Oriented Quantum Dots By Buffer Layer Growth Process

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Introduction

For both scientific study and technological application, small and uniform quantum dots have advantages. One approach toward this goal is to grow dots on a buffer layer, which is subsequently removed. The buffer layer promotes small 3-dimensional clusters, instead of the extended islands observed after direct deposition. Results from this experiment show for the first time that quantum dots grown by this process can be epitaxially oriented with the substrate. In addition, a new epitaxial alignment between bcc Fe and fcc Cu is reported which has not been observed previously in thin-film and precipitate growth.

Methods and Materials

Growth of quantum dots involved deposition of Fe on a buffer of ~200 layers of condensed Xe which were subsequently removed by heating. In situ scanning tunneling microscopy results reveal formation of 3-D Fe clusters averaging ~10 nm in diameter. An additional ~20 nm thick cap of Cu was deposited over the Fe to allow ex situ x-ray studies at the Advanced Photon Source. The resulting structure is shown in Fig. 1

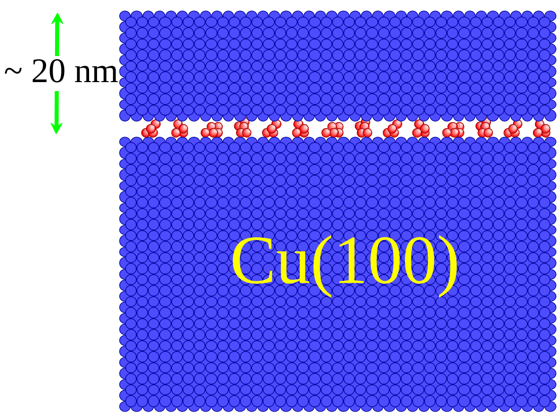

Fig. 1 Schematic illustration of ~1 ML of Fe grown in quantum dots on Cu(100), then capped with additional Cu. The side view is shown, not to scale.

Results and Discussion

The crystal orientation of the Fe clusters was determined using ID9, the newly commissioned beam line built and operated by the Complex Materials Consortium. X rays were used to study the subsurface quantum dots by selecting diffraction conditions met by Fe but not by Cu. As shown in Fig. 2, rotating the sample under conditions for Fe(200) diffraction produces sharp x-ray peaks aligned at 0° and ±35.3°, with respect to the substrate.

These results show that Fe dots are oriented with the close-packed Fe(110) direction normal to the Cu surface and with two possible in-plane rotational orientations, which are shown in Fig. 3. On the left of Fig. 3 is the Pitsch orientation,[1] first identified in 1958 and observed in thin-film and precipitate growth of Fe on or in Cu. The second is a new orientation not previously observed. This new alignment occurs because the buffer layer growth process bypasses the intermediate fcc Fe phase present when Fe clusters grow in direct contact with Cu.

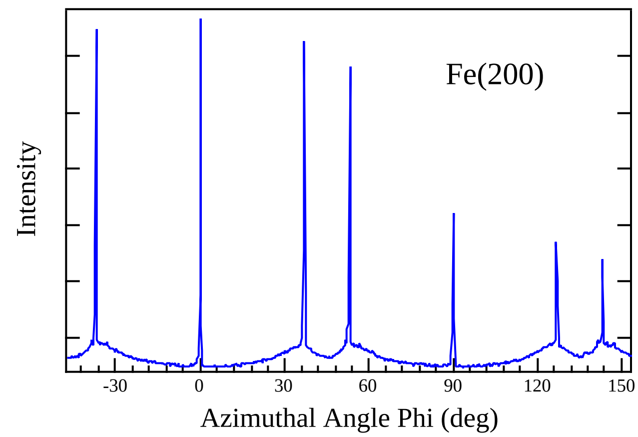

Fig. 2 X-ray diffraction intensity as the sample azimuth is rotated with the incident and detector angles positioned for Fe(200) diffraction. Sharp peaks indicate quantum dots are highly oriented.

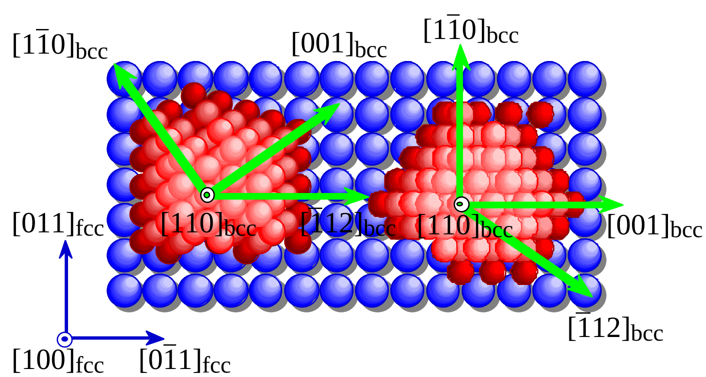

Fig. 3 Ball models of the two Fe quantum dot orientations observed. The left cluster is in the Pitsch orientation. The right cluster, rotated 35.3°, is a new orientation.

Acknowledgments

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References

[1] W. Pitsch, "The Martensitic Transformation in Thin Foils of Iron-Nitrogen Alloys" Philos. Mag. 4, 577 (1959).