

Characterizing the Structure of Self-Assembled Lead (II) Sulfide Nanoparticle Superlattices Based on Variable Ligand Surface Coverage

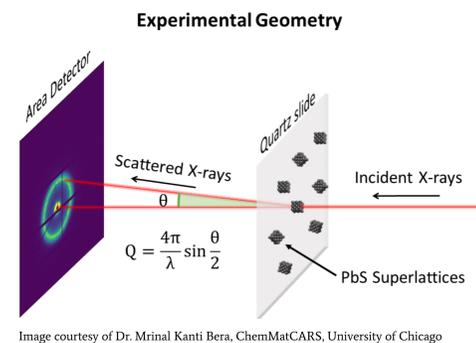
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Abstract

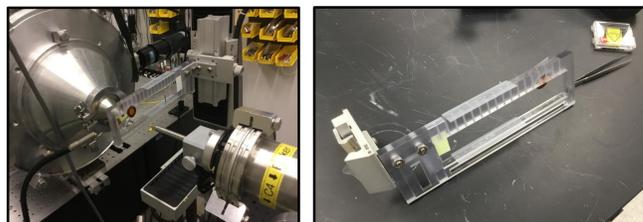
Inorganic nanoparticles (NPs) coated with interfacial organic molecules known as ligands are able to self-assemble into complex three-dimensional structures. Periodic crystal lattices of NPs known as superlattices possess useful chemical, electrical, and magnetic properties. An important objective within the field of nanotechnology is to understand how parameters of the self-assembly process can be tuned to reach a desired outcome, such as a superlattice. The surface coverage of ligands and the type of solvent used during self-assembly are known to determine the organization of NPs and shape of the nanostructure. Studying the effects of these properties will contribute to a general understanding of how nanostructures form. Lead (II) sulfide (PbS) nanostructures are of particular interest for their potential to be used as a semiconductor material. Interparticle spacing and structural ordering are the determining factors of the charge transport properties of superlattices. We investigated the relationship between these factors and ligand surface coverage in binary PbS superlattices formed with various solvent mixtures. Tests were performed using small angle x-ray scattering (SAXS) at the Advanced Photon Source (APS) and scanning electron microscopy (SEM) at the Center for Nanoscale Materials (CNM).

Background

Small angle x-ray scattering (SAXS) is an x-ray diffraction technique that is useful for determining characteristic distances of nanoscale structures. PbS nanoparticles are known to form superlattice structures, but the conditions leading to this result are not fully understood. During the formation of the sample structures four unique solvent mixtures were used to prepare two samples, one coated with oleic acid ligands and another with both oleic acid and hexadecyl amine ligands. SAXS was performed with all eight of these samples in addition to a solution of PbS nanoparticles. Scanning electron microscopy (SEM) was used to visualize the crystalline structures. SEM data is used to help interpret SAXS peak data.



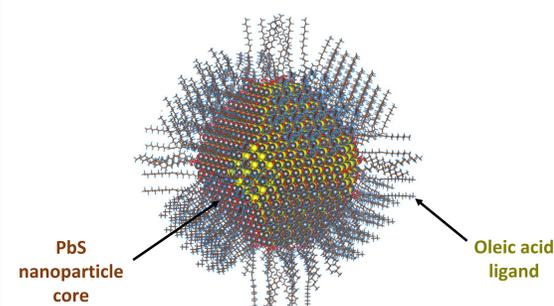
Sample Preparation Procedure



Multiple PbS samples, altered with various solvent mixtures, were placed on quartz slides and transported to ChemMatCARS Sector 15 for small angle x-ray scattering (SAXS). The beamline was calibrated to a series of specific coordinates for each sample. Data from the samples regarding peak concentration was collected and displayed using computer software. The peak data was then processed and analyzed using custom ASAXS and peak fitting software.

