DOI: 10.1017/S143192760550758X

Microsc Microanal 11(Suppl 2), 2005
Copyright 2005 Microscopy Society of America

Reaction of Co with Ge Studied by *in situ* UHV TEM

H.P. Sun*, Y.B. Chen*, D. Z. Chi**, R. Nath**, Y. L. Foo**, and X.Q. Pan*,

[*]Department of Materials Science and Engineering, University of Michigan, Ann Arbor, MI 48109
[**]Institute of Materials Research and Engineering, Singapore, 117602

Channel mobility is a major challenge for scaled silicon devices to meet the requirements of sub-45nm device geometries. Ge recently attracted considerable attention due to its high carrier mobility and excellent compatibility with high-k materials.[1] The development of Ge-based complimentary metal-oxide-semiconductor (CMOS) technology requires knowledge about the formation of local metal-semiconductor contact for which metal germanides will be used. Silicides have been extensively investigated,[2] however formation of germanides on single crystal Ge surface attracted less attention in the past. In this paper, we report the formation and microstructural evolution of epitaxial Co_5Ge_7 phase on a single crystal Ge (001) surface by reactive deposition and solid state reaction in an *in situ* ultra high vacuum (UHV) transmission electron microscope (TEM).

The microscope used for the present work is a modified JEOL-2010 TEM under UHV condition. Atomic Co flux was generated by the electron beam evaporation of high purity Co metal inside the TEM chamber. For reactive deposition, the Ge substrate was maintained at 350ºC. For solid state reaction, the deposition of Co on the Ge substrate was at a room temperature, and then the sample was *in situ* annealed at 125ºC, 225ºC, 300ºC and 350ºC, respectively. The morphology and structural evolutions of the epitaxial Co_5Ge_7 phase during the reaction of Co with Ge surface in the two experiments were recorded in real-time.

It was found that the reaction and formation mechanisms of cobalt germanide phase and its structural evolution during the reaction are different for two different processes. For the reactive deposition, Co_5Ge_7 phase nucleates on the (001) Ge surface in the form of epitaxial islands with square and rectangular shapes. The morphological evolution of the islands is shown in Fig.1. Two epitaxial orientation relationships between Co_5Ge_7 and (001) Ge surface were observed by *in-situ* electron diffraction and further confirmed by x-ray diffraction for the same sample: Co_5Ge_7 <001>(110) || Ge <100>(001) and Co_5Ge_7 <110>(001) || Ge <100>(001). Anisotropic strain relaxation results in the elongation of the Co_5Ge_7 islands along the Ge <110> direction. For the solid state reaction, a continuous epitaxial Co_5Ge_7 layer on the Ge(001) surface forms at ~300°C, as shown in Fig.2. The epitaxial orientation relationship is identical to that obtained in the reactive deposition at 350°C. By further annealing at 350°C the Co_5Ge_7 film becomes discontinuous with a number of pinholes. This work demonstrates that *in situ* TEM provides a unique way to study the interaction between metal and semiconductor.

References:

[1] SOITEC, "Applied Materials and Soitec Collaborate to Develop Advanced Germanium-on-Insulator Substrates for 45nm and Beyond ," http://www.soitec.com News and events/Press releases/Company releases/ March 11, 2004.
[2] S. L. Zhang and M. Ostling, *Critical Rev.in Solid State and Mater.Sci.* 28, (2003) 1.

https://doi.org/10.1017/S143192760550758X Published online by Cambridge University Press

