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Magnetic Iron – Cobalt Silicide Nanowires on Si(110) Surface

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Spintronics is an emerging technology that exploits the quantum spin states of electrons as well as their charge state. To realize this system, ferromagnetic-semiconductor hybrid structures have received significant attention for their possible application in spintronics. One of most well-known devices in silicon technology is a metal oxide semiconductor field effect transistor (MOSFET). In the "spin-MOSFET", the source and drain are ferromagnetic materials [1]. To combine spintronics with silicon technology, it is necessary to grow ferromagnetic materials directly on the silicon substrate. Adsorbed magnetic metals form silicides on the clean Si surface, and lose the magnetism generally. In the case of Fe/Si(110), however, nanowires (NWs) formed on clean Si(110) surfaces [2-3] show weak ferromagnetism at 2 K [3]. In this study, we report the investigation of the growth of Heusler alloys (Co_2FeSi) shaped NWs on Si(110) surface and its ferromagnetism at room temperature (RT).

The sample preparation were carried out in an UHV (base pressure < 2.0×10^{-8} Pa) chamber. A phosphorous-doped n-type Si(110) wafer (< 0.01 Ω· cm) was used as a substrate. After cleaning preparation, Fe and Co were deposited on the substrate held at 750 ºC by electron beam deposition. The shape of structure formed on Si substrate was evaluated using SEM and TEM. For the cross-sectional TEM observation, the specimens were prepared to the wedge shape by only mechanical polishing. TEM and electron holography (EH) observations were performed using Hitachi HF-2000 with an acceleration voltage of 200 kV.

SEM image in Fig. 1 (a) shows that NWs along <$\bar{1}$10> are formed by Fe and Co co-deposition onto clean Si(110) surface held at 750 ºC similar to the cases of Fe/Si(110) and Co/Si(110) systems. The length of the NW along the <$\bar{1}$10> direction is about 1 μm and the width is about 50 nm. We also confirm both Fe and Co peak using SEM-EDX. In order to reveal the structure of the NWs/silicon interface, cross-sectional TEM observation along the <$\bar{1}$10> direction was conducted. A rhombic shape contrasts are observed at the interface between the glue and the silicon substrate as shown in Fig. 1 (b). This suggests that the growth of NWs is endotaxy.

Figure 2 shows a high-resolution TEM image of the interface between NW and silicon substrate. This image shows that the NW grows parallel to Si (111) surface and also shows rhomboid-shaped unit cell with spacings of $|\mathbf{a}| = |\mathbf{b}| = 0.31$ nm. Because the unit cell in NWs of Fe/Si(110) and Co/Si(110) are cubic, we conclude that the NWs are Fe – Co – Si alloy.

In EH, a vacuum area is required for a reference wave. We remove the glue which has been pasted to protect the surface including NWs in the mechanical polishing process. Figure 3 (a) shows cross-sectional TEM images of an interface between Si substrate and vacuum at low magnification. To observe magnetic field, this specimen is tiled from the horizontal and objective lens current turn off. Figure 3 (b) shows contoured phase image (10 times amplification) reconstructed by EH. The magnetic flux extending into vacuum is clearly resolved. In-plane **B** field is estimated 4.7 T around NW. The reason why the convergence points of the magnetic field are partial is speculated that NWs alloyed Fe – Co –Si is partially formed. We have succeeded in directly forming NWs on Si(110) substrate with magnetism at RT.

[1] S. Sugahara, et al., *Appl. Phys. Lett.* 84 (2004) 2307.
[2] Y. Ohira, et al., *Jpn. J. Appl. Phys.* 47 (2008) 6138.
[3] S. Liang et al., *Appl. Phys. Lett.* 88 (2006) 113111.

