Tailored Magnetic Nanostructures on Surfaces

This highlight briefly describes a project done in collaboration with Dr. Jian Shen (ORNL), involving two University of Tennessee (UT) graduate students, John Pierce and Maria Torija. This project was aimed at novel fabrication of nanoscale magnetic systems, in situ characterization of the physical properties, modeling of the functionality, followed by design of new nanoscale configurations [1-6]. John's thesis (Tailored Magnetic Nanostructures on Surfaces) won him the Fowler-Marion Outstanding Physics Graduate Student Award from the Department of Physics and Astronomy at UT, and Wayne Nottingham Prize from the 2003 Physical Electronics Conference. John also received a Tennessee Advanced Materials Laboratory Fellowship. He is now at Lawrence Livermore National Laboratory as a postdoc.

Here the results of the research on the growth and characterization of magnetic dot arrays is described. Fe dots are deposited using the buffer layer-assisted growth [7] technique, where Xe films are adsorbed on Cu(111) at 15 K followed by evaporation of Fe producing Fe balls on top of the Xe film (Fig. 1). The Xe layer is removed by warming to 300 K leaving a uniform array

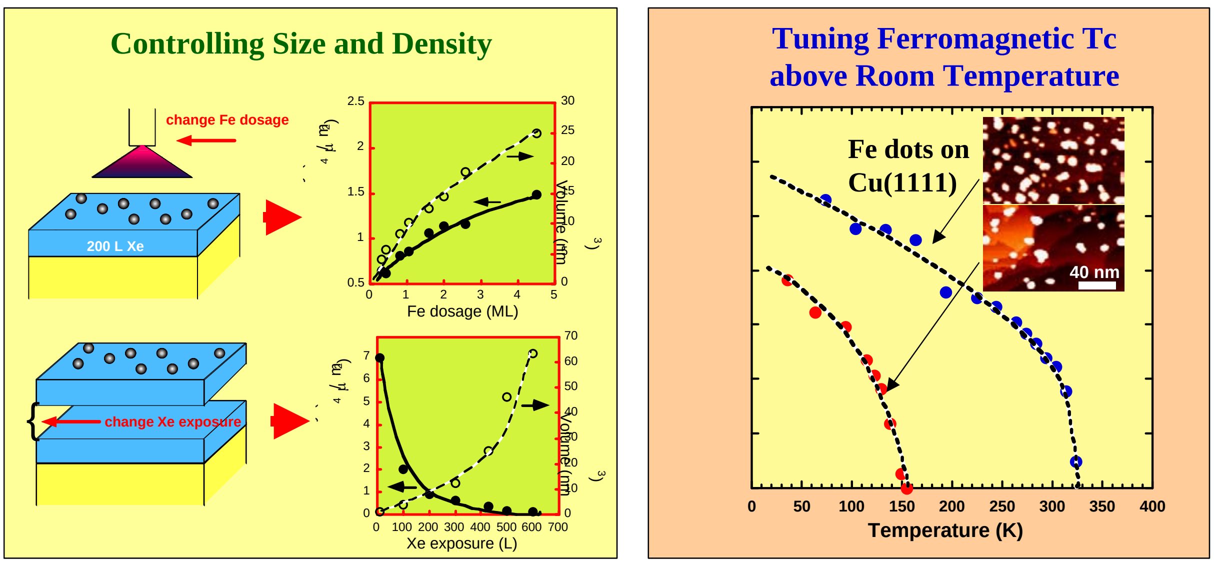

Fig. 1. Figure to left shows buffer layer growth process and control of size and density of dots [6]. The right hand panel shows the magnetization curves for two different Fe dot arrangements on Cu(111). The inserts are the STM images of the ~25 nm^3 size dots with different densities [5].

of Fe dots. Pierce mapped out the size and density of Fe dots as a function of the two parameters in the experiment, Xe film thickness, and the amount of Fe evaporated onto the Xe layer [5]. The top panel on the left of Fig. 6 shows the size and density of Fe dots for a 200 L exposure of Xe as a function of the Fe dosage. The panel below shows the size and density dependence on the Xe exposure for 1 ML Fe. The panel on the right shows the dramatic difference that a factor of 5 in density ($0.3 \rightarrow 1.5 \times 10^4/\mu m^2$) makes in the remanent magnetization (fixed size) as a function of temperature [5]. This observation can't be a result of magnetic anisotropy because the dots are the same size. Therefore the magnetization must result from dot-dot interaction. Dipolar interactions are of the order of 2.5 K, so there must be a strong substrate-mediated, indirect exchange interaction between the dots.

