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Low-temperature growth of $L2_1$ -ordered Co_2MnSi layers on sputtered $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ [☆]

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ABSTRACT

Germanium–Tin (GeSn) alloys have a significant potential as next-generation electronic materials in the field of semiconductor technologies. In this study, to integrate spintronic technologies with next-generation semiconductor ones, we explore low-temperature growth of half-metallic Co_2MnSi layers on sputtered $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ with an insertion of a ~ 100 -nm-thick Ge buffer layer on Si(111) substrates by molecular beam epitaxy. The surface roughness of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ layer derived from a large mismatch of $\sim 5\%$ between $\text{Ge}_{0.95}\text{Sn}_{0.05}$ and Si is significantly decreased by Catalyst Referred Etching with ruthenium, leading to a sufficiently flat $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface. As a result, on top of the flat $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface, an $L2_1$ -ordered Co_2MnSi layer is obtained at less than 80°C with an insertion of a ~ 1 -nm-thick Fe layer. Because of the low-growth temperature, atomic interdiffusion between Co_2MnSi and $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ and the surface segregation of Sn in the $\text{Ge}_{0.95}\text{Sn}_{0.05}$ layer are suppressed. This study will pave the way toward the integration of high-performance spintronic technologies with group-IV semiconductor-based photonic and/or electronic devices on a Si platform.

1. Introduction

Toward the realization of a sustainable society, the development of innovative advanced technologies has been progressed in various research fields [1–6]. Spintronics, which utilizes both electronic charge and spin as carriers, is expected to offer several advantages over traditional electronic devices in terms of non-volatile memory, ultra-low power consumption, high-speed switching, increased integration density, and so on [1–3]. To integrate spintronic technologies to semiconductor ones, many studies on semiconductor-based spintronic devices such as spin-based light emitting diodes (spin-LEDs) and spin-based field-effect transistors (spin-FETs) have so far been reported in theory and experiment for various applications in life sciences, encrypted communications, and next-generation information systems [1–4,7–19]. Among semiconductor materials, Germanium–tin (GeSn) alloys have recently attracted significant attention because the band structure transitions from an indirect to a direct band gap by incorporating a few percent of Sn into Ge [20], enabling efficient light emission even on a silicon (Si) platform [21–23]. A recent study has reported laser emission from GeSn-based devices at liquid nitrogen temperatures [24], further

highlighting its optoelectronic potential. In addition, GeSn alloys can be expected to exhibit high carrier mobility [25], making them attractive for next-generation electronic materials. GeSn layers have been typically grown by chemical vapor deposition, but thin-film fabrication for GeSn layers by using sputtering has also been studied [26–28]. These features of GeSn make it a promising material for integrating spintronic technologies with photonic and/or electronic devices on a Si platform [29,30].

In general, to integrate spintronic technologies with semiconductors, it is essential to form high-quality spintronic materials on semiconductors [16,17]. For high-performance spintronic materials, we have focused on Co-based ferromagnetic Heusler compounds such as Co_2MnSi [31–33] and $\text{Co}_2\text{FeAl}_{1-x}\text{Si}_x$ [34–36] because of their high spin polarization (half-metal) and high Curie temperature. Up to now, a number of high-performance Co-based Heusler compounds have already been reported as ferromagnetic electrodes in various spintronic devices [16,17,33,35,36]. In our group, we have developed growth techniques of Co-based Heusler compounds on Ge(111) by molecular beam epitaxy (MBE) [16,17,37,38]. We have also achieved electrical

