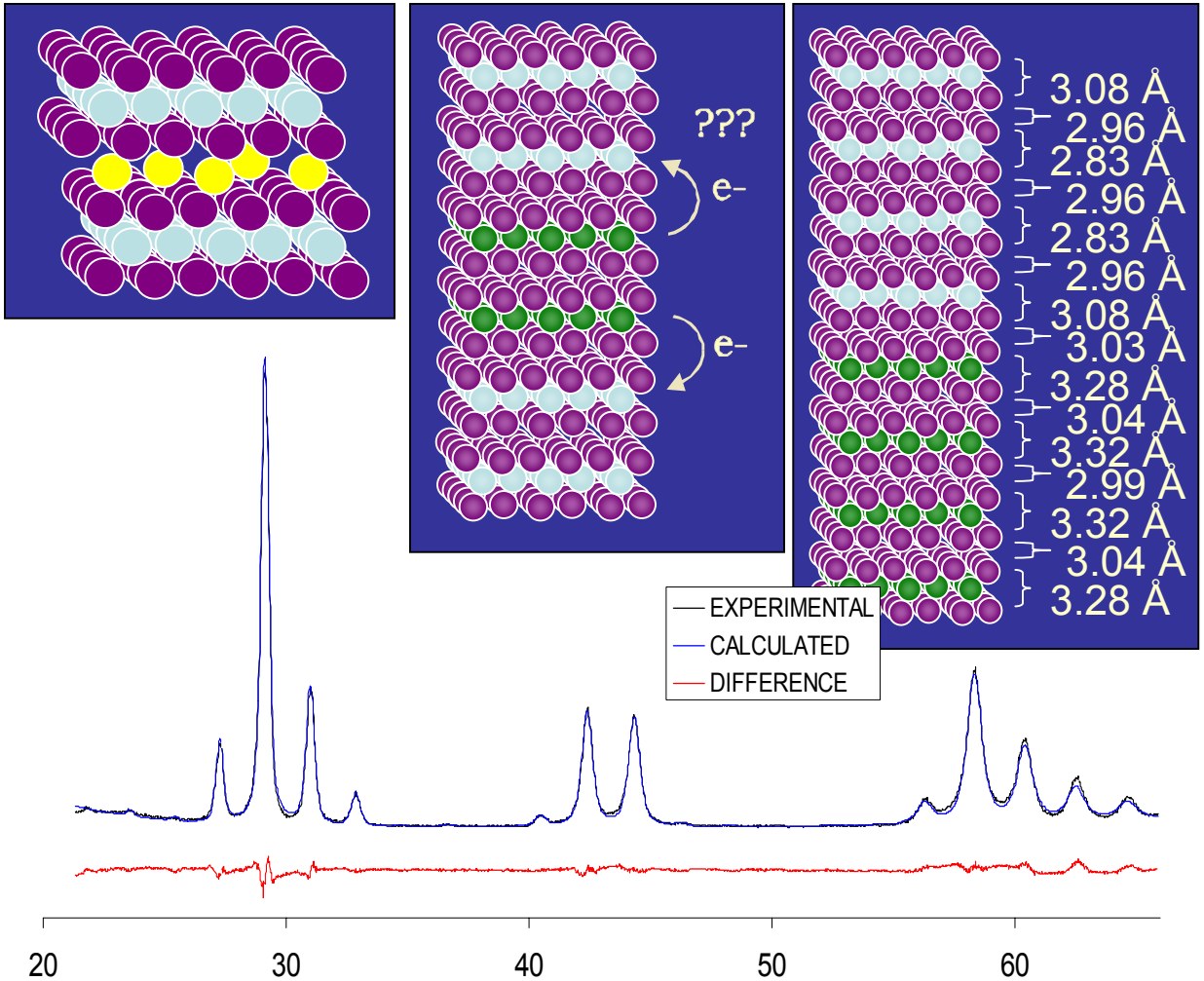
University of Oregon DMR-0103409

Nanoscience creates new materials and new properties as sizes decrease below the fundamental length scale associated with the phenomena. Understanding how properties evolve or are created as a function of length scale in nanostructured materials is both fundamentally important to designing new materials and crucial for the development of applications for nanoarchitectures. We have created a series of $(CrSe_2)_x(NbSe_2)_y$ superlattices analgous to the known compound $AgCrSe_2$. Charge donation from the $NbSe_2$ to the $CrSe_2$ stabilizes the new superlattices. Magnetic and electrical measurements are currently underway to understand the correlation between superlattice structure and properties..