Maria Torija has now made the same measurements on a Cu(001) and Ge(111) substrates. She finds that on average the T_C (obtained from magnetization curves like shown in Fig. 1) is twice as large on Cu(111) as on Cu(001) which is roughly twice as large as Ge(111) for the same size and density of Fe dots (see Fig. 2). It was speculated that the Cu(111) surface states mediate this indirect exchange interaction [5]. The abstract that Maria Torija submitted to this fall's AVS meeting, competing for the Leo Falicov Student Award is being written up as a news release by Ben Stein (Senior Science Writer for the American Institute of Physics).

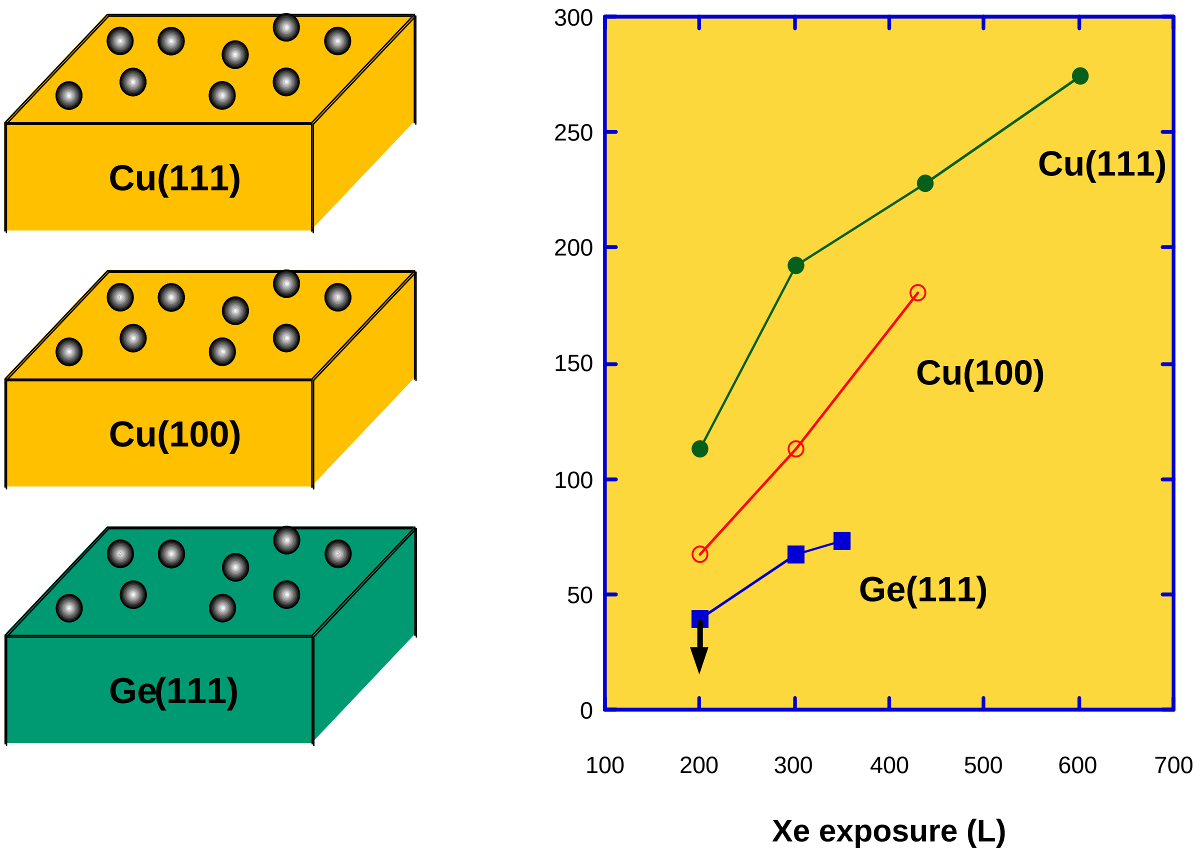

Fig. 2: On left is the schematic drawing of Fe dots on three different substrates. On the right is measured critical temperature for magnetic disorder as a function of the Xe exposure for three different substrates [6]. The Fe nominal thickness is fixes at 1 ML in all cases. The arrow for the Fe'Ge(111) dots (200L Xe) indicates that the T_C is below 40 K.

The review article [1] has been listed as one of the "Top Papers 2003 Showcase," by Journal of Physics: Condensed Matter (http://ej.iop.org/pdf/jpcm_newsletter.pdf)

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