Films of colloidal PbX (X = S, Se, Te) nanocrystals (NCs) are a class of granular electronic materials of current interest for thin-film field-effect transistors, photodetectors, and solar cells. To date, PbSe NC films have shown large film conductivities and decent carrier nobilities but poor short- and long-range order. Improving the positional and orientation order of the NCs within conductive NC films provides a promising route to improving the electronic performance of devices such as NC solar cells by increasing carrier diffusion lengths.

Small angle X-ray scattering (SAXS) can be used to analyze how and how well the NCs are ordered, and X-ray diffraction (XRD) can characterize the crystalline NC cores by analyzing the crystal structure related parameters including crystallite size and preferred orientation.

In this study, spun-cast PbSe NC superlattice films with and without a protective coating of amorphous alumina deposited by atomic layer deposition (ALD) were characterized using SXAS and XRD in both out-of-plane and in-plane directions to fully understand the NC superlattice and the PbSe core crystal structures. SAXS analysis of a NC film without alumina protection shows clear superlattice order and a preferred orientation of the superlattice. However, the alumina coating results in a degradation of superlattice order that depends on the ALD processing temperature. In addition, XRD analysis shows evidence of a significant preferred orientation and potential non-stoichiometry (selenium deficiency) of the PbSe NC cores.