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Experiment Brief

K3 IS Camera

Title

Magnetite nanoparticle orientation mapping from a single low-dose transmission electron microscope (TEM) image

Gatan Instrument Used

K3™ IS direct detection camera delivers simultaneous low-dose imaging via real-time electron counting, fast continuous data capture, and a large field of view.

Background

Magnetite (Fe_3O_4) nanoparticles are promising magnetic materials for hyperthermia, MRI contrast agents, and as magnetic cores in high switching frequency inductors and transformers. In each of these applications, a strong magnetic saturation (M_{sat}) is necessary. Recent studies show that the presence of antiphase boundaries (internal defects) can significantly reduce this value. Identifying optimal synthetic conditions is useful to produce high-quality NPs with M_{sat} approaching maximum bulk values.

Materials and Methods

Magnetite nanoparticles were observed using a Gatan K3 IS camera on a Titan ETEM, which captured single TEM images of large numbers of nanoparticles while maintaining a 1Å pixel size and a low electron dose of just 14.6 $e^-/Å^2$. Python scripting in Gatan Microscopy Suite® (GMS) was then used to process this data to produce a map of lattice spacing orientation and visibility. FFTs were computed from 64 x 64 pixel regions, with 32 pixel spacing between regional centers. Then the direction and magnitude of the strongest peaks in these FFTs were mapped.

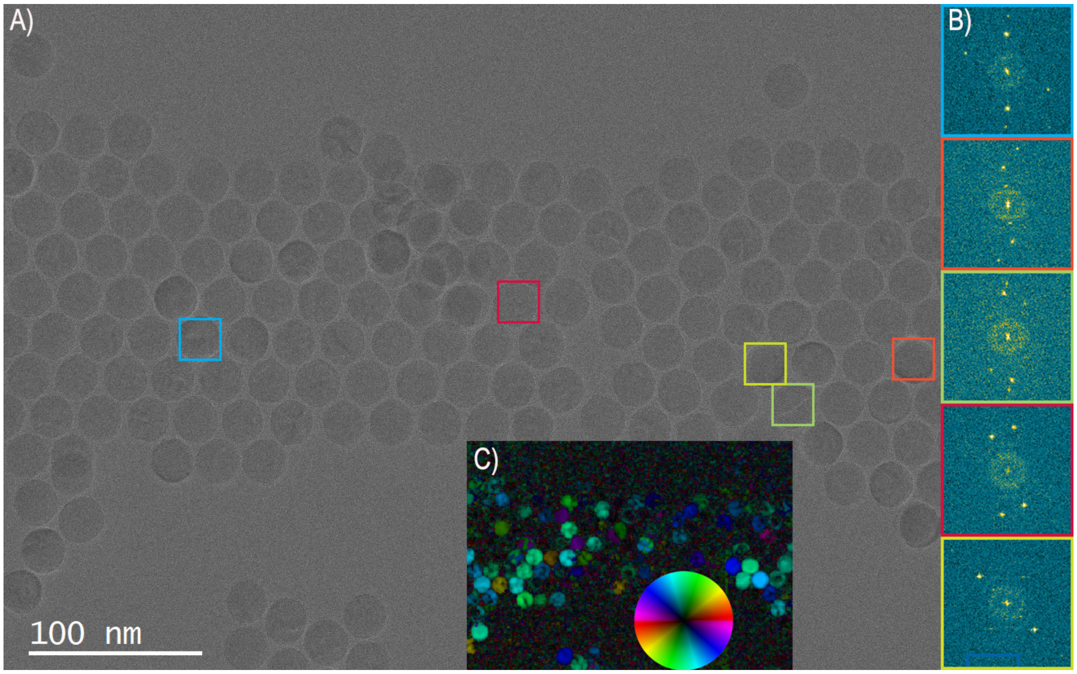

Figure 1. Diffractogram Mapping. A) TEM image with a large field of view showing over 150 magnetite nanoparticles. B) Diffractograms from 5 nanoparticles, showing different orientations. C) Map of lattice spacing orientation and visibility. The color hue in the map specifies the direction from the center of the strongest lattice spacing peak in the diffractogram, while the brightness corresponds to the intensity of this peak.

Summary

The map of lattice spacing orientation can be used to determine which particles are similarly oriented, as well as the number of particles where there is significant structural variation within a single particle. The K3 IS, therefore, provides statistically relevant information on the presence of particle defects, which can then inform batch synthesis to produce high-quality, single-crystal magnetite nanoparticles. The observation of any correlated orientation between particles is important, as interparticle interactions can adversely affect the desired magnetic behavior.

Credit(s)

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Gatan, Inc. is the world's leading manufacturer of instrumentation and software used to enhance and extend electron microscopes—from specimen preparation and manipulation to imaging and analysis.

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