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Metallic Magnetic Nanocrystals – Shapes, Self-assembly and Phase Transformation

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Controlled assembly of magnetic nanocrystals (NCs) has been a key issue in fabricating functional nanodevices. Extensive investigations in NC assemblies have revealed that the symmetry of the observed superlattices is influenced by the NC size, NC shape and relative dimensions of the NC core and the organic capping. Our study has been focused on investigating the roles played by NC shape in self-assembly and the mechanism by which defects are created [1]. The key challenges in this self-assembly method are to control the defects of the self-assembly to ensure an ordered structure, and to prepare an assembly with uniform thickness and large lateral dimension. For the 11 nm Co NCs and their superlattice assembly (Fig. 1), the Co NCs have anisotropic polyhedral shapes (Fig. 2) [2]. The self-assembly of the NCs and the defect structures in the NC arrays are governed by the anisotropic shape. The self-assembly of nanocrystals with faceted shape is dominated by a surface-to-surface contact. This simple geometrical matching is the root for creating defects in the self-assembly. The structural transformation of shape-controlled nanocrystals has been studied by transmission electron microscopy.

Our second study is about the FePt nanocrystals, which have been demonstrated as a potential candidate for high-density magnetic transitions at room temperature [3]. Depending on the Fe to Pt elemental ratio, the Fe-Pt alloys can display chemically disordered face centered cubic (fcc) phase (A1, $Fm\bar{3}m$) or chemically ordered phases. High-resolution transmission electron microscopy (HRTEM) studies show that A1 to $L1_0$ phase transformation occurs at 530 ^oC [4,5]. The multilayered nanocrystal assemblies coalesce to form larger grains at 600 ^oC. The coalescent temperature of the nanocrystal monolayer assembly depends on the substrate used (Fig. 3). On SiO_2 surface, the FePt nanocrystal monolayer can stand up to 700 ^oC without any obvious aggregation. The coalesced nanocrystals show dominant {111} twin defect inside, while their surface and coalescent grain boundary consist of both {111} and (001) facets [6].

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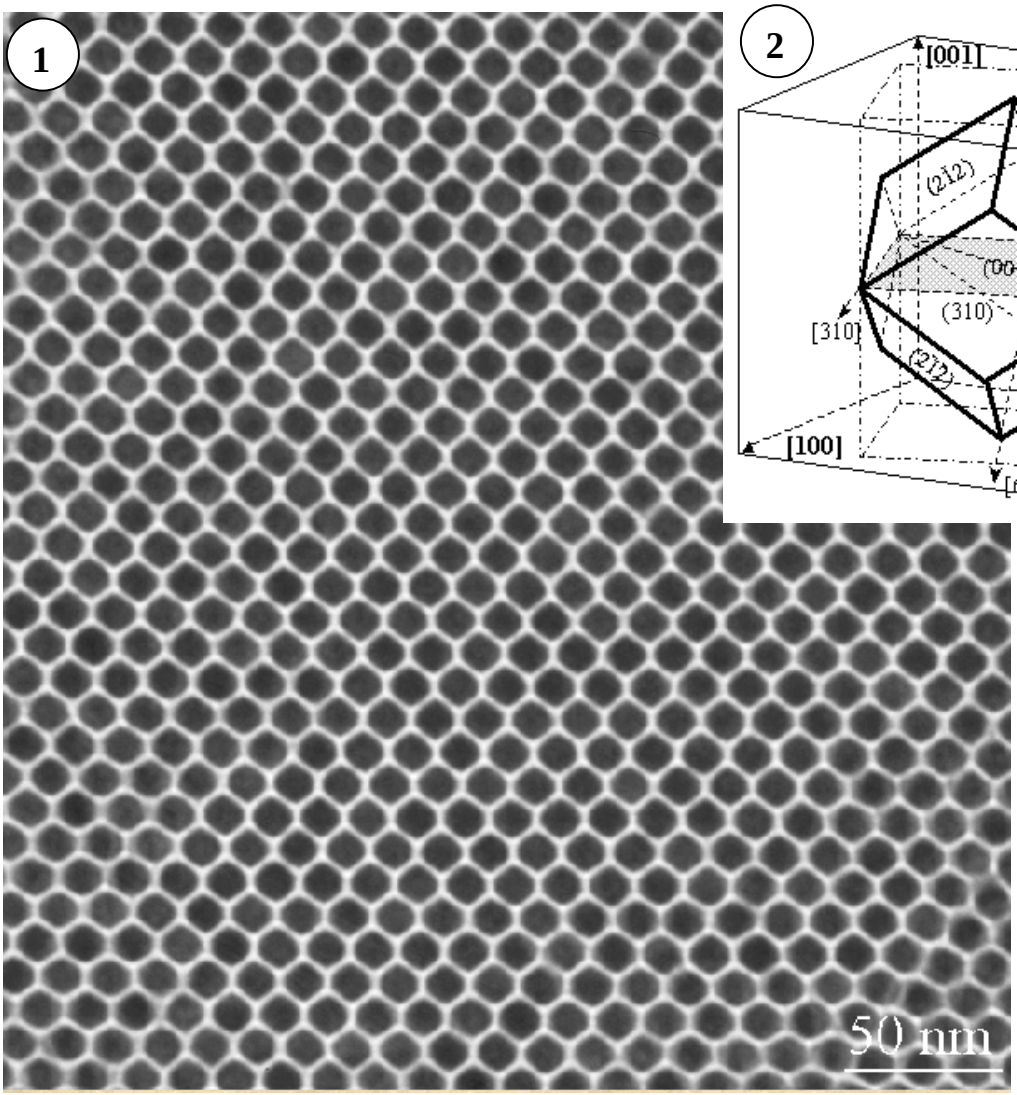