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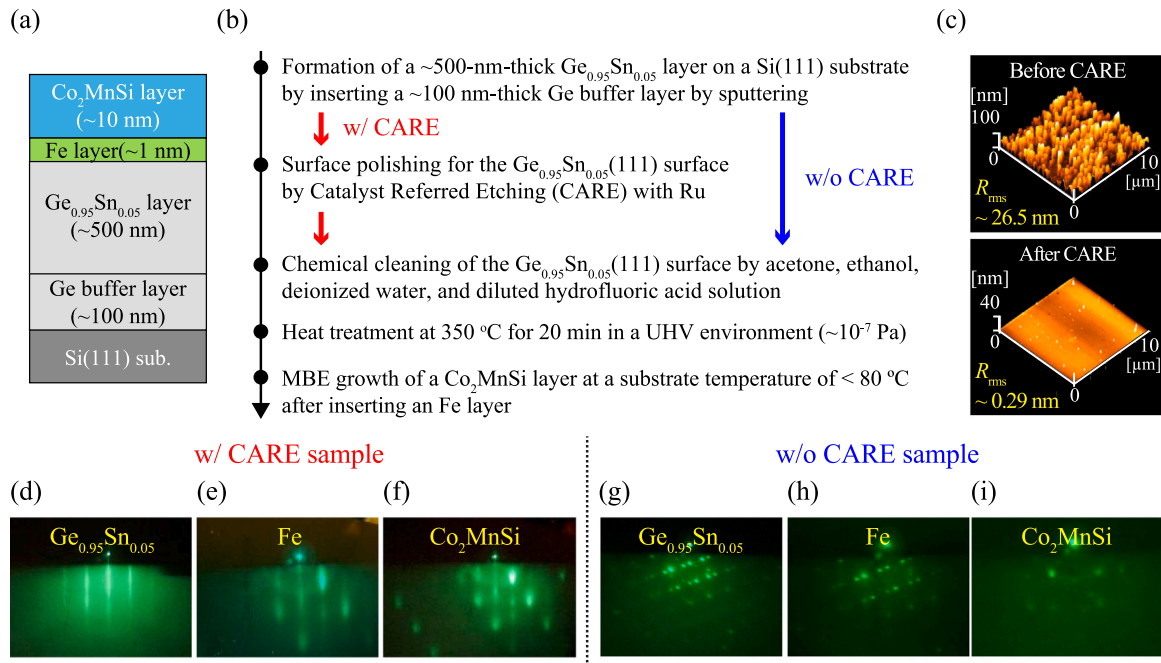


Fig. 1. (a) Schematic of a fabricated heterostructure and (b) process flow for the growth of Co_2MnSi on $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ in this study. (c) AFM images for the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface before and after surface polishing by CARE with Ru. [(d)–(i)]. RHEED images of the surface for $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ and Co_2MnSi layers for w/ CARE and w/o CARE samples.

spin injection and detection in Ge using lateral-type [16,17,38–40] and vertical-type spin-valve devices [41] with Co-based Heusler compound electrodes. At the present time, while the progress of semiconductor spintronic devices with Co-based Heusler compounds has been made on GaAs [13,36] and Ge [16,17,41], there has been almost no studies on the growth of Co-based Heusler compounds on GeSn alloys.

In this study, we explore low-temperature growth of half-metallic Co_2MnSi layers on sputtered $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ with an insertion of a ~100-nm-thick Ge buffer layer on Si(111) substrates by MBE. Although the surface roughness of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ layer is large due to a large mismatch of ~5 % between $\text{Ge}_{0.95}\text{Sn}_{0.05}$ and Si, the use of Catalyst Referred Etching (CARE) with ruthenium (Ru) [42–44] enables to obtain a sufficiently flat $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface. Here the CARE method selectively etches protrusions of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface by utilizing the catalytic reaction between Ge and Ru [43]. As a result, on top of the flat $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface, an $L2_1$ -ordered Co_2MnSi layer can be epitaxially grown at less than 80 °C with an insertion of ~1-nm-thick Fe layer. Owing to the low-temperature growth, atomic interdiffusion between Co_2MnSi and $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ and the surface segregation of Sn in the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ layer can be suppressed. We also compare the growth of Co_2MnSi on $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ without performing the CARE treatments with Ru.

2. Experimental details

The target heterostructure and the process flow for the growth of Co_2MnSi on sputtered $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ are shown in Fig. 1(a) and (b), respectively. First, a $\text{Ge}_{0.95}\text{Sn}_{0.05}$ layer with a thickness of ~500 nm was deposited on commercial Si(111) substrates by using a multi-cathode sputter deposition system (ULVAC, QAM-4-STS) with a nominal Sn target concentration of 5 % [28]. Because of a large lattice mismatch of ~5 % between $\text{Ge}_{0.95}\text{Sn}_{0.05}$ and Si, a Ge buffer layer with a thickness of ~100 nm was inserted. The substrate temperature during the deposition of the $\text{Ge}_{0.95}\text{Sn}_{0.05}$ and Ge layers was set to 300 °C. The deposition rates of the $\text{Ge}_{0.95}\text{Sn}_{0.05}$ and Ge layers were ~0.77 and ~1.06 Å/s, respectively. From the Raman spectroscopy, a peak

