Spin-resolved electronic structure studies of ultrathin films of Fe on GaAs

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To understand and improve the magnetic properties of ultrathin Fe films on GaAs has been the aim of many research groups over recent years. The interest in this system has both technological and fundamental scientific motivations. Technologically, Fe on GaAs may serve to realize spin electronic devices, which make use of both the spin and the charge of electrons injected through metallic overlayers into the semiconducting substrates. From a fundamental science point of view, Fe on GaAs serves as a prototype for studies of the interplay between the crystalline structure and morphology of an ultrathin film, its electronic structure and the long range magnetic order it exhibits.

In contrast to the attention given to Fe on variously prepared GaAs substrates, the magnetism of Fe on vicinal GaAs substrates has received scant attention. This in spite of the fact that films grown on vicinal substrates present a number of advantages and opportunities. For example, they are known to exhibit enhanced structural homogeneity, surface diffusion tends to follow well mapped patterns (the quasi-periodicity has been exploited to produce quantum wires) and there is an additional degree of control of the film growth beyond those associated with temperature and substrate surface composition.[1]

In a preliminary combined spin-polarized secondary electron spectroscopy, photoelectron spectroscopy and LEED study (carried out on the SRS, Daresbury Laboratory) of the remanent magnetic properties of Fe on singular and vicinal (3° offset) GaAs we have shown both that the various magnetic phases formed are dependant upon the Ga to As surface composition of the substrate and that they evolve in characteristic (but not well understood) ways with Fe overlayer thickness.[2,3] A remarkable feature in this system, which illustrates the importance of the Fe overlayer/substrate interaction, is the magnetic anisotropy; the easy axis of the Fe films on Ga-terminated substrates is perpendicular to that for As-terminated substrates.[4,5]

These measurements were followed up with combined spin-resolved photoemission and magnetic linear dichroism experiments on Fe deposited on vicinal (offcut by 3º and 6º) or singular GaAs substrates on Beamline 7 at the ALS. The GaAs(100) substrates were available for film deposition at room temperature after substrate decapping *in-situ* (by thermal annealing). By mounting both singular and vicinal GaAs substrates on the same sample tile the same growth conditions applied for both films facilitating direct comparison. The surface quality was monitored using LEED. The following data were obtained:

- High resolution spin-integrated valence bands.
- The spin-resolved valence bands and their energy dispersion.
- The film thickness dependence of the spin-resolved valence bands.
- Magnetic linear dichroism data on the Fe3p and Fe2p core levels at a variety of photon energies.

The experimental results, which were obtained in November 2000, have not yet been analysed fully but it is already clear that the data challenge much received wisdom concerning the spin-resolved electronic structure of this system.

The significant differences in the spin-resolved valence bands between *ca*. 20 Å thick Fe films on singular and vicinal (3º) GaAs are illustrated in Fig.1. As the terrace width is *ca*. 55 Å the spectral differences are not due to step-localized features.

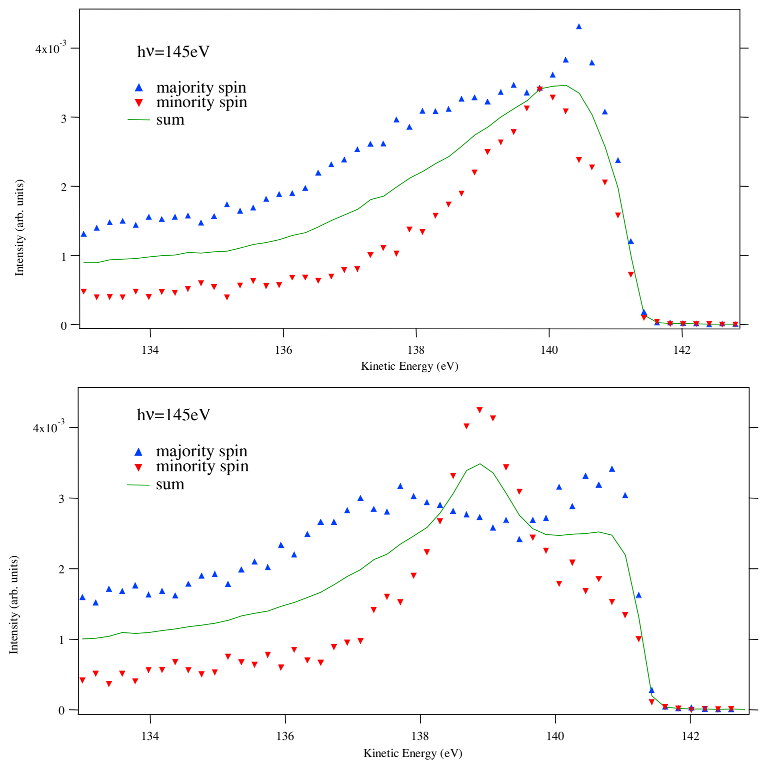

Figure 1. Spin-resolved valence band photoemission results for (A) Fe on singular GaAs and (B) Fe on vicinal (3º) GaAs.

Other results include:

- At low film thicknesses, Fe deposited on singular substrates has a lower Curie temperature than Fe films on vicinal substrates.
- Fe deposited on singular substrates reveals a larger energy dispersion of the spin-resolved valence bands than Fe on vicinal substrates.
- Only marginal differences can be seen between the spin-resolved valence bands of Fe deposited on 3º stepped GaAs substrates and Fe deposited on 6º stepped GaAs substrates.
- In contrast to the valence band studies, the linear magnetic dichroism results obtained for these samples are very similar.

The samples prepared and measured during the run at the ALS were capped with Au and are currently being structurally characterized by X-ray diffraction measurements. They will then undergo analysis by cross sectional TEM. This may help resolve whether different substrates induce different crystalline structures of the Fe films.[6] Additionally, we are carrying out *ex situ* magnetization measurements by MOKE and VSM.

In summary, the experiments have been extremely rewarding. They have answered some questions, clarified our thinking on others and raised yet other questions for which we have no answers at the moment.

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