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In situ Observation of Fe growth on GaAs(001) and InAs(001) by X-ray diffraction

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1. Introduction

Recently, the heterostructure of semiconductor and ferromagnetic metal has attracted much attention for its potential applications to electromagnetic devices. Iron of GaAs(001) is one of the most intensively studied systems because the lattice constant of bcc Fe is close to half that of GaAs (001), so that low-misfit epitaxy is expected. The lattice mismatch between Fe and GaAs is as small as 1.4 %. In fact, several authors have reported that single crystal Fe grows on GaAs (001) in an epitaxial relationship of Fe(001)<100>||GaAs(001)<100> [1]. Moreover, epitaxial growth of Fe on InAs(001) has also been reported [2]. However, detail of the Fe thin film structures have not been clear yet. In this work, we performed in situ X-ray diffraction study of Fe films grown on GaAs (001) and InAs (001) by molecular beam epitaxy (MBE).

2. Experimental

Experiments were carried out using a MBE system combined with a six-circle diffractometer at BL11XU beamline of SPring-8 synchrotron facility [3]. A 100-nm-thick buffer layer was grown on GaAs(001) at 550 ºC after removing native oxide layer. After the GaAs(001)-2×4 reconstructed surface was prepared by annealing at 540 ºC with As flux of 3×10^{-4} Pa, the substrate was quenched to room temperature without As flux to keep this reconstructed surface. The InAs(001)-4×2 reconstructed surface were prepared by annealing under background pressure below 7×10^{-7} Pa after removing native oxide layer. X-rays with a wavelength of 0.124 nm were impinged on the GaAs(001) and InAs(001) substrate at the glancing angle of 0.23˚ and 0.29˚, respectively. A series of in-plane reciprocal space mappings (RSMs) in the vicinity of the GaAs and InAs 040 diffraction were measured with increasing Fe thickness. During growth, the background pressure was kept below 1×10^{-6} Pa to avoid the reaction of Fe with As in the environment.

3. Results and discussion

Figure 1(a) shows RSM of Fe/InAs(001) for Fe thickness of 0, 6 and 20 monolayers (ML). A diffraction peak corresponding to Fe 020 comes up at a Fe thickness of 6 ML. The Fe peak was found to broaden in [100]. The peak is located at K=4.15, indicating that the Fe film is under the tensile strain. For Fe/GaAs(001), the Fe 020 peak was observed from a thickness of 4 ML as shown in Fig 1(b). A careful inspection of the RSMs revealed that another peak develops around GaAs 040. This extra peak is identified as $2\bar{2}\bar{2}$ diffraction of the hexagonal pseudo-cubic compound, $Fe_3Ga_{2-x}As_x$ [4,5], which shows epitaxial orientation of $(1\bar{2}0)Fe_3Ga_{2-x}As_x||(220)GaAs$ and $(10\bar{2})Fe_3Ga_{2-x}As_x||(\bar{2}20)GaAs$ [6].

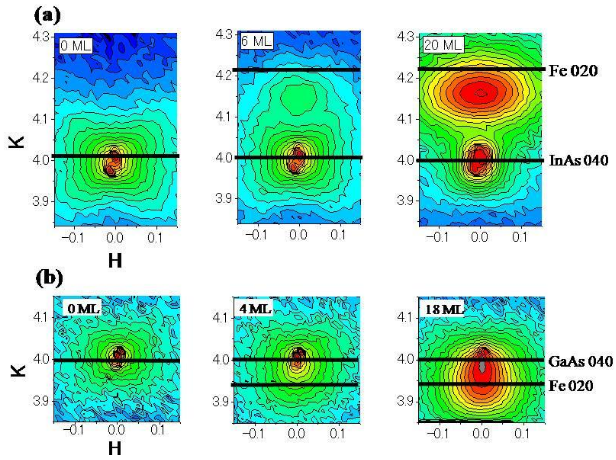

Fig. 1. Reciprocal space maps of InAs(a) and GaAs(b) 040 diffraction at varying Fe thickness.

Figure 2 shows changes of the in-plane lattice constant of Fe on GaAs(001) and InAs(001) as a function of the Fe thickness. While the Fe film on InAs(001) is strained even at 30 ML, Fe on GaAs(001) is fully relaxed at 4 ML. This suggests that interfacial $Fe_3Ga_{2-x}As_x$ on GaAs(001) facilitate the strain relief of Fe/GaAs(001).

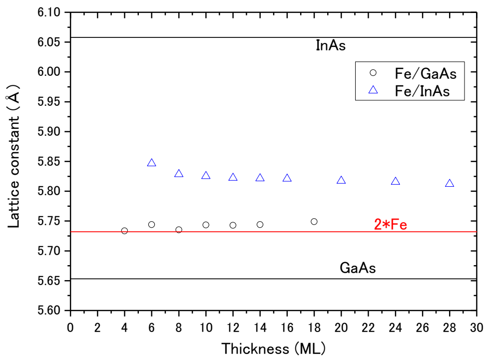

Fig. 2. Changes in lattice constant of Fe/GaAs(001) and Fe/InAs(001) along [010] direction as a function of Fe thickness.

Figure 3 shows the changes in integrated intensity of the 020 diffraction of Fe on GaAs(001), the $2\bar{2}\bar{2}$ diffraction of $Fe_3Ga_{2-x}As_x$ on GaAs(001) and the 020 diffraction of Fe on InAs(001) as a function of the Fe thickness. While the increase of $Fe_3Ga_{2-x}As_x$ $2\bar{2}\bar{2}$ intensity shows down at 12 ML, The intensity of Fe 020 increasingly rises. For Fe 020 on InAs(001), a similar increase in intensity is observed at 16 ML.

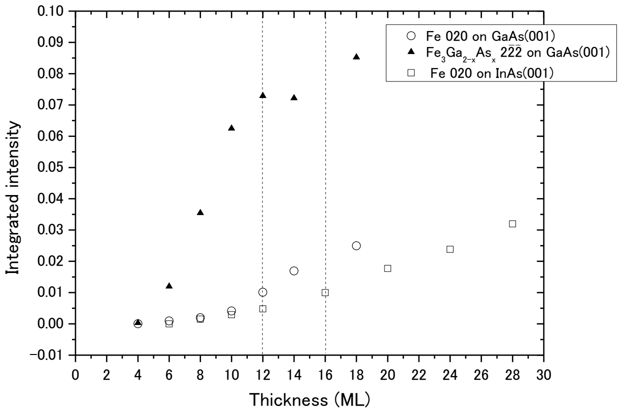

Fig. 3 the changes in the integrated intensity of the 020 diffraction of Fe on GaAs(001), the $2\bar{2}\bar{2}$ diffraction of $Fe_3Ga_{2-x}As_x$ on GaAs(001) and the 020 diffraction of Fe on InAs(001) as a function of the Fe thickness.

4. Summary

We evaluated Fe films on GaAs(001) and InAs(001) by in-situ X-ray diffraction measurements with increasing Fe thickness. Until the Fe thickness reaches 4 and 6 ML, diffraction from Fe was not observed on GaAs(001) and InAs(001), respectively. While the Fe film on InAs(001) was strained even at 30 ML, Fe on GaAs(001) was already relaxed at 4 ML. The integrated intensity of the 020 diffraction of Fe on GaAs(001) and InAs(001) increased rapidly above 12 ML and 16 ML, respectively.

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