Fig. 1 Self-assembly of 11 nm Co nanocrystals forming an ordered structure with translation symmetry but no long-range orientation symmetry.

Fig. 2 The shape of the 11 nm Co particle (ε-Co phase with β–Mn structure).

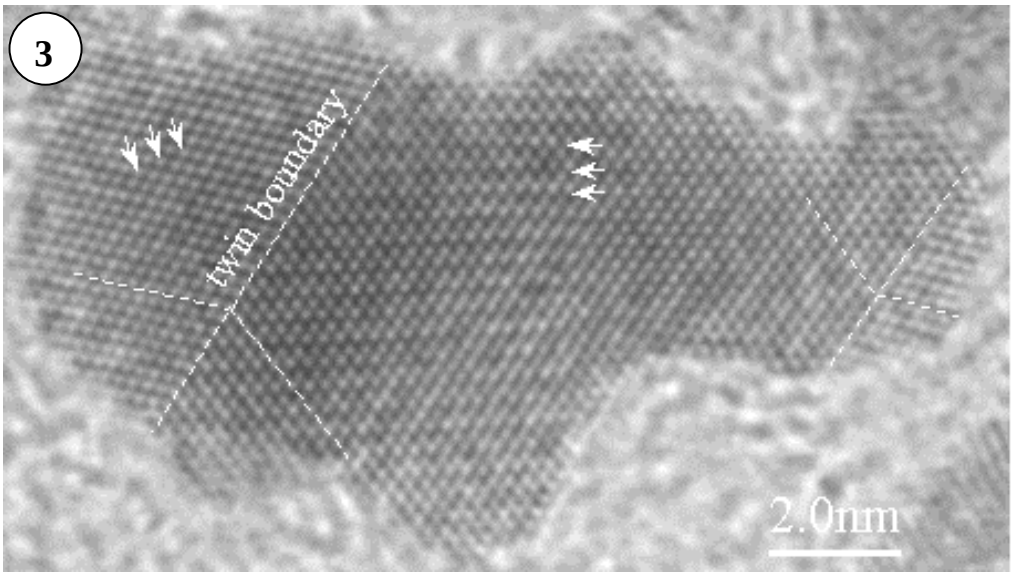

Fig. 3 Coalescing and phase transformation of FePt nanocrystals. The twin is formed due to the coalescing of two particles, and the ordered Fe and Pt stacking is indicated by arrowheads.

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