Quantum Well States and Oscillatory Magnetic Anisotropy in Ultrathin Fe Films

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In dimensionally reduced magnetic systems, such as ultrathin films, electrons can be confined perpendicular to the film plane and form quantum well states (QWS). The formation of QWS can directly alternate the electronic structure at the Fermi level and therefore result in oscillatory physical properties such as magnetic anisotropy.

In thin films grown on stepped surfaces, magnetic anisotropy can be modified in comparison to the anisotropy of films grown on atomically flat surfaces. Such a modification is often described as an additional uniaxial anisotropy with the easy magnetization axis in the film plane oriented along or perpendicular to the step direction.

I will report on large amplitude quantum oscillations of such uniaxial magnetic anisotropy in Fe films grown on Ag vicinal surfaces of high step density. I will show that the magnetic anisotropy, and easy magnetization axis, oscillates as a function of film thickness. For the Fe/Ag(1,1,6) system, at low temperatures, the anisotropy clearly oscillates with Fe thickness with a period of 5.9 ML, which is exactly the same as observed for the Fe films grown on Ag(1,1,10). This is natural since there is the same ultrathin film of Fe, grown on the same Ag(001) substrate. The oscillation amplitude, however, depends on how much the anisotropy in the film volume is modified by the steps and scales quadratically with the step density.

There are no theoretical calculations available to which we can compare our experimental results for Fe films on Ag(001) surfaces. The only available theory predicts oscillations of the magnetocrystalline anisotropy energy as a function of film thickness for fcc Co films on Cu(001). These predictions, made nearly 15 years ago, have so far not been confirmed experimentally.