Images courtesy of Wayne Oras, Hoffman Estates High School

Goals



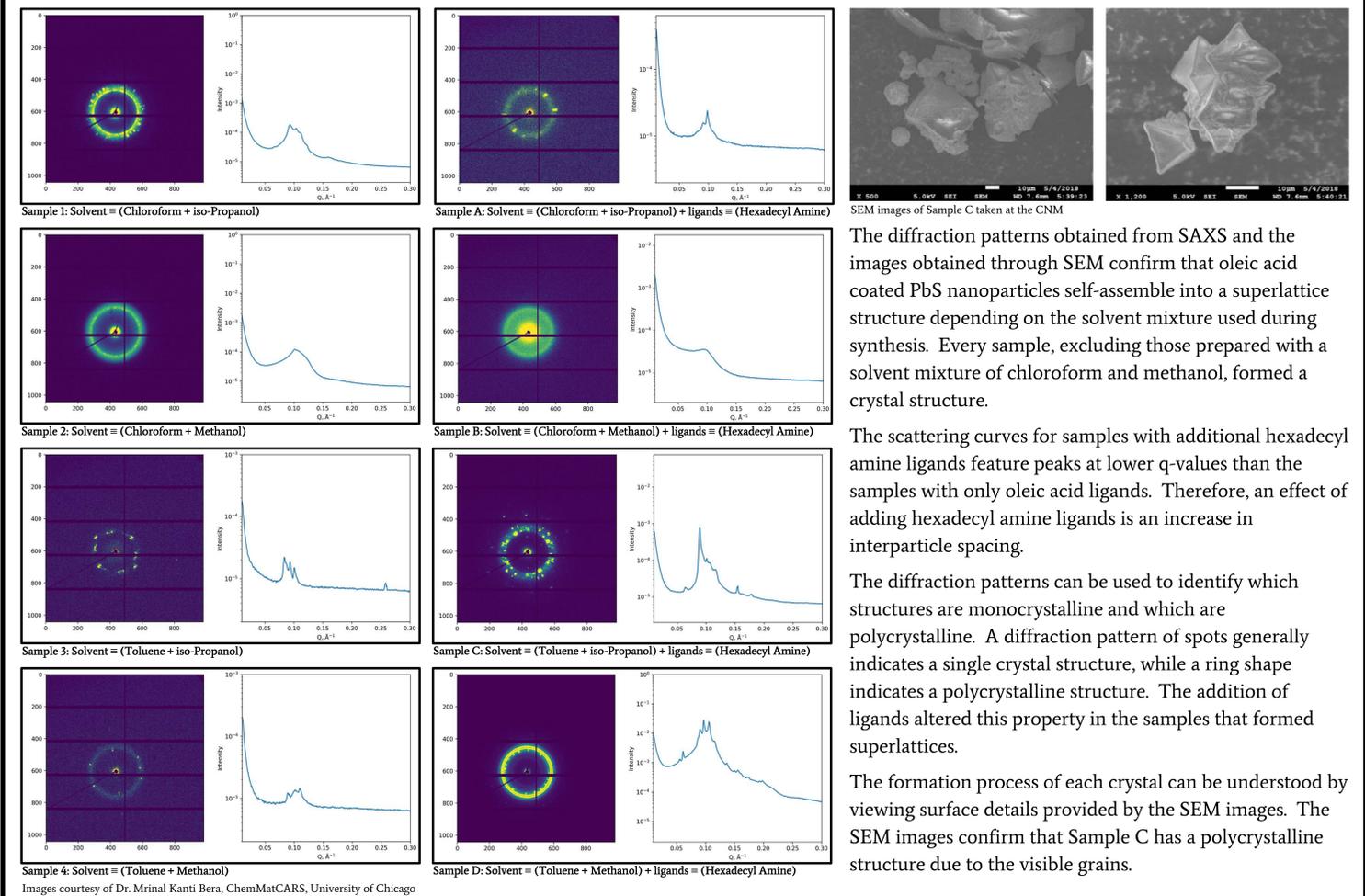
- Determine the relationship between solvent mixture and crystallinity for PbS nanostructures
- Determine the relationship between presence of oleic acid ligands and degree of crystallinity for PbS nanostructures

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References

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Results



Conclusions

The interaction between solvents and ligands during self-assembly is a critical factor in determining nanoparticle superlattice structures.

The surface density and type of ligands can alter interparticle spacing. The size of the nanoparticle core does not have to change to affect the superlattice structure.

Future Directions

The ability to fine-tune properties of self-assembled nanostructures will continue to be a leading goal of materials science research. Further research must be done to better understand the interaction between solvents and ligands in the self-assembly process.

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