# Structure and magnetic properties of Fe-As films grown on GaAs (111)B substrates

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Iron(Fe)-arsenide(As) compounds are interesting materials, which potentially host a wide spectrum of quantum states such as ferromagnetism with half-metallic properties in the zinc-blende structure[1] and superconductivity in the layer-structure iron-based superconductors[2]. However, the Fe-As films grown on the GaAs (001) plane usually possess the same crystal structure as the equilibrium states ($Fe_2As$, $FeAs_2$ and FeAs)[3,4], which are anti-ferromagnetic. In this study, we grow Fe-As films on GaAs (111)B substrates, which have a three-fold symmetry, under various Fe/$As_4$ flux ratios, and investigate their crystal structures and magnetic properties.

We grew GaAs (100 nm) / Fe-As (28 ~ 40 nm) on GaAs (111)B substrates at substrate temperature ($T_S$) = 280 - 330° C by molecular beam epitaxy (MBE). The $As_4$/Fe flux ratio $\gamma$ was controlled by the beam equivalent pressure values measured with a beam flux monitor. Figure 1 shows X-ray diffraction (XRD, $\omega$–$2\theta$ scan) data for three samples A, B, C with $\gamma$ = 0 (only Fe), 0.3, 4, respectively. Comparing with the Fe layer grown with no $As_4$ flux (sample A), sample B with $\gamma$ = 0.3 exhibits XRD peaks indicating a similar BCC structure (the only difference is a $Fe_3Ga$ peak is observed in sample A but absent in sample B). Indeed, scanning transmission electron microscopy (STEM) images reveal a BCC structure without any second phase in the Fe-As layer and an atomically flat interface between the Fe-As layer and the GaAs buffer in sample B, as shown in Figure 2(a). In sample C with higher $As_4$ flux ($\gamma$ = 4), there is a top layer which contains domains with two different crystalline structures observed at different locations on top of a 5 - 10 nm-thick dislocation-rich intermediate layer (Fig. 2(b) and (c)). This intermediate layer has a hexagonal structure and an elemental composition Fe:Ga:As ratio = 66:5:29, estimated by energy dispersive X-ray spectroscopy (EDX), suggesting a $Fe_3Ga_{2-x}As_x$ layer with $x$ = 1.74 (generally in bulk $Fe_3Ga_{2-x}As_x$, 0.875 < $x$ < 1.125[5]). Meanwhile, domains in the top layer have FCC- (Fig. 2(b)) and BCC-like (Fig. 2(c)) crystal structures. The Fe:Ga:As ratio = 61:5:34 in the top layer of Fig 2(c). These crystal structure does not match with any compounds of Fe-Ga-As in previous reports. Sample A and B showed similar magnetic properties with very high Currie temperature ($T_C$ > 400 K) and strong in-plane anisotropy, while sample C also showed ferromagnetism but a much lower $T_C$ = 390 K. The results of our work suggest that Fe-As compounds on GaAs (111)B are promising for practical spintronic applications such as spin injection and spin transport in ferromagnet/semiconductor heterostructures.

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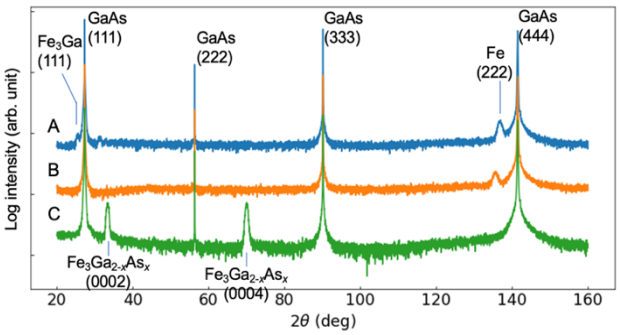


Figure 1. $\omega$ -$2\theta$ XRD data for different Fe-As films grown without As flux (sample A, $\gamma$ = 0) at substrate temperature ($T_S$) = 280°C, with $\gamma$ = 0.3 at $Ts$ = 330°C (sample B), and with $\gamma$ = 4 at $Ts$ = 330°C (sample C).

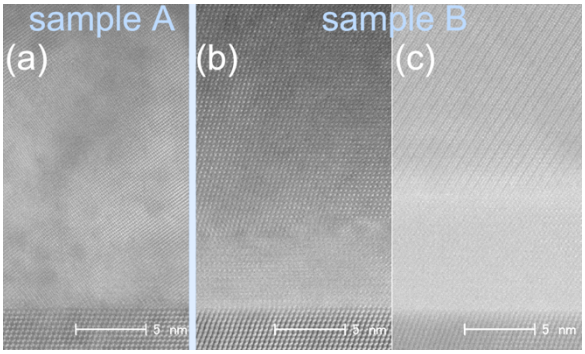


Figure 2 STEM image of the interface between the Fe-As layer and the GaAs buffer in the sample grown with (a) γ = 0.3 (sample B), (b) (c) γ = 4 (sample C). (b) and (c) show different positions of sample C.

## References

[1] T. Fukushima *et al*. Appl. Phys. Express **12**, 063006 (2019). [2] H. Takahashi., *et al*. Nature **453**, 376 (2008). [3] A. T. M. K. Jamil, *et al*. Thin Solid Films, **516**(10), 3015 (2008). [4] H. Okamoto. J. Phas.e Equilib., **12**(4), 57 (1991). [5] I. R. Harris, *et al*. J. Less- Common Met., **146**(C), 103 (1989).