due to the Ge–Sn bonding was observed, indicating that Sn remains incorporated in the $\text{Ge}_{0.95}\text{Sn}_{0.05}$ layer (not shown here). Then, the rough surface of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ layer was polished by CARE with Ru to obtain a smooth surface with a roughness of less than 1 nm (IMT Co. Ltd., SP-As1) [42,44]. In this study, ~30-nm-thick $\text{Ge}_{0.95}\text{Sn}_{0.05}$ layer was etched from the surface. After chemical cleaning of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface with ultrasonic cleaning for 3 min in acetone, for 3 min in ethanol, and for 2 min in deionized water, and with immerse for 5 min in ~1 % diluted hydrofluoric acid solution, the $\text{Ge}_{0.95}\text{Sn}_{0.05}$ surface was blow-dried with N_2 . Subsequently, the substrate was loaded into an MBE chamber (EpiQuest Inc.). Then, a heat treatment at 350 °C for 20 min was conducted in an ultrahigh vacuum (UHV) environment (~ 10^{-7} Pa), where the heat treatment temperature is lower than the surface segregation temperature of Sn in the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ layer [45]. Cooling the substrate temperature less than 80 °C, a Co_2MnSi layer with a thickness of ~10 nm was grown on $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ by MBE with an insertion of a ~1-nm-thick Fe layer, where the inserted Fe layer is essential for obtaining $L2_1$ -ordered Co_2MnSi layers on Ge(111) at less than 80 °C [46]. The growth rates of the Fe and Co_2MnSi layer were ~0.41 nm/min and ~0.78 nm/min, respectively. To investigate the influence of the surface roughness of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ layer on growth of Co_2MnSi , we also grow Co_2MnSi on $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ without performing the CARE treatments with Ru. Here we refer to these two samples as w/ CARE and w/o CARE samples, respectively. Structural characterizations were investigated by using atomic force microscopy (AFM) (SII, NanoNaviReal Probe Station), in situ reflection high-energy electron diffraction (RHEED) (R-DEC Co. Ltd., RDA-004G, RDA-004P), X-ray diffraction (XRD) (Rigaku, SmartLab, X-ray source: Cu, wave length of X-ray: ~0.154 nm), high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) (JEOL, JEM-ACE200F), and energy dispersive X-ray spectroscopy (EDX) (JEOL, JEM-ACE200F) measurements. Magnetic properties were measured at 300 K by using a vibrating sample magnetometer (Tamakawa Co. Ltd).

