QUANTIFYING ELECTROPHORETIC DEPOSITION OF NANOCRYSTAL SUPERLATTICES USING QUARTZ CRYSTAL MICROBALANCE

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Nanocrystal structures (films, superlattices) are promising photovoltaic and LED materials due to their size-tunable properties and potentially low integration cost into devices. Although nanocrystal superlattices have been intensively studied for more than two decades, standard solution-based deposition techniques such as spin coating or evaporation methods force a choice between fast fabrication—which results in disordered structures—or highly-ordered superlattices that require slow fabrication. It has recently been shown [1] that electrophoretic deposition (EPD) can be used to both deposit and to induce order in nanocrystal assemblies (Fig 1a). This approach opens the door to quantitatively studying nanocrystal superlattice-assembly because the externally applied field controls the particle-flux and, thereby, adds a level of control to this process that has not previously been available. In turn, this improved control is required to optimize and more broadly realize solution phase nanocrystal film growth.

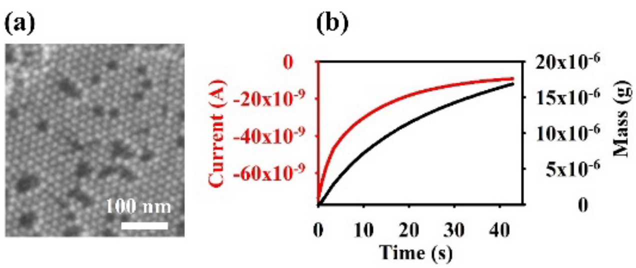

Figure 1: Nanocrystal films grown with EPD. (a) SEM image of a superlattice composed of 15 nm nickel nanocrystals. (b) The QCM allows simultaneous measurement of mass and charge. Plot shows the mass change as a function of time (black) and the current flowing through external circuit (red) during film growth.

We have applied EPD to oleic acid capped nickel nanoparticles to grow metal nanoparticle films in the solution phase. To quantify the film growth rates, we use the quartz crystal microbalance (QCM) method. A fraction of the nanocrystals are (positively and negatively) charged. Hence, in addition to the deposited film mass, we have simultaneously record the electric current associated with electrophoretic particle motion. The black curve in Fig. 1(b) shows how mass of the film builds up in real time. We have further modified this method by creating a dual-QCM mode that permits simultaneous detection of positive mass at one electrode and negative mass at the other. Key parameters in the growth of nanocrystal films are the charged particle concentrations, the average charge per particle, and the nanoparticle sticking coefficients. Through these measurements, we are working to determine these properties, permitting nanoparticle-deposition theories to be tested, as required for quantitative nanoparticle EPD.

The impact of this work is that (for the first time) we are able to apply the same crystal growth formalism that we use for vapor deposition to nanocrystal assembly. This will enable us to relate film properties with particle level parameters (field strength, size, charge, surface chemistry) which will in turn allow us to control and improve the growth process. We expect this to impact nanocrystal-based device fabrication (such as solar cells, LEDs and infrared detectors).

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References

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