The artificial layering of different materials often leads to novel phenomena when the layer dimension is comparable to a characteristic length scale of some underlying physical property. In this circumstance, the material can no longer be considered to be composed of independent constituent layers and may possess unique and useful properties. Indeed, the excitement created by nanoscience stems from this phenomena. Relevant length scales include the de Broglie wavelength of electrons, the phonon wavelength, the elastic and inelastic mean free path of elementary excitations, the spatial extent of localized wave functions, the dielectric screening length or depletion width in semiconductors, the cyclotron radius of carriers in a magnetic field, and the coherence lengths and domain sizes of ordered magnetic, superconducting, spin- and charge-density-wave-distorted, and ferroelectric phases. These lengths range typically from a few to a few thousand Ångstroms. Despite this successful activity, the diverse range of possibilities in artificial layering has certainly not been exhaustively explored because of the difficulty in growing well defined crystalline heterostructures using materials having a large entropic and possibly energetic driving force for intermixing.

We have been apply a new synthetic approach based upon kinetic trapping from a designed superlattice reactant to synthesize a wide variety of novel heterostructures and superlattices based upon transition metal dichalcogenide compounds and their 3d transition metal intercalates, characterizing the structure of the resulting superlattices using x-ray diffraction and transition electron microscopy, and characterizing the physical properties of these new materials with a variety of analytical techniques. The $CrSe_2/NbSe_2$ superlattices show the ability to stabilize a structure ($CrSe_2$) through charge donation from the other constituent. This phenomena greatly expands the range of materials that potentially can be synthesized.

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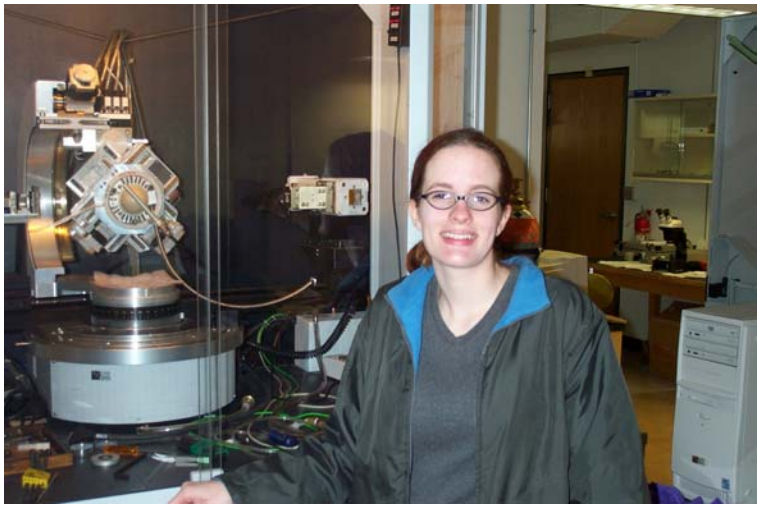
Education:
Five undergraduates (Stacey Standridge, Carolyn Feik, Thomas Allen, Luke Sheppard, Maisha Kamunde), four graduate students (Fred Harris, Polly Berseth, Ngoc Nguyen and Michael Fenci), one research associate (Lance Miller)and Tso visiting faculty members (Brian McBurnett and Robert Schneidmiller) contributed to this work. Fred Harris is currently doing an Internship with Intel Corporation. Fred Harris and Polly Berseth will receive their Ph.D.'s in the Fall and plan to work in industry.

Outreach:
A research "boot camp' was held to prepare undergraduate students for research in materials chemistry. 7 students from throughout the Northwest participated.



Stacey Standridge performs an X-ray Diffraction scan

The educational efforts of our program have grown to include a research ‘boot camp” designed to prepare undergraduates for research in the general area of materials science. The students made materials using several different synthesis methods, analyzed the products using XRD, SEM and several surface analysis techniques, and performed thermal analysis experiments to understand both phase diagrams and the importance of kinetics in attaining thermodynamic equilibrium. The seven students in this inaugural program all went on to do summer research either in connected with this grant (Luke Shepard (University of Oregon), Maisha Kamunde (Chico State University))or working at their home institutions (Oregon State University, Southern Oregon University or Central Washington University). Feedback from the students and their research mentors have all be very positive as the students were able to make significant progress faster as a result of the ‘boot camp’.