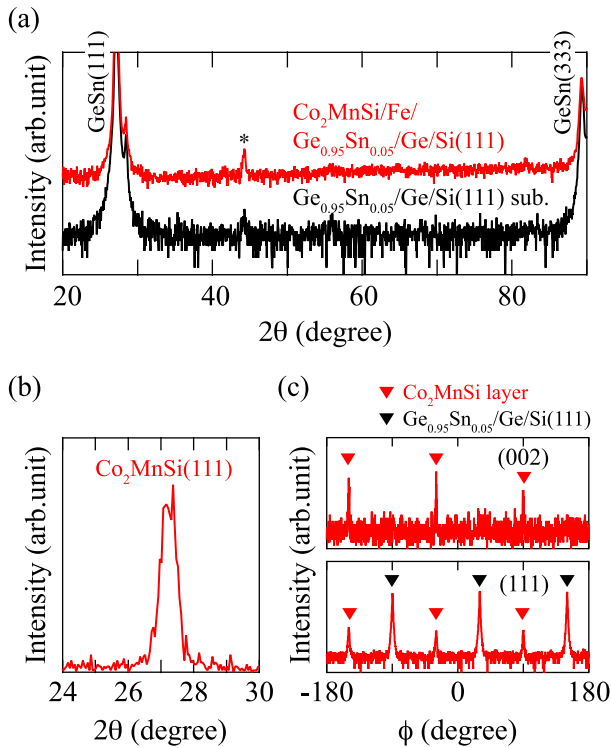


Fig. 2. (a) XRD θ - 2θ scan profile for of the $\text{Co}_2\text{MnSi}/\text{Fe}/\text{Ge}_{0.95}\text{Sn}_{0.05}/\text{Ge}/\text{Si}(111)$ structure for w/ CARE sample (red), together with that for the $\text{Ge}_{0.95}\text{Sn}_{0.05}/\text{Ge}/\text{Si}(111)$ substrate (black). (b) XRD 2θ scan profile for (111) plane of the Co_2MnSi layer. (c) XRD ϕ -scan profiles for (002) and (111) planes for the Co_2MnSi layer.

3. Results and discussion

Fig. 1(c) shows AFM images of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface before and after the CARE treatments. It can be seen that surface morphology of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface is significantly improved by the CARE treatments. The root-mean-square roughness (R_{RMS}) value of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface reduces from ~ 26.5 nm to ~ 0.29 nm, sufficiently smooth for two-dimensional epitaxial growth of a Co_2MnSi layer. A RHEED image of the w/ CARE $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$

surface after the surface cleaning in the MBE chamber is shown in Fig. 1(d). The RHEED pattern clearly shows a streak, indicating a smooth $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface. After a 1-nm-thick Fe insertion layer is grown on top of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface [Fig. 1(e)] [40,46], a 10-nm-thick Co_2MnSi layer is grown at less than 80°C [46]. As a result, after the growth of Co_2MnSi , a clear streak pattern due to the epitaxial growth is observed [Fig. 1(f)]. For comparison, RHEED images for the w/o CARE sample are shown in Fig. 1(g)–(i). The RHEED image of the w/o CARE $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface shows spotty patterns [Fig. 1(g)] derived from the rough $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface [see upper in Fig. 1(c)]. The rough $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface disturbs the two-dimensional epitaxial growth of an Fe insertion layer [Fig. 1(h)]. After the growth of the Co_2MnSi layer, ring patterns are superimposed on spotty patterns and these diffraction peaks are very weak, as shown in Fig. 1(i). These indicate that the surface polishing of a $\text{Ge}_{0.95}\text{Sn}_{0.05}$ surface by CARE with Ru is very effective for obtaining a smooth surface, enabling the two-dimensional epitaxial growth of the Co_2MnSi layer on $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$.

To evaluate interfacial and structural characteristics, we performed XRD measurements. Fig. 2(a) shows XRD θ - 2θ scan profile for the $\text{Co}_2\text{MnSi}/\text{Fe}/\text{Ge}_{0.95}\text{Sn}_{0.05}/\text{Ge}/\text{Si}(111)$ heterostructure with the CARE treatments (red), together with that for a $\text{Ge}_{0.95}\text{Sn}_{0.05}/\text{Ge}/\text{Si}(111)$ substrate (black). Because the lattice mismatch between Co_2MnSi and $\text{Ge}_{0.95}\text{Sn}_{0.05}$ is nearly 1 % and that between Co_2MnSi and Ge is almost zero, diffraction peaks derived from the Co_2MnSi layer are superimposed on those for the $\text{Ge}_{0.95}\text{Sn}_{0.05}/\text{Ge}/\text{Si}(111)$ substrate. If atomic diffusion occurred at the $\text{Co}_2\text{MnSi}/\text{Fe}/\text{Ge}$ interface, diffraction peaks due to the formation of other phases such as CoGe could be observed [47]. For both samples, the diffraction peaks, probably derived from the presence of some amount of polycrystalline phases in the $\text{Ge}_{0.95}\text{Sn}_{0.05}/\text{Ge}$ layer due to the large lattice mismatch with Si, are observed at 2θ of $\sim 44^\circ$ (see asterisks). Except for the diffraction peaks derived from the $\text{Ge}_{0.95}\text{Sn}_{0.05}/\text{Ge}/\text{Si}(111)$ substrate, there is no diffraction peak from the w/ CARE sample, meaning that the formation of other phases is suppressed during the growth of Co_2MnSi . Fig. 2(b) shows 2θ scan profile for (111) plane of the Co_2MnSi layer for the w/ CARE sample. A clear $\text{Co}_2\text{MnSi}(111)$ diffraction peak, indicating the formation of an $L2_1$ -ordered structure even in the 80°C -grown Co_2MnSi layer, is observed at 2θ of $\sim 27^\circ$. In Fig. 2(c), we also show XRD ϕ -scan profiles for (200) and (111) planes, respectively, for the grown Co_2MnSi layer. Like as our previous study on an epitaxial $\text{Co}_2\text{MnSi}/\text{Fe}/\text{Ge}(111)$ heterostructure [46], sharp diffraction peaks with threefold symmetry are clearly observed. From these data, we estimated the degree of

