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Epitaxial formation and electrical property of Ni Germanide/Ge contacts

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Introduction Epitaxial metal contact becomes much more important as the dimensional scaling of complementary metal-oxide-semiconductor (CMOS) devices shrinks deeper into nanometer order. Considering the situation that the contact dimension scales down to a magnitude of grain size of contact materials, variability of crystalline orientation of grains in metal/semiconductor interface may give rise to an unignorable variation of the work function and morphology stability, which implies that the problem of electrical fluctuation and non-reproducibility may occur for each source and drain part when the metal contact layer is polycrystalline. As for the fabrication of shallow junction, epitaxial metal contact is also necessary, because the polycrystalline metal/semiconductor generally has a rough interface due to grain boundaries of the polycrystalline grains [1].

Experimental procedure To control the epitaxial formation of Ni germanide, solid phase reaction and reactive deposition were used to form an epitaxial NiGe layer on Ge(110) and Ge(001) substrate, respectively. After the epitaxial formation, X-ray diffraction (XRD) and cross-sectional transmission electron microscopy (XTEM) were performed to reveal the crystalline structure of epitaxial NiGe layers. Current density-voltage (J-V) characteristics of Schottky diodes were also measured.

Results and discussion In this study, we achieved the formation of epitaxial NiGe layers not only on Ge(001) substrate, but also on Ge(110) substrate, as summarized in Table 1. For NiGe/Ge(001) system, polycrystalline NiGe is formed by the solid phase reaction, while an epitaxial NiGe layer could be achieved by reactive deposition at 350 °C, the orientation relationship with respect to Ge(001) substrate is NiGe(111) // Ge(001). On the contrary, for the NiGe/Ge(110) system, solid phase reaction leads to the epitaxial formation of NiGe layer with the orientation relationship of NiGe(100) // Ge(110), moreover, we also found the orientation of epitaxial NiGe on Ge(110) could be changed by an ultra-thin interfacial GeO_x layer, the orientation relationship is NiGe(102) // Ge(110). Reactive deposition gives rise to the polycrystalline formation of NiGe on Ge(110) substrate. We consider that those different crystalline structures of NiGe are due to the different surface energy and strain energy for each germanidation method. As for electrical property of Ni germanide/Ge contacts, an Epi. NiGe(100)/Ge(110) contact shows a lower Schottky barrier height (SBH) of 0.44 eV, compared with that of other contacts. Of interesting, although epitaxial NiGe is formed on Ge(001) substrate, the SBH has no distinctive difference with that of Poly. NiGe/Ge, it is understood by inspection of the atomic arrangement at the interface of Epi. NiGe(111)/Ge(001). The atomic arrangement at the interface of NiGe(111)/Ge(001) is found to be disorder, which might result into the high SBH similar with that of Poly. NiGe/Ge contact.

Reference [1] O. Nakatsuka *et al.*, Jpn. J. Appl. Phys. **47** (2008) 2402.

Table 1. The summarization of the epitaxial formation of NiGe layers on Ge(001) and Ge(110) substrates.

Orientation relationship	Fabrication methods
Epi. NiGe(100) // Ge(110)	Solid phase reaction
Epi. NiGe(102) // Ge(110)	Solid phase reaction (an ultra-thin GeOx interfacial layer)
Poly. NiGe // Ge(110)	Reactive deposition
Epi. NiGe(111) // Ge(001)	Reactive deposition
Poly. NiGe // Ge(001)	Solid phase reaction

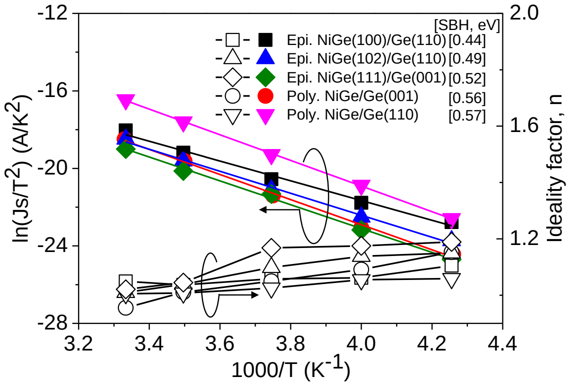

Fig. 1. Arrhenius plots of the saturate current density of NiGe/Ge Schottky contacts with various crystalline structures.