Introduction of wired-heavy metal dopants into Si substrates

Kazushi Miki,

Graduate school of engineering, University of Hyogo, Shosya 2167, Himeji 671-2280, Japan.
*e-mail: miki@eng.u-hyogo.ac.jp

A dopant makes localized electronic state useful for a laser, an electronic device and so on. 1D dopants rather than a lone dopants have advantages: reduction of alloy scattering in electronic devices; useful structure for quantum information platform; and etc. Recently we succeeded in introduction of wired-heavy metal dopants such as wired-Mn or wired-Bi dopants into Si substrates[1,2,3].

As the first example, we realized Mn δ-doping into Si/Si and Si/Ge interfaces by using Mn atomic chains on Si(001) as a starting material[1]. Encapsulation of the Mn chains of 0.5ML (defined with an atom density of 6.8×10^{14} atoms cm^{-2} on Si(001) surface as 1ML) with a growth of Si or Ge capping layer at room temperature avoids either the formation of silicides or germanides. We characterized the local structure around the Mn atoms by employing highly sensitive X-ray absorption fine structure measurements at Spring-8 BL37XU. The obtained results for the Ge capping case showed anisotropic profiles of its radius atomic function in case the incident X-ray polarization is normal or parallel to the Mn chain, as show in Fig. 1 (middle and bottom). It means that Mn dopants have 1 dimensional structure even after its burial at Ge/Si interface. Independently we studied the hall measurement of the Ge/Mn chain/Si(001) and it was found that Mn acts as a p-type dopant. Therefore, we strongly infer that 1D Mn dopants at the Ge/Si interface could be obtained. The density functional theory calculation of the corresponding model supports our analysis.

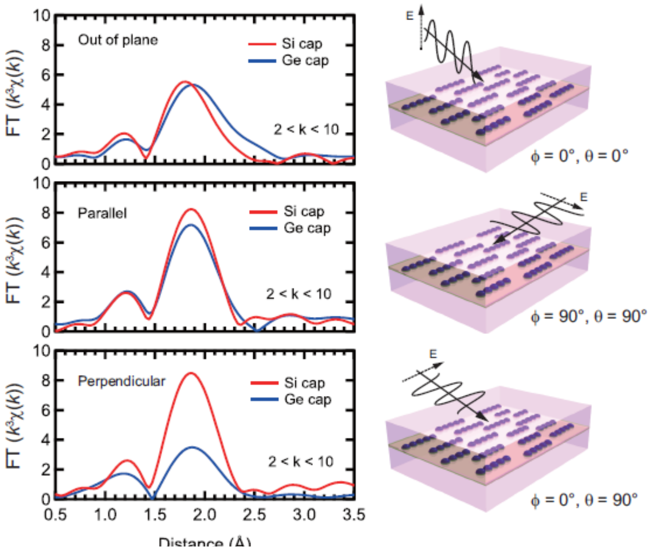

Fig. 1: Fourier transforms at $k = 2 - 10$ Å^{-1} of the Mn K-edge EXAFS spectra of Mn δ–doped samples capped by Si and Ge. EXAFS spectra were obtained in three different directions, out-of-plane ($\phi = 0^\circ;\ \theta = 0^\circ$), parallel ($\phi = 90^\circ;\ \theta = 90^\circ$) and perpendicular ($\phi = 0^\circ;\ \theta = 90^\circ$).

I would also introduce the other case of the wired-Bi dopants in Si crystal in my talk[2,3].

Acknowledgment:

I would thank all my collaborators: K. Murata (Central Research Institute of Electric Power Industry); S. Fukatsu (University of Tokyo); Kiyofumi Nitta, Tomoya Uruga, and Yasuko Terada (JASRI); Christopher Kirkham, and David R Bowler (University College, London), Satoshi Tsubomatsu, and Takashi Kanazawa, (University of Tsukuba and NIMS); Koh-ichi Nittoh (NIMS). This study has been carried out in a part of JSPS KAKENHI (19206003, 24246017, 17H02777 and 17H05225).

References:

1. Koichi Murata, Christopher Kirkham, Satoshi Tsubomatsu, Takashi Kanazawa, Kiyofumi Nitta, Yasuko Terada, Tomoya Uruga, Koh-ichi Nittoh, David R Bowler and Kazushi Miki, appears soon in Nanoscale.
2. Koichi Murata, Kazushi Miki, and Susumu Fukatsu, *Appl. Phys. Lett.* **111** (2017) 152104.
3. Koichi Murata, Christopher Kirkham, Masaru Shimomura, Kiyofumi Nitta, Tomoya Uruga, Yasuko Terada, Koh-ichi Nittoh, David R Bowler and Kazushi Miki. *J. Phys.: Condens. Matter* **29** (2017) 155001 (7pp).