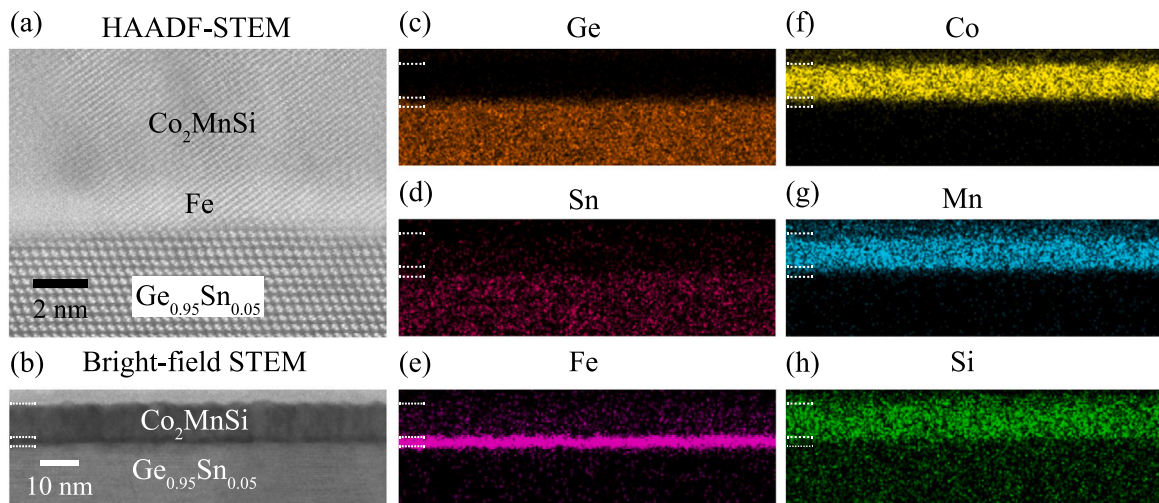


Fig. 3. (a) High-magnification cross-sectional HAADF-STEM image near the $\text{Co}_2\text{MnSi}/\text{Fe}/\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ heterointerface. (b) Bright-field STEM image and [(c)–(h)] EDX elemental maps (Ge, Sn, Fe, Co, Mn, and Si) for the $\text{Co}_2\text{MnSi}/\text{Fe}/\text{Ge}_{0.95}\text{Sn}_{0.05}/\text{Ge}/\text{Si}(111)$ heterostructure over the wide area.

Table 1

Comparison of structural and magnetic properties of Co₂MnSi with reported studies for thin-film [46,50–52] and bulk [31] samples.

Sample	Method	Fabrication temperature	Structure	M_S (emu/cc)	H_C (Oe)
Co ₂ MnSi/Fe/Ge _{0.95} Sn _{0.05} (111) (This study)	MBE	≤80 °C	L_{21} ($S_{L_{21}} \sim 0.22$)	~625 (300 K)	~100
Co ₂ MnSi/Fe/Ge(111) Ref. [46]	MBE	≤80 °C	L_{21} ($S_{L_{21}} \sim 0.33$)	~890 (300 K)	~20
Co ₂ MnSi/Ge(111) Ref. [50,51]	MBE	130 °C	A2 + amorphous	~320 (300 K)	~120
Co ₂ MnSi/Ge(111) Ref. [52,53]	Sputtering	200 °C 400 °C	Amorphous L_{21}	~0 (300 K) ~500 (300 K)	– –
Co ₂ MnSi/graphene/Ge(111) Ref. [54]	Sputtering	350 °C 450 °C	$B2$ L_{21}	~615 (300 K) ~862 (300 K)	– –
Co ₂ MnSi (bulk) Ref. [31]	Arc melting	1250 °C	L_{21}	~1050 (5 K)	~5

