ODA Shunri "Pioneering Research on Silicon Quantum Dot Devices"

Shunri Oda (born August 7, 1951) is a Japanese physicist and electrical engineer. Oda is famous for pioneering study of nanoelectronics, particularly on silicon quantum dot devices. [1]-[4] He is a Professor Emeritus at Tokyo Institute of Technology, and a Fellow of IEEE and Japan Society of Applied Physics, a Distinguished Lecturer of IEEE Electron Device Society and a member of Engineering Academy of Japan.

Biography:

Born on August 7, 1951 in Tokyo.

Completed B.S. in physics in 1974, D. Eng. in physical processing of information in 1979 both from Tokyo Institute of Technology.

Appointed as a Research Associate of imaging science and engineering in 1979, an Associate Professor of physical electronics in 1986 and a Professor of quantum nanoelectronics in 1995 at Tokyo Institute of Technology. He was a Visiting Scientist, Department of Physics at MIT. In 2017, he became a Professor Emeritus. He was a Research Leader of COI Program at Tokyo Institute of Technology between 2013 and 2018.

Research:

1. Fabrication of amorphous silicon by VHF plasma CVD:
   Amorphous silicon (a-Si) thin films were extensively studied in 1980s because of possible application in solar cells and thin-film transistors for display devices. Researchers fabricate a-Si films by RF plasma CVD using 13:56MHz source frequency. In 1987, Oda fabricated a-Si films by VHF (144MHz) plasma CVD and discovered that deposition rate of a-Si films was enhanced due to high plasma electron density. [5] A Neuchatel group led by Professor A, Shah also published the same work simultaneously. Later, Oda varied the excitation frequency and proposed that plasma source frequency should not be a "fixed" parameter, but a "variable" parameter to optimize plasma CVD apparatus.[6] Many industrial companies use VHF plasma to deposit a-Si films for solar cells and thin-film transistors for display applications, and for etching to form microstructure in integrated

circuit processes.

2. Fabrication of nanocrystalline Si and its application to quantum dot devices:
Oda invented a fabrication method of nanocrystalline silicon with controlled size based on an idea that separation of nucleation and crystal growth processes by pulsed supply of precursor gases in the VHF plasma. [7] He studied novel properties of nano-scale silicon quantum dots such as single-electron tunneling, high efficiency light emission due to quasi-direct transition, and high efficiency electron emission, and demonstrated various possibilities for the application of ultrahigh sensitivity sensors, low-power consumption devices, silicon-based light emitters and electron emitters for display devices. He also studied high density non-volatile memories based on nano-electromechanical devices. [8]

3. Study of quantum information processing devices based on coupled Si quantum dots:
Semiconductor quantum dots had been investigated mostly for compound semiconductors because of lighter carrier effective mass hence easy manifestation of quantum size effects. It turned out, however, coherence time of electron spins in compound semiconductors was too short for qubit application because of the existence of nuclear spins in compound semiconductors. On the other hand, Si with heavier effective mass compared with compound semiconductors is required small size fabrication processes to manifest quantum effects but inherently has longer spin coherence time. Moreover, high-density integration is possible owing to matured CMOS process technology. A group at Tokyo Teck led by Oda prepared physically defined multiple coupled quantum dots by the combination of electron beam lithography and anisotropic etching. They demonstrated Pauli spin blockade and a few electron regimes which were essential for quantum spin operation and paved the way to the application of quantum computing. [9]

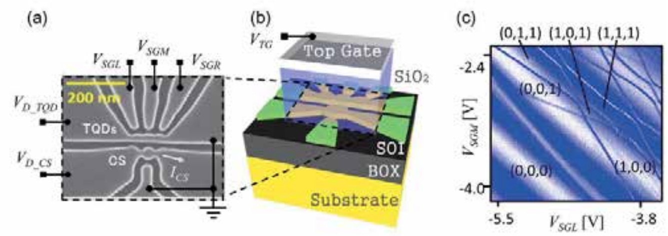

Fig. 1(a) SEM image of a physically defined triple-quantum dot with a charge sensor SET. (b) Schematic device structure. (c) Transconductance, d*ICS*/d*VSGL*, of the CS as functions of *VSGM* and *VSGL*. *n*, *m*, and *l* in (*n*, *m*, *l*) indicate the number of electrons confined in the left, middle, and right QDs, respectively. A few-electron regime is clearly indicated. *VTG* = 2.0 V, *VD_TQD* = 0.8 mV, *VD_CS* = 3 mV and *VSGR* = −1.3 V. [9]

Oda and scientists in Cambridge University has been collaborated in the area of nano-scale devices for more than a quarter of century since 1991. MEXT-JSPS Kakenhi, JST-CREST/SORST, JSPS-

IRCP, Global-COE supported this collaboration program. Three of Cambridge PhD graduates worked in Oda-Laboratory as postdocs, together with total 16 postdocs from U.S.A., India, China, etc, published excellent results and found good positions at world famous research institutions, making Oda-laboratory as a global career step for young researchers.[10-12]

4. Fabrication of oxide superconductors and high-k dielectric thin films:
   Oda prepared oxide high-temperature superconducting thin-films, for the first time, by atomic layer CVD methods. Combined with in-situ atomic scale growth monitoring by spectroscopic ellipsometry, he successfully prepared very smooth surface thin-films and demonstrated superconductivity properties from a few molecular layer ultra-thin films.[13] He applied this method also to fabricate high dielectric constant thin-films, which contributed to fabricate smaller scale CMOS integrated circuits and hence gave a great impact to ULSI industries such as Intel Corporation.

5. A COI project, Happiness Co-Creation Society through Intelligent Communications:
   A project called "Happiness Co-Creation Society through Intelligent Communications", one of the Center-of-Innovation programs (2013-2022), sponsored by the MEXT, the Japanese Government, is carried out at Tokyo Institute of Technology. Oda organized the project as a Research Leader together with Dr. Akiba (former Director of KDDI Laboratories) as a Project Leader. 16 institutions (universities, companies, local governments) joined this project. 40 faculty members of Tokyo Tech participated in this program. The aim of this project is to create the Happiness Co-Creation Society, where people's mind is tied in a variety of bonds with increased empathy and compassion and people are active and live vividly.

   Development of information communication technologies has been focused on the increase of quantity of the communications by extending higher frequency ranges. However, conventional text-based information communications may cause misunderstanding particularly in case of a dialog between different groups of generations, gender or cultural background. Intelligent communications may solve these problems by the aid of "happiness sensor" and retrieving additional information of personal record of the counterparts. In order to realize the intelligent communications, it is necessary to develop technologies for analysis of big-data, any-place any-time communications in all frequency bands, and zero-power wearable devices that require no recharging, relying instead on low-power devices utilizing energy harvesting.

   In order to realize Happiness Co-Creation Society, they develop revolutionary heart-to-heart communication which can interpret and convey people's minds as well as the on-site atmosphere and can read the meaning between the lines. They call it intelligent communications and will create pioneering new services for implementation into society. They develop innovative core technologies consisting of AI technology for experience database and fuzzy search, device technology for wearable recharge-free zero-power happiness sensors and actuators, and all band intelligent communication platform technology with advanced network security. [14]

After retirement from Tokyo Tech, Oda continued the Research Leader for one year. After April 2018, Prof. H. Wakabayashi took over the position and project goal was changed to "The Earth Inclusive Sensing Empathizing with Silent Voices".

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