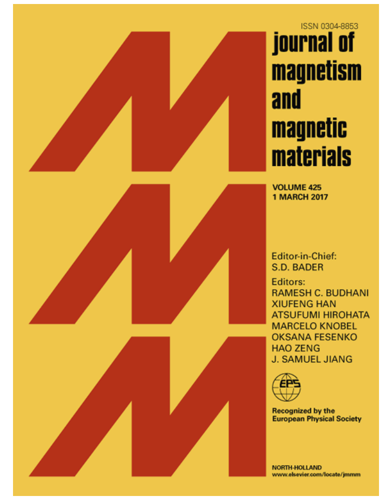

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Heusler Alloys with bcc Tungsten Seed Layers for GMR Junctions

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Abstract

We demonstrate that polycrystalline Co_2FeSi Heusler alloys films can be grown with perpendicular anisotropy without the use of an MgO interface. By heating the substrate to 400 °C prior to deposition and using a tungsten seed layer perpendicular anisotropy is induced in the Heusler layer. This is maintained as the thickness of the Co_2FeSi is increased up to 12.5 nm. The layers with thickness dependent coercivity can be implemented into a giant magnetoresistance structure leading to spin-valve behaviour without the need for an exchange biased pinned layer.

Keywords

- Heusler Alloys
- Perpendicular Anisotropy
- Spintronics
- Spin-valves

1. Introduction

The advancement of spintronic devices requires the further minimisation of device dimensions and signal outputs while reducing device power consumption and heating via reduction of the resistance area product RA[1–4]. This is especially true in the instance of magnetic tunnel junctions (MTJs) where the tunnelling barrier is an insulator and therefore R is unavoidably high. The solution is to transfer back to giant magnetoresistive (GMR) devices with low R but these devices have a far lower signal-to-noise ratio (SNR) due to a smaller GMR ratio compared to a tunnelling magnetoresistance (TMR) ratio [1, 2, 5]. Another obstacle is the implementation of perpendicular magnetic anisotropy (PMA) in junctions which has been realised by the insertion of the MgO layer, where hybridisation of the O-p orbitals with neighbouring layers generates the PMA in MTJs [6, 7].

Heusler alloys have attracted attention in spintronics due to high Curie temperatures and predicted 100% spin polarisations [2, 8–13]. Since TMR and GMR are spin dependent phenomena the Heusler alloys allow for potentially infinite MR ratios and are hence exceedingly attractive. These alloys are, however, cubic and as such possess little magnetocrystalline anisotropy [12]. Therefore thin films have anisotropy in-plane which is non-ideal for the latest applications. This could be overcome as in conventional MTJs by using an MgO/Co-based Heusler interface but this is contradictory to the low RA target [7]. Instead crystallographic manipulation can be implemented via seed layers. If sufficient strain is induced in the Heusler alloy then PMA can be achieved without an MgO layer. Additionally interfaces with heavy metals have been found to induce strong anisotropy in ferromegnetic layers, however the origins of this are largely unknown [14, 15]. Therefore GMR devices with Heusler alloys with PMA can be a strong competitor for MTJs.

Previous work has shown that a vanadium seed layer can induce PMA in Co_2FeSi. Furthermore a second vanadium interface can maximise this effect leading to a film with a weak but dominant PMA [16]. In this work we have used a tungsten seed layer for Co_2FeSi layers of increasing thickness. Deposition on heated substrates has been used to crystallise the films. The films have been characterised crystallographiically and magnetically to investigate the magnetic anisotropy. The optimised condition has then been implemented into GMR multilayers and further characterised. Co_2FeSi was used as the ferromagnetic Heusler alloy due to a saturation magnetisation M_S of 1200 emu/cm^3 and a Curie temperature T_C of 1100 K and to easily compare to the anisotropy induced with a V seed layer [12, 16, 17].

2. Materials and Methods

Samples were deposited on Si(001) substrates using a PlasmaQuest High Target Utilisation Sputtering system (HiTUS) with a bias voltage of −900 V and a process pressure of 1.86 mTorr in order to maximise grain volume [18]. Prior to deposition the native SiO_2 layer was removed by exposure to the plasma. Substrates were heated to a temperature of 400 °C in order to encourage crystallisation of the Heusler alloy [7, 19–21]. Tungsten was chosen as a seed layer for the Heusler alloy due to

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