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NANONET INTERVIEW

Shunri ODA,
Professor, Research Center for Quantum Effect Electronics, Tokyo Institute of Technology

NeoSilicon
— Ultrafine silicon particles will change the general knowledge on silicon —

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Shunri ODA

Professor, Research Center for Quantum Effect Electronics, Tokyo Institute of Technology

1974	Bachelor's degree, Department of Physics, Faculty of Science, Tokyo Institute of Technology
1979	Doctor of Engineering, Tokyo Institute of Technology
1979	Research Associate, Imaging Science and Engineering Laboratory, Faculty of Engineering, Tokyo Institute of Technology
1982 -1983	Post-doctoral Researcher, Department of Physics, Massachusetts Institute of Technology
1986	Associate Professor, Department of Physical Electronics, Tokyo Institute of Technology

The nanocrystalline silicon particles fabricated by Prof. Oda consist of ultrafine silicon particles with 10 nm in diameter. The lattice image observed through a transmission electron microscope indicates that the silicon particles are perfect single crystals. Amorphous silicon oxide, the thin film covers the silicon particles, controls tunneling current and confines electrons. Prof. Oda aims at developing single electron transistors and single electron memory devices by utilizing these particles.

He got a doctoral degree in applied physics in 1979 and joined a chemistry group as a research associate at Imaging Science and Engineering Laboratory. He started to study amorphous silicon there. Later in 1986, he became an associate professor in physical electronics and started works on device application of amorphous silicon. The ultrafine silicon particles were fabricated by accident. At that time, there was still much to be elucidated for it, which attracted him to study amorphous silicon. " We were trying to prevent crystallization during synthesis of amorphous silicon. However it was difficult to prevent it from amorphous material. So we considered two approaches to take, either preventing partial crystallization or utilizing crystallization. " What Prof. Oda chose was to utilize crystallization. He had an idea that controlling crystal size in the amorphous material could be achieved by controlling the nucleation and growth of the crystals separately. He first investigated a method to control the growth of the crystals in amorphous material. Then he developed a method to supply a hydrogen gas on the amorphous silicon synthesis on a substrate at intervals in the process of plasma-enhanced decomposition of silane. However, the result was totally unexpected. He discovered the accumulation of silicon nanocrystalline particles in various sizes on the substrate. In further research, it has become possible to control particle size and the thickness of the oxide films covering the particles. Currently, average of 8nm silicon nanocrystalline particles with a small dispersion of 1nm can be obtained. It has also become possible to control the confinement of a single-electron at temperatures as low as 20K using these particles. However, the next-generation silicon particles, the NeoSilicon, must be prepared in order to utilize a quantum effect even at room temperature. Particles of 3 to 4nm size and the oxide film with 0.5 to 1nm thick are essential to implement NeoSilicon.

These particles are arranged on a substrate at an interparticle distance of 5nm in order to control the interaction between them. The arrangement of the nanocrysalline particles is much more difficult than controlling particle size and oxide film thickness precisely. In order to arrange these small particles precisely, the surface of the substrate processed with electronic beams is too rough. At the moment, various processing methods including chemical modification are being tested for the preparation of substrates.

The nanocrystalline silicon particles have great advantage of synthesizing particles at lower temperatures. Usually, it requires temperatures higher than 600 ° C to prepare such perfect crystals. However, nanocrystalline silicon particles require lower temperatures like 100 ° C. At such low temperatures, glass or plastic substrates can be used instead of silicon wafer. Generally speaking, silicon is an inefficient light emitter, but the nanocrystalline silicon particles emit high intensity visible light. “ Depending on the size of the nanocrystalline particles, the nanocrystalline silicon particles emit different light colors like red, green, or blue by the electron confinement. Flexible substrates like plastic would be possible applications of nanocrystalline silicon particles. An inexpensive disposable display is one thing. ” Prof. Oda says, however, it will take much time till nanocrystalline silicon particles can be put

1995-present	Professor, Research Center of Quantum Effect Electronics, Tokyo Institute of Technology

