Fabrication of fully epitaxial $Co_2Fe(Ga,Ge)$/Ge/CoFe trilayer structures

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1. Introduction

A vertical structure consisting of F/SC/F, where F is a ferromagnetic material and SC is a semiconductor, has attracted much interest for novel semiconductor-based spintronic devices, such as a vertical-type spin transistor or magnetoresistive devices, similar to magnetic tunnel junction or giant magnetoresistance (GMR) devices. However, it is not easy to fabricate a single crystalline semiconductor material on a ferromagnetic metal, there has been very few reports on the fabrication of such structures: Fe_3Si/Ge/CoFe [1] and Co_2FeSi/Ge/Co_2Fe/Si [2]. Recently, relatively high MR ratios of 82% at room temperature was reported in $Co_2Fe(Ga,Ge)$ (CFGG)–based GMR device [3], indicating that CFGG is a highly spin-polarized ferromagnetic material. Given these background, the purpose of the present study is to fabricate a fully epitaxial CFGG/Ge/CoFe trilayer structure.

2. Experimental method

A vertically stacked structure consisting of (from substrate side) CFGG (30 nm)/Ge (5 nm)/CoFe (8 nm) was grown by magnetron sputtering on a MgO-buffered MgO(001) substrate. A CFGG layer was grown at room temperature (RT) and subsequently annealed *in situ* at 550 ℃. Then, a Ge layer was grown at various temperatures ranging from RT to 400℃. After cooling the substrate down to RT, a CoFe layer was grown on the Ge layer. The structural property of CFGG/Ge/CoFe trilayer was evaluated by reflection high energy electron diffraction (RHEED), and the magnetic properties of top CoFe was characterized by magneto optical Kerr effect (MOKE) measurement.

3. Results and Discussion

A clear streak RHEED pattern was observed for the CFGG layer annealed at 550℃ (*not shown*). Figure 1 shows RHEED patterns of the Ge layer grown on CFGG at different growth temperatures (T_{sub}). With increasing T_{sub}, the crystalline quality of Ge was gradually improved. At T_{sub} lower than 300℃, the halo pattern was observed, indicating that the Ge is amorphous. At T_{sub} = 400℃, on the other hand, a clear streak pattern was observed [Fig. 1(d)], indicating that the Ge is epitaxially grown on CFGG and is single crystalline. Moreover, top CoFe was also epitaxially grown on the Ge with T_{sub} = 400℃, and showed clear ferromagnetic property, as shown in Fig. 2.

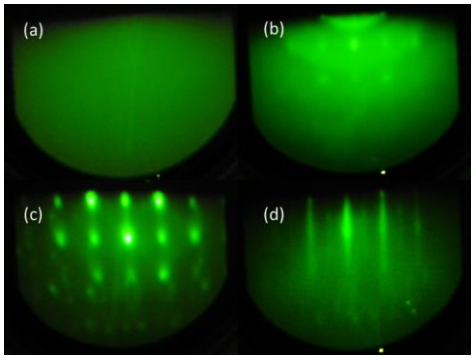

Fig. 1. RHEED observation of Ge grown at (a) RT, (b) 300℃, (c) 350℃, and (d) 400℃.

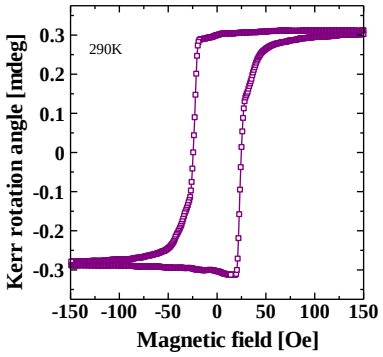

Fig. 2. MOKE signal for CFGG/Ge/CoFe trilayer with T_{sub} = 400℃.

Reference

[1] M. Ikawa et al., J. Cryst. Growth **468**, 676 (2017).
[2] M. Kawano et al., J. Appl. Phys. **119**, 045302 (2016).
[3] J. W. Jung et al., Appl. Phys. Lett. **108**, 102408 (2016).