Success in encapsulation of atomic-scale nanolines in epitaxial silicon

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Drs. Osami Sakata (Japan Synchrotron Radiation Research Institute(JASRI) / SPring-8), Kazushi Miki (Nanomaterials Laboratory (NML), National Institute for Materials Science (NIMS)), David R. Bowler (International Centre for Young Scientists (ICYS)), and co-workers demonstrated, using X-ray diffraction, that they have taken one-dimensional Bi nanolines fabricated on a Si(001) surface, and buried them in crystalline silicon while retaining both their one dimensional character and important aspects of their structure.

Most of nanstructures that have been so far fabricated have a single-unit structure. For nanoelectronic applications, a nanostructure comprised of more than two nanoscale single-unit structures is required, and it is called a nanoscale architecture. Dr. Miki's research group has developed a new processing method for forming Bi nanolines in epitaxial silicon; eventually, this method will allow us to form a nanoscale-cross or nano-wiring structure in the silicon. During growth by the conventional process, a nanostructure will be fragile or destroyed because a surface segregation phenomenon occurs. The research group succeeded in encapsulating nanowires in silicon by a new method they proposed to avoid the phenomena.

It is in general difficult to nondesructively observe such a nanostructure in a crystal. This is because we cannot use the standard techniques for surface-structural analysis such as scanning probe microscopy or electron diffraction. The established X-ray diffraction techniques combined with synchrotron radiation have not revealed a structure of the embedded Bi nanolines having ca. 1/10 monolayers.

Dr. Sakata succeeded in showing a diffraction pattern of the nanolines by the reciprocal-lattice space imaging method using high-energy and monochromatic X-rays. Furthermore, using the X-ray diffraction results, Dr. Bowler has proposed its atomic structure by nanosimulation based on the density functional theory.

Hopefully, the present outcomes will spur us to realize the fabrication of nanoscale architectures. It is also demonstrated that the reciprocal-lattice space imaging is one of ultrahigh-sensitive diffraction methods for evaluating nanostructures. The research we here introduced shows that rapid and close cooperation between nanostructural fabrication, evaluation, and simulation is important. SPring-8 is, in particular, of great significance for nanostructural evaluation.

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