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Colloidal Nanocrystals: A Model System for the Study of Phase Transformations Since 1950

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Shock waves provide a means of rapidly compressing a condensed phase sample and studying the resulting structural changes. However, shock studies to date have focused on bulk materials, in which multiple uncorrelated nucleation events lead to complex transformation kinetics. An individual nanocrystal, by comparison, can transform completely with ~ 10 ps following nucleation of the daughter phase, reducing the likelihood that a second nucleation event will occur during the transformation time. In a diamond anvil cell, the wurtzite to rocksalt phase transformation in CdSe nanocrystals, for example, has been shown to follow simple first-order kinetics. The slow, ensemble kinetics observed in those experiments, however, obscured the dynamics within each nanocrystal. Rapidly compressing a nanocrystalline sample using a laser-driven shock wave, the pressure around each nanocrystal can rise on a timescale comparable to that for a sound wave to traverse the crystal. Shock experiments on nanoscale materials therefore have the potential to elucidate aspects of the transformation mechanism inaccessible to further quasi-static diamond anvil cell measurements. Behavior of CdSe nanocrystals under shock stresses of 2–3.75 GPa has been studied. Above 3 GPa a near-complete disappearance of the first excitonic feature and broadening of the low-energy absorption edge were observed, consistent with a wurtzite to rocksalt structural transformation. The transformation pressure was reduced relative to hydrostatic compression in a diamond anvil cell, and the rate increased, attributed to shock induced shear stress along the reaction coordinate. The especially rapid rate observed for a 3.75 GPa shock suggests multiple nucleation events occurring in each particle.