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Electron Holography for Developing Advanced Materials and Devices

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Electron holography, which enables us to observe electro-magnetic micro-fields, is currently not only an indispensable technique for studying fundamental physics, but also for developing advanced materials and devices in industry. We have been developing new types of electron holography, such as phase-shifting electron holography [1,2] to obtain higher sensitivity phase measurements, real-time electron holography for dynamic observations [3,4], and electron tomographic holography for the three-dimensional analysis of electro-magnetic micro-fields [5,6]. In addition, we have been trying to use these new types of holography for research and development in the industry [7,8]. In this paper we presents our recent studies on the dipolar ferromagnetism of cobalt nano-particle film and the dopant profiling in a GaAs model sample.

Figures 1(a) and 1(b) show the reconstructed interference micrographs of a 250-nm thick random assembly of Co/CoO clusters at room temperature and at 123 K, respectively [9]. The film consists of Co clusters that are smaller than 10 nm, and each cluster is covered with CoO. No magnetic field can be observed in Fig 1(a), while several magnetic flux lines can be seen in Fig. 1(b), which implies that large-scale ferromagnetic domains are formed at 123 K. This is primarily attributed to the magnetic dipole interaction between Co clusters, because antiferromagnetic CoO surface layers interrupt the exchange coupling between neighboring Co cores.

Figure 2 shows the results from the dopant profiling of a GaAs model sample. This model sample contained both p-region and n-region. The p-region consists of five layers of heavily-doped to lightly-doped regions. In the phase profile, the potential drop between 10^{19} cm^{-3} and 10^{18} cm^{-3} layers or that between 10^{18} cm^{-3} and 10^{17} cm^{-3} layers are clearly distinguished. This type of measurement is useful for developing solid-state laser devices.

In summary, we succeeded in observing dipolar ferromagnetism and the precise dopant profiling of a GaAs model sample. We believe that electron holography, which enables us to observe electro-magnetic nano-fields, will become an increasingly more important technique in the development of advanced materials and devices.

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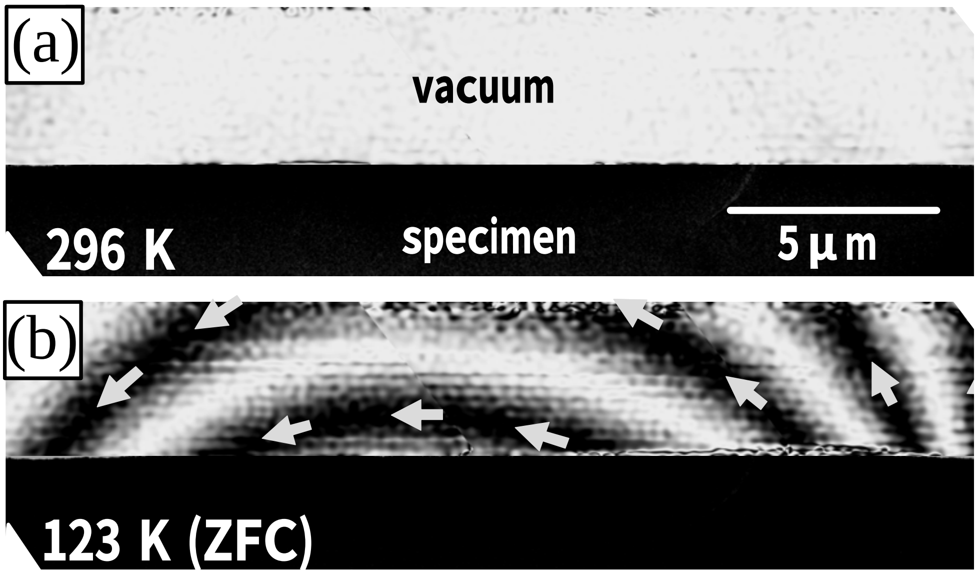

FIG. 1. Reconstructed interference micrograph of 250 nm thick random assembly of Co/CoO clusters at (a) room temperature and (b) 123 K.

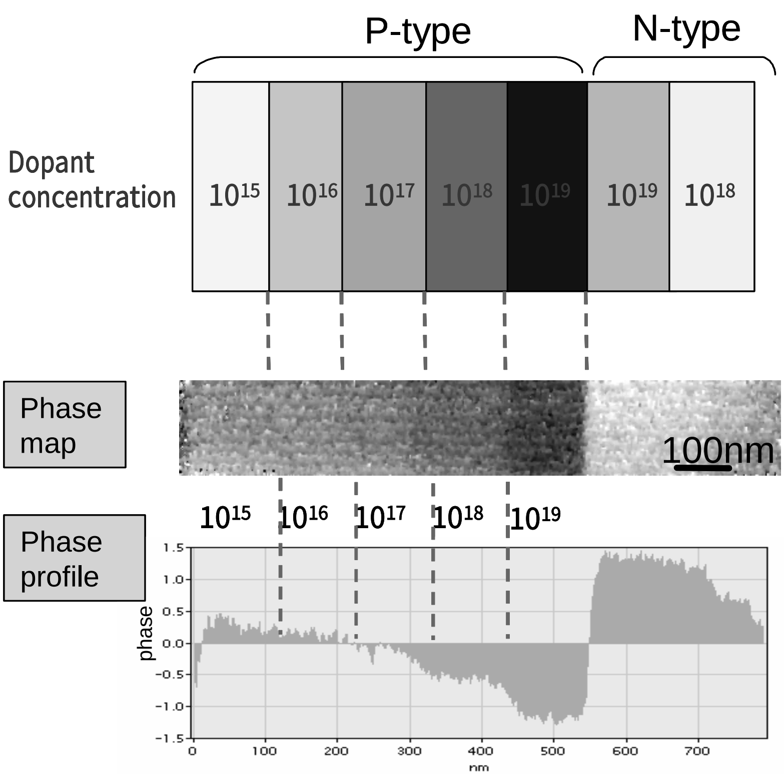

FIG. 2. Dopant profiling in GaAs by electron holography.