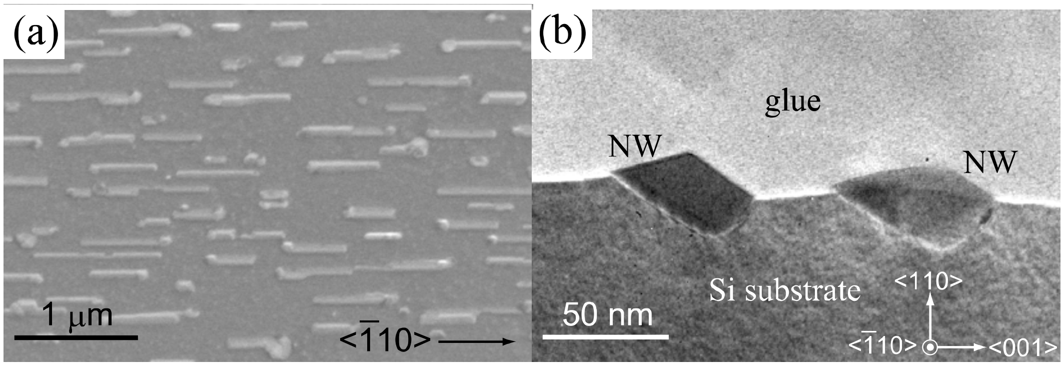

Fig. 1. (a) SEM image of wire-shaped silicides on Si(110) surface. (b) Cross-sectional TEM image of wire-shaped silicides observed along <$\bar{1}$10>

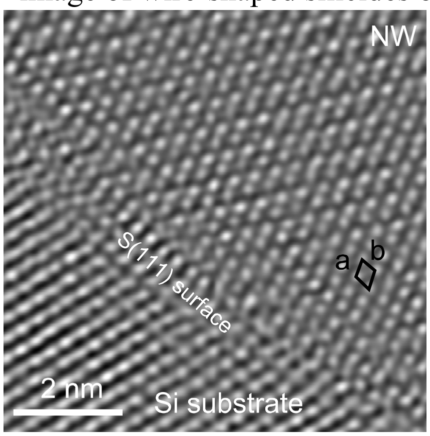

Fig. 2. High-resolution TEM image of interface between NW and Si substrate.

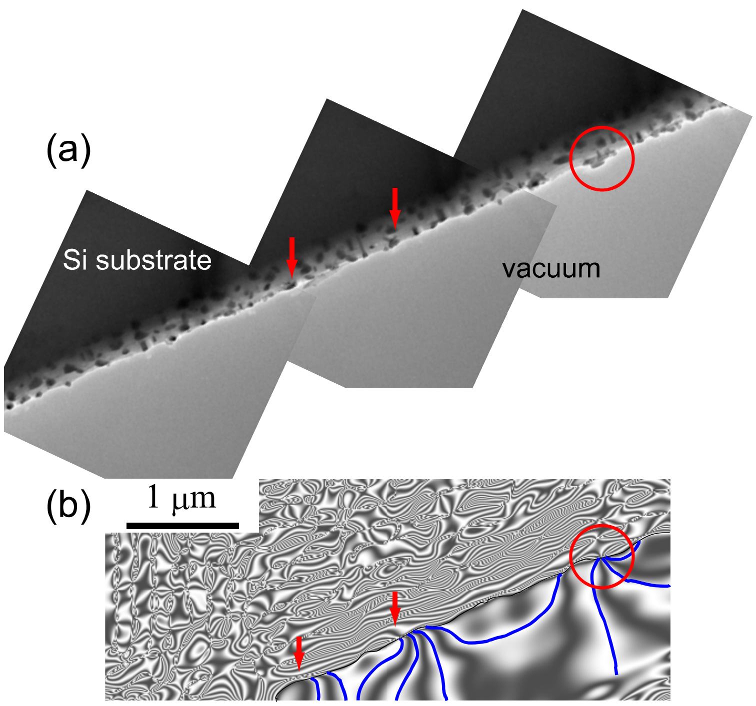

Fig. 3. (a) Cross-sectional TEM image of wired-shaped silicides observed along <$\bar{1}$10> without glue. (b) Contoured phase image (10 times) showing magnetic flux extending into vacuum. Superimposing that magnetic induction map is schematically.

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