Structural Characteristics of Fe_3Si Epitaxial Magnetic Films on GaAs(001)

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Fe_3Si is a ferromagnet with a T_c of 840K, and it can be regarded as a Heusler alloy with a composition of Fe_2FeSi. There is good possibility that Fe_3Si is a half metal which is an ideal candidate for spin injection, since some of the Heusler alloys are predicted to be 100% spin polarized. In this worlk, high-resolution x-ray diffraction measurements were made on our films using synchrotron radiations at NSRRC BL17A, BL17B, and SP12B2 beam lines.

The epitaxial film growth was carried out in a multi-chamber MBE system, which includes a solid source III-IV MBE chamber and a metal deposition chamber. Fe_3Si film was grown at 150 ºC first to minimize the interface reactions, then the sample was heated up to 250 ºC to achieve high quality epitaxial film. The epitaxial orientation between Fe_3Si and GaAs was determined by RHEED and later confirmed by X-ray diffraction. A sequence of RHEED patterns taken during the MBE growth of Fe_3Si along [110] and [100] directions were shown in Figure 1. The presence of Kikuchi arcs indicated a high quality crystal surface.

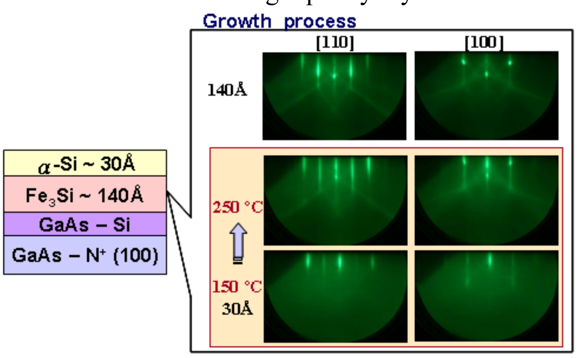
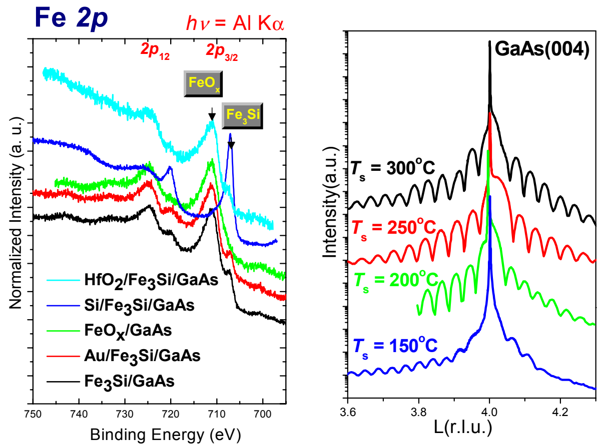


Figure 1. RHEED patterns of Fe_3Si grown on GaAs surface along [110] and [100] directions

Figure 2 (a) shows XPS Fe 2p spectrum of FeO_x and Fe_3Si films which were coated with different materials. It was obtained that the Fe 2p spectrums of Fe_3Si/GaAs, Au/Fe_3Si/GaAs and HfO_2/Fe_3Si/GaAs were almost the same with the spectrum of iron oxide except the peak at 707eV. This is evidence indicating that the signal of 711eV came from iron oxide and the signal of 707eV came from iron silicide. From the energy spectrum of Fe_3Si film capped with amorphous Si, we have obtained that there was almost no signal of iron oxide and the peak at 707eV increased in evidence. The additional broad lobe at 725 eV due to the plasmon loss feature of Fe 2p, and the phenomenon is similar to iorn silicide. The XPS analysis suggests that the amorphous Si may be a good candidate for protecting Fe_3Si surface from oxidized.

X-ray diffraction measurements using synchrotron radiation in 8-circle x-ray diffractometer on the Fe_3Si films gave a rocking curve of about 0.014º. Figure 2 (b) showed the scattering profiles of the (004) reflections of the films grown with different subtract temperature. It indicated that the quality of epitaxital films related to the growth temperature, and the best temperature was about 200~300 ºC in this case.



(a) (b)

Figure 2. (a) XPS Fe 2p spectrum of FeO_x and Fe_3Si films coated with different materials. (b) X-ray diffraction profiles of Fe_3Si films with different growth temperature.

Furthermore, by changing the energy of incident x-ray beam from 10keV to 12.38keV at SP12B2 beam line, we were able to separate Fe_3Si (006) and GaAs (006) reflections easily. Longitudinal scans along the collinear direction of GaAs (006) peak indicted a tetragonal distortion of the films from their cubic lattice due to a -0.5% lattice mismatch between Fe_3Si and GaAs (Figure 3). The Fe_3Si films are almost lattice matched to GaAs, and we can control the chemical composition to obtain perfectly lattice-matched material.

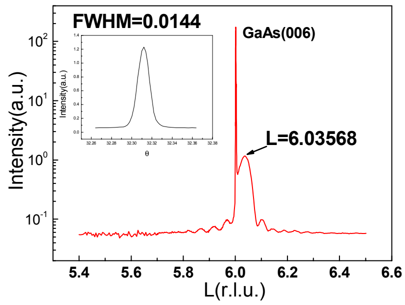


Figure 3. By using the SP12B2 beam line, we were able to separate Fe_3Si (006) and GaAs (006) reflections easily.