ordering parameters for $B2$ and L_{21} , S_{B2} and $S_{L_{21}}$, following the following equations [48,49],

$$S_{B2} = \sqrt{\frac{I_{002}/I_{004}}{I_{002}^R/I_{004}^R}} \quad (1)$$

$$S_{L_{21}} = \frac{2}{3 - S_{B2}} \sqrt{\frac{I_{111}/I_{202}}{I_{111}^R/I_{202}^R}}, \quad (2)$$

where I_{hkl} and I_{hkl}^R are the experimental and theoretical peak intensities for the hkl plane. As a result, the values of S_{B2} and $S_{L_{21}}$ were estimated to be ~0.59 and ~0.22, respectively. Although these values are smaller than those for the Co₂MnSi/Fe/Ge(111) heterostructure reported in our previous study ($S_{B2} \sim 0.66$, $S_{L_{21}} \sim 0.33$) [46], L_{21} -ordered structures (approximately 20 %) are included even in the low-temperature-grown Co₂MnSi layer on a GeSn alloy.

Further structural characterizations were carried out by HAADF-STEM and EDX measurements. Fig. 3(a) shows a high-magnification cross-sectional HAADF-STEM image near the Co₂MnSi/Fe/Ge_{0.95}Sn_{0.05}(111) heterointerface. The Co₂MnSi layer is uniformly grown without forming reaction layers at the Co₂MnSi/Fe/Ge_{0.95}Sn_{0.05}(111) interface over the measured area. Even for the low growth temperature less than 80 °C, we can see the lattice image derived from the formation of the L_{21} -ordered structure in the Co₂MnSi layer. Bright-field STEM image and EDX elemental maps over the wide area are displayed in Fig. 3(b)–(h). We can see the surface of the Ge_{0.95}Sn_{0.05}(111) layer is smooth, consist with the results of Fig. 1(c) and (d). On top of the smooth Ge_{0.95}Sn_{0.05}(111) layer, the Fe insertion layer is uniformly grown. The atomic interdiffusion between Ge_{0.95}Sn_{0.05} and Fe layers is nearly suppressed. On top of the Fe insertion layer, the Co₂MnSi layer is also uniformly grown with suppressed interdiffusion. Owing to the low-temperature growth less than 80 °C, the segregation of Sn toward the Co₂MnSi surface is suppressed during the growth. From these data, we understand that the surface flatness of the Ge_{0.95}Sn_{0.05}(111) layer by CARE and the insertion of the thin Fe layer enable to demonstrate epitaxial growth of L_{21} -ordered Co₂MnSi layers on Ge_{0.95}Sn_{0.05}(111) less than 80 °C.

Fig. 4 show a field-dependent magnetization curve (M – H curve) measured at 300 K for a Co₂MnSi/Fe/Ge_{0.95}Sn_{0.05}/Ge/Si(111) heterostructure (red plots), together with those for Co₂MnSi/Ge(111) (black plots) [50] and Co₂MnSi/Fe/Ge(111) ones (gray plots) [46]. The value of the saturation magnetization (M_S) is estimated to be ~625 emu/cm³, smaller than a theoretical value (~1050 emu/cm³) [31,32] and thin-film samples [46,55] reported previously. The coercivity (H_C) of the Co₂MnSi layer is ~100 Oe, which deviates from the characteristics of highly ordered Co-based Heusler alloys [50,56,57]. We speculate that the small M_S and relative large H_C values are derived from the relatively low S_{B2} and $S_{L_{21}}$ values. Although the Co₂MnSi layers directly grown on Ge(111) consisted of mixed phases with crystalline

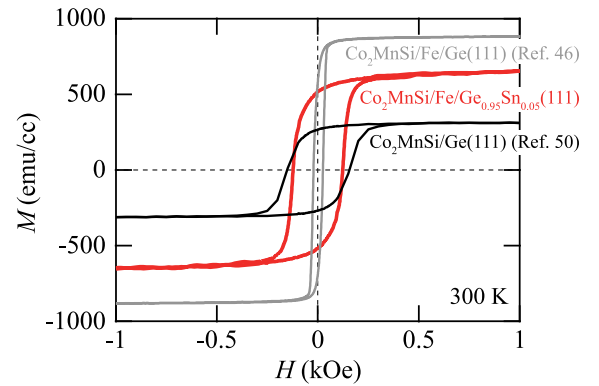


Fig. 4. M – H curve measured at 300 K for a Co₂MnSi/Fe/Ge_{0.95}Sn_{0.05}/Ge/Si(111) heterostructure (red plots), together with those for Co₂MnSi/Ge(111) [50] and Co₂MnSi/Fe/Ge(111) ones (gray plots) [46].

phases and amorphous ones [50,51], the insertion of a thin Fe layer enabled to grow L_{21} -ordered Co₂MnSi layers [46]. Reflecting the large difference in the crystal quality with and without the inserted Fe layer, magnetic properties of the Co₂MnSi layer are significantly changed, as shown in black and gray plots of Fig. 4. Actually, the M – H curve for the w/ CARE sample shows higher M_S and lower H_C values than Co₂MnSi/Ge(111) [50,51].

Finally, we describe the superiority of this study. In Table 1, we summarize structural and magnetic properties of our sample with related previous studies [46,50–54]. Here we compare this study with the results for the growth on Ge(111) since there have been no examples of growth of a Co-based Heusler alloys on GeSn(111). For reference, we also show data for bulk sample [31]. For thin-film samples, the use of the MBE technique with an Fe insertion layer enables epitaxial growth of L_{21} -ordered Co₂MnSi layers at less than 80 °C [46]. Although L_{21} -ordered Co₂MnSi layers are also obtained on Ge(111) by sputtering, annealing temperatures above 350 °C are mostly required [52–54], higher than the surface segregation temperature of Sn in the GeSn(111) layer [45]. Given such situations, this study presents a potential for demonstrating high-performance GeSn-based semiconductor spintronic devices. Compared with Co₂MnSi/Fe/Ge(111) [46], although there is still room to improve the crystal quality of the Co₂MnSi/Fe/Ge_{0.95}Sn_{0.05} heterostructure, L_{21} -ordered Co₂MnSi layers can be obtained on sputtered Ge_{0.95}Sn_{0.05}(111) even at less than 80 °C, significantly lower than the typical L_{21} -ordering temperature of Co₂MnSi [33,52–54,58] and the surface segregation temperature of Sn in GeSn layers [45]. This study will pave the way toward the

integration of high-performance spintronic technologies with group-IV semiconductor-based photonic and/or electronic devices on a Si platform.

4. Conclusion

For applications to GeSn-based semiconductor spintronic devices such as a spin laser, we have explored low-temperature growth of half-metallic Co_2MnSi layers on sputtered $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ with an insertion of a $\sim 100\text{-nm}$ -thick Ge buffer layer on $\text{Si}(111)$ substrates by MBE. The surface roughness of the $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ layer derived from a large mismatch of $\sim 5\%$ between $\text{Ge}_{0.95}\text{Sn}_{0.05}$ and Si was significantly decreased by Catalyst-Referred Etching with Ru, leading to a sufficiently flat $\text{Ge}_{0.95}\text{Sn}_{0.05}$ surface. As a result, on top of the flat $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ surface, an $L2_1$ -ordered Co_2MnSi layer was obtained at less than 80°C with an insertion of a $\sim 1\text{-nm}$ -thick Fe layer. Because of the low-temperature growth, atomic interdiffusion between Co_2MnSi and $\text{Ge}_{0.95}\text{Sn}_{0.05}(111)$ and the surface segregation of Sn in the $\text{Ge}_{0.95}\text{Sn}_{0.05}$ layer were suppressed. The technologies developed in this study have an advantage in terms of the integration of high-performance spintronic materials with GeSn alloys, paving the way toward the realization of GeSn-based semiconductor spintronic devices on a Si platform.

CRediT authorship contribution statement

Kento Yamaguchi: Writing – original draft, Investigation, Data curation. **Shinya Yamada:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization. **Ryo Ishikawa:** Writing – review & editing, Resources, Investigation, Data curation. **Kohei Hamaya:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

No data was used for the research described in the article.

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