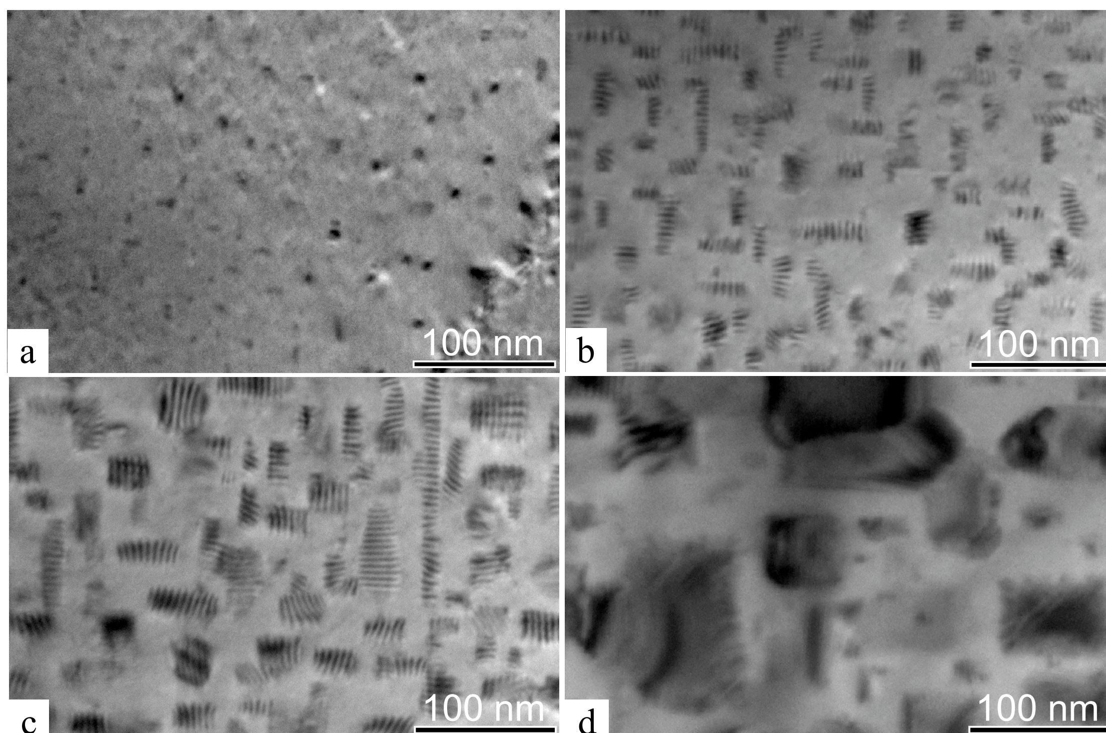

FIG. 1. Time series TEM images showing the morphology evolution of Co deposited on Ge (001) surface (a)2min, (b)32min, (c) 61min and (d) 145min during reactive deposition at 350ºC.

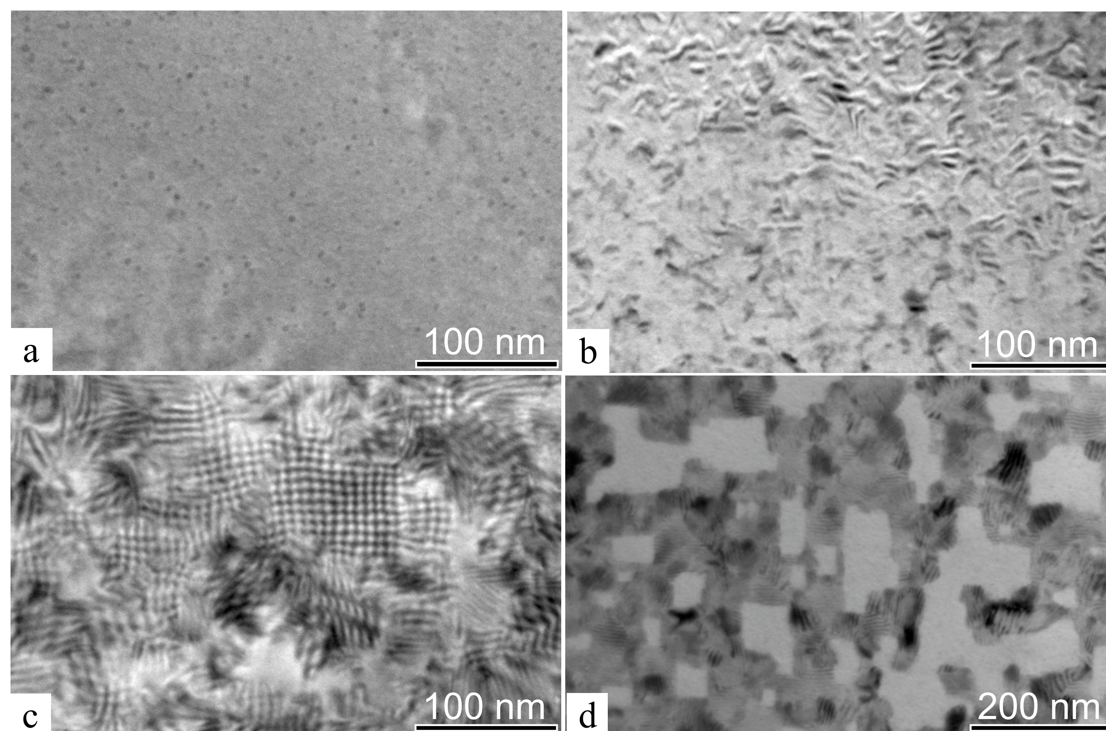

FIG. 2. TEM images showing the morphology of a Co film deposited on the Ge (001) surface and annealed at (a) 125°C, (b) 225°C, (c) 300°C and (d) 350°C.

https://doi.org/10.1017/S143192760550758X Published online by Cambridge University Press