GROWTH OF LOW-DIMENSIONAL MAGNETIC NANOSTRUCTURES ON AN INSULATOR

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In well-defined nanostructures, confinement of electrons in less than three dimensions results in magnetic, electronic and transport properties that are dramatically different than those of conventional bulk materials. When studying these characteristics and the correlation between magnetic and transport properties, it is necessary to grow magnetic nanostructures on a common insulating or semiconducting substrate.

We report here on the successful growth and i*n-situ* noncontact atomic force microscopy (NC-AFM), and magneto-optical Kerr effect (MOKE) studies of nanometer-scaled Fe dots, nanowires, and ultrathin films with the same amount of deposited material on the same insulating substrate, a cleaved NaCl(001) surface, under different growth conditions.

Under proper growth conditions, nanometer-scale magnetic iron dots with remarkably narrow size distributions can be achieved in the absence of a wetting layer (Volmer-Weber growth). The lateral size and the height of the dots are several nanometers, and the dispersions of the lateral and vertical size distributions are all less than 10%. Furthermore, both the vertical and lateral sizes of the dots can be tuned with the iron dosage without introducing any apparent size broadening, even though the clustering is clearly in the strong coarsening regime. These striking observations are in clear contradiction with the expectations of existing understanding of clustering on surfaces, but can be interpreted with the development of a phenomenological mean-field elasticity theory, in which a coverage-dependent optimal dot size is selected by the competition between the self-energy of a dot and the energy of the dipolar interaction between the dots.

The Fe wires are formed by nanometer-sized Fe dots, which are aligned along the upper terraces of the step edges of the NaCl(100) surface. The wires are almost parallel to each other, with less than 15 nm spacing. We observe the extension of wires to lengths of several microns. The orientations of the wire arrays are governed by the substrate step directions. The heights and widths of the wires can be controlled by varying the Fe dosages.

The Fe ultrathin films are grown at temperature below 30 K. In general the formation of continuous Fe films on NaCl is hindered by the large difference of the surface free energies between Fe and NaCl. We overcome this obstacle with so called “reentrant layer-by-layer growth” at low temperatures. The resulting film is atomically smooth; the corrugation of the film is of the order of the height of a single atomic step of the substrate.

The magnetic properties of all three nanostructures are investigated and compared.

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