1996-KH-E-Tokyo-Tech-EEIC-Engrg

KUKIMOTO Hiroshi, (1937 – 2022) “Control of Deep Levels in Semiconductors and Application for High-Efficiency Light-Emitting-Devices”

1. Biography

Born in Kagoshima Prefecture in 1937. Graduated from Univ. of Tokyo, B. Eng. in applied physics in 1961, and D. Eng. in 1966. Appointed as a Research Associate at the Institute of Solid-State Physics, Univ. of Tokyo, and then as a Researcher at Bell Laboratories. Appointed as an Associate Professor at Imaging Science and Engineering Laboratory, Tokyo Institute of Technology in 1972. Resigned as a Professor in 1996 and joined Toppan Printing Co Ltd as a Board Member, then Vice-President in 2003. Nominated as a Board Member of JCV Kenwood Corp. in 2010.

2. Abstract

Kukimoto Hiroshi developed measurement technologies for deep levels in compound semiconductors which he had explored at Bell Laboratories into Tokyo Institute of Technology, and established application for high-efficiency light-emitting devices. Particularly, he clarified the nature and origin of DX center in AlGaAs and established high-quality crystal growth method by metalorganic vapor phase epitaxy. These two discoveries significantly contributed high-efficiency and long-lifetime light-emitting diodes and double-heterostructure semiconductor lasers, highly appreciