Off-axis electron holography of magnetic fields in nanostructured materials

Rafal E Dunin-Borkowski

Department of Materials Science and Metallurgy, Pembroke Street, Cambridge CB2 3QZ, UK

Off-axis electron holography in the transmission electron microscope (TEM) allows the magnetic fields within nanostructured elements and the magnetic interactions between them to be quantified on a nm scale [1]. Unwanted compositional contributions to the contrast, such as those at the edges of submicron-sized magnetic elements, can be removed much more easily from a holographic phase image than from equivalent phase gradient images recorded using techniques such as differential phase contrast microscopy. We have used off-axis electron holography to characterise the magnetic microstructure of periodic arrays of nanomagnets that were fabricated directly onto Si using interferometric lithography [2] and prepared for TEM examination using focused ion beam milling. Figure 1 shows results obtained from evaporated 100 nm diameter 20 nm thick Co dots arranged in square arrays of side 200 nm. The addition of contours to the magnetic contribution to the measured phase (Fig. 1b) provides a semi-quantitative map of the magnetic fields within the dots and the strength of the interactions between them. Subtraction of the mean inner potential contribution to the measured phase is essential for the successful characterisation of such samples.

Fig. 1. a) Scanning electron micrograph of Co dots; b) Magnetic contribution to measured electron holographic phase for remanent state of Co dots examined in plan-view, obtained at 200 kV using a Philips CM200 field emission gun transmission electron microscope. The contour spacing (0.033 radians) is inversely proportional to the in-plane component of the magnetic induction integrated in the incident beam direction. The microscope was operated in Lorentz mode with the conventional objective lens switched off. Holograms were recorded digitally using acquisition times of 4 s and a biprism voltage of 160 V. Reference holograms were always recorded to take account of artefacts associated with the imaging and recording system.

References:
