FURUKAWA Seijiro, "Research and Development on Semiconductor Materials and Process Technologies for High-frequency and Highly Integrated Devices"

1. Biography：

Born on 11th February 1934 and passed away in 1993.

1956 Bachelor of Engineering (Electric Eng.), Tokyo Inst. Tech.
1961 Doctor of Engineering (Electric Eng.), Tokyo Inst. Tech.
1961 Research Associate, Precision and Intelligence Lab., Tokyo Inst. Tech.
1963 Associate Professor, Faculty of Sci. & Eng., Tokyo Inst. Tech.
1973 Professor, Precision and Intelligence Lab., Tokyo Inst. Tech.
1975 Professor, Interdisciplinary Graduate School of Sci. & Eng., Tokyo Inst. Tech.

Concurrent posts: 1986-88: Director of Information Center for Research Exchange, 1987-90: Councilor, 1990-1992: Dean of Interdisciplinary Graduate School of Sci. & Eng.

The Senior Forth Rank and the Third Order of the Rising Sun, Gold Rays with Neck Ribbon (1993), Commendation for Sci. & Technol. by the Governor of Tokyo (1993), Fellow; IEEE (1988), Seiichi Tejima Paper Award (1988, 1982), Kurata Award (1971), Inada Award (1959).

2. Research Summary

Prof. Furukawa has conducted pioneering research and development on microwave oscillation devices and semiconductor integrated circuits, which form the backbone of modern electronics, in terms of both materials and device processing technologies. In particular, he has made important contributions to the development of theories essential for the practical application of ion implantation methods and the integration technologies of different materials beyond the realm of semiconductors.

3. Research Results

(1) Mechanism analysis of microwave oscillation by semiconductor diodes

At a time when research on using semiconductor diodes instead of vacuum tubes for microwave oscillation was gaining momentum, especially in U.S., he focused on the phenomena of diodes operating with high output power and high efficiency in a specific operating mode, and proposed the operating mechanism (presented at the Solid-State Device Research Conf. in 1968 [1]). This had a great impact on the worldwide discussion at the time, and contributed to the subsequent development of this field.

(2) Establishment of the theory of the ion implantation method into semiconductors

At the dawn of the ion implantation method, which is now a major technology for doping impurities in semiconductors, he theoretically considered the distribution of implanted ions in the structure peculiar to semiconductor devices, and contributed to the practical application of the ion implantation method. Specifically, he clarified that the lateral spread of implanted ions from the edge of the shielding mask could not be ignored [2], and that when ions are implanted into a two-layer structure made of different materials, such as the SiO_2/Si structure essential for Si-MOS devices, a step in the ion concentration distribution occurs at the interface [3]. The papers summarizing these results are still widely cited today.

(3) Proposal and experimental study of three-dimensional integrated circuits consisting of hetero-structures of different semiconductor materials

As a basic technology to greatly develop the functionality of integrated circuits, he proposed to stack various semiconductor materials with non-semiconductor materials such as dielectrics and metals at the crystal level. Furthermore, he pointed out that the surface energy mismatch is a problem in fabricating such heterostructures of different materials, and presented an effective solution.

Specifically, a single crystal of cobalt silicide ($CoSi_2$) was uniformly grown on Si crystals [4], and this was processed into stripes to realize a permeable base transistor with a Si/$CoSi_2$/Si structure [5]. In addition, heteroepitaxial growth of insulating fluoride thin films such as CaF_2, SrF_2, and BaF_2 and semiconductor thin films such as Ge [6] and GaAs [7] on Si substrates was carried out to realize a semiconductor on insulator (SOI) structure suitable for high-speed device operation. In the experiments to fabricate this stacked structure, there was a problem that the semiconductor film did not grow uniformly due to the low surface energy and poor wettability of the fluoride film, but it was shown that this problem could be solved by modifying the fluoride surface by electron beam irradiation [8].

This research on heterostructures composed of various materials can be regarded as a pioneering work on three-dimensional integrated circuits, and now, 30 years later, three-dimensional integrated circuits are one of the most important technologies and are changing the world.

4. Contribution to Society

He has served as the Editor-in-Chief and Director of the Japan Society of Applied Physics (JSAP), the Chair of the Solid State Physics and Applications Division of JSAP, the Chair of the Electronic Devices Committee of IEICE, the Chair of the Electronics Group of IEICE, the Chair of the ED Group of IEEE Tokyo Section, and the Vice Editor-in-Chief of IEEE T-ED Asia Region. He has also served as an expert member of the Science Council (Ministry of Education), the Council for Science and Technology (Science and Technology Agency), and other national committees.

5. Representative Papers [Number of citation based on “Research gate”]

1) S. Furukawa, “(1) Generation of microwave by solid-state devices”, Electronics Mater. **29**, No.1-3 (1990) (in Japanese)
2) S. Furukawa, H. Matsumura and H. Ishiwara, “Theoretical consideration on lateral spread of implanted ions”, Jpn. J. Appl. Phys., **11**, 134 (1972) [208]
3) S. Furukawa and H. Ishiwara, “Range distribution theory based on energy distribution of implanted ions “, J. Appl. Phys., **43**, 1268 (1972) [50]
4) S. Furukawa and H. Ishiwara, "Epitaxial silicide films for integrated circuits and future devices", Jpn. J. Appl. Phys. Suppl., **22-1**, 21 (1983) [26]
5) K. Ishibashi and S. Furukawa, “SPE-$CoSi_2$ sub-micrometer lines by lift-off using selective reaction and its application to a permeable-base transistor”, IEEE Trans. on Electron Devices, **ED-33**, 322 (1986)
6) S. Kanemaru, H. Ishiwara and S. Furukawa, "A novel heteroepitaxy method of Ge films on CaF_2 by electron beam exposure", J. Appl. Phys., **63,** 1060 (1988) [29]
7) K. Tsutsui, T. Nakazawa, T. Asano, H. Ishiwara and S. Furukawa, "MESFETs on a GaAs-on-insulator structure", IEEE Electron Device Lett., **EDL-8**, 277 (1987) [17]
8) H. C. Lee, H. Ishiwara, S. Kanemaru and S. Furukawa, "A novel electron-beam exposure epitaxy for growing GaAs films on fluoride/Si structures", Jpn. J. Appl. Phys., **26**, L1834 (1987) [14]

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