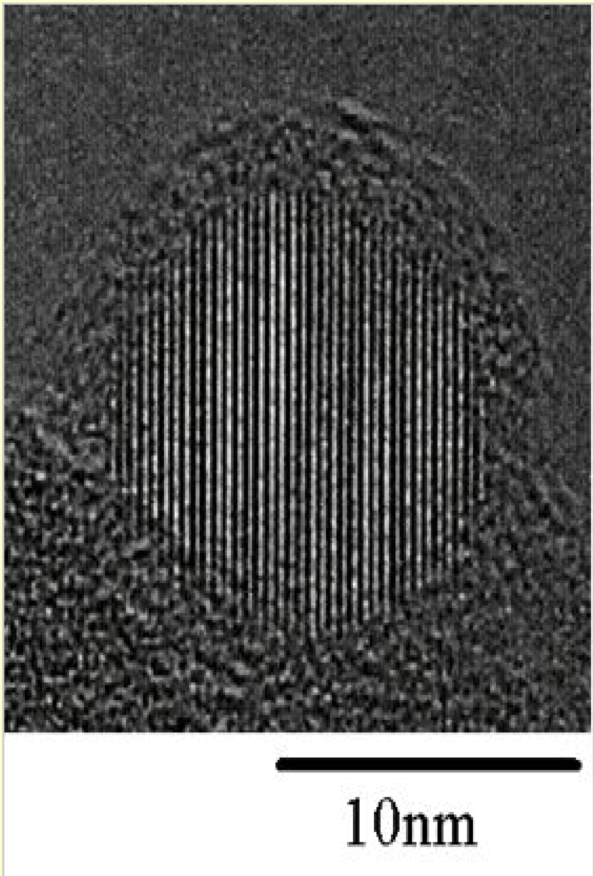

Fig. 1 Large Image

Nanocrystalline silicon particles

Single-crystal silicon particles with a diameter of 10nm are covered with silicon oxide film. They exhibit new functions such as single-electron devices and high efficiency visible light emission.

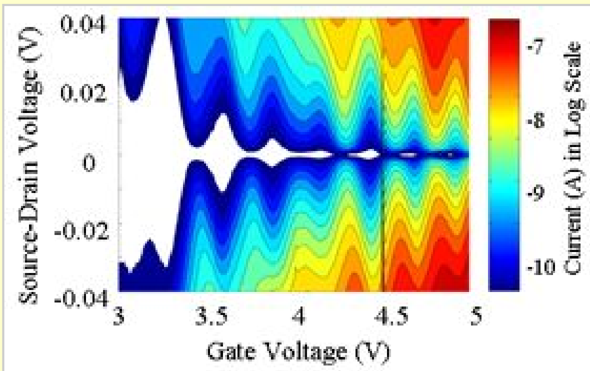

Fig. 2 Large Image

Single-electron transistor that operates with a single electron

Ultrafine transistor that uses silicon particles with a diameter of 8nm. Wave patterns show that electrical current can be greatly modulated by putting electrons into a particle one by one.

them into practical use. “ I ’ d rather reflect the achievements of the research on the NeoSilicon like oxidation behavior of ultrafine structures to the current silicon technology in a few years than waiting for nanocrystalline silicon particles to be put into practical use for another 10 to 20 years.

Prof. Oda ’ s research career started out with physics. “ As a student, I strongly believed that physics could explain everything in any field, including economics and even psychology. I wanted to build up a system that would provide a very sophisticated explanation for everything. ” However, he was gradually attracted to application of physics and finally switched to applied physics in the graduate school. Then, he became a research associate in chemistry, and now he is working in electronics. His specialty in research has changed gradually. “ I did not have a specific reason when I switched a research field but I was not going all the way in one field, either. However, I switched my specialty to the related field to avoid risk in switching it drastically. ”

Prof. Oda realizes such experience helped him to widen his perspective so that he recommends the same to young researchers. “ I want them to jump into different research fields in different laboratories from the ones they have been. Consequently, they will be able to conduct new research and widen their perspectives.I think this would be mutual advantage for young researchers and research laboratories. If you conduct research only in one field, you can ’ t get away easily from the conventional approaches of that research field. As for the nanocrystalline silicon particles, I would not have been able to discover them if I had aimed to fabricate them with the conventional approach in the first place. A failure is a stepping stone to invention. A failure happens when things did not go with conventional way. Sometimes, a failure brings new phenomena that were never expected to happen. If you are trapped by stereotypical views, you learn nothing from your failure. A failure will remain as failure. You have to open yourself up to it and analyze what went wrong for further step of your research and yourself. ”

(Interviewer: Kuniko Ishiguro, Cosmopia Inc.)

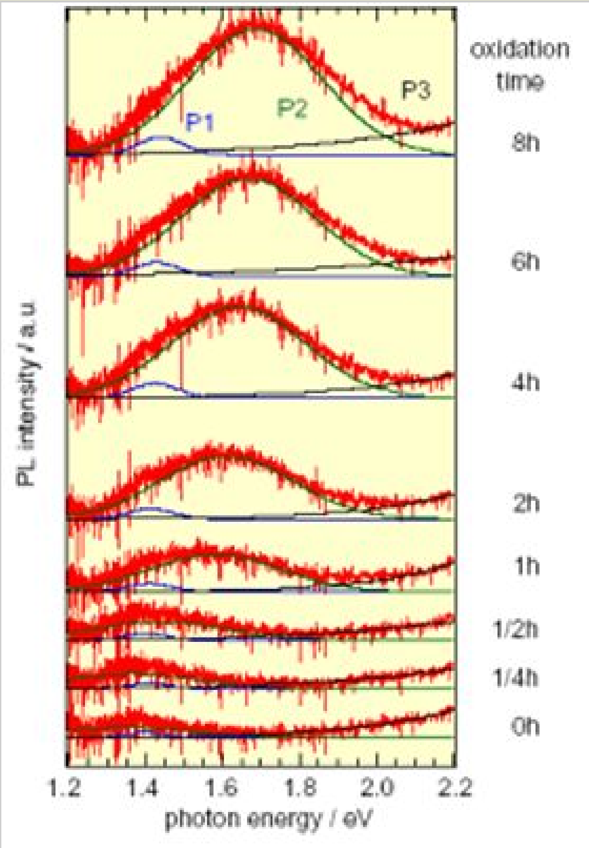

Fig. 3 Large Image
Light emission from nanocrystalline silicon particles
By reducing the size of the particles, quantum effect is utilized in enhanced visible light emission. The particles have the potential for fabricating silicon-based optical devices or optical integrated circuits.

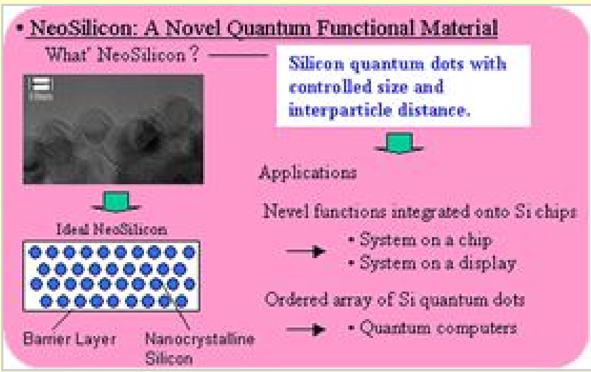

Fig. 4 Large Image
Toward the fabrication of a novel material: NeoSilicon
In NeoSilicon, both particle size and interparticle distance of nanocrystalline silicon particles are precisely controlled. New functions in electron transport, photon emission, and electron emission are expected from quantum size effects within the particle and quantum tunneling effect between particles. NeoSilicon is a third silicon material that is expected to go beyond the conventional single-crystal or amorphous silicon.

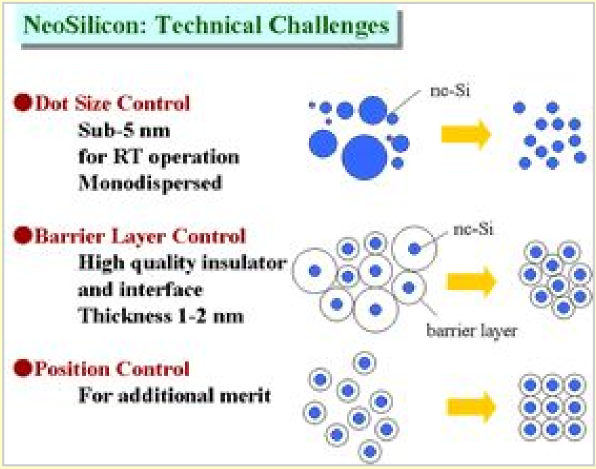

Fig. 5 Large Image
Technical keys to the fabrication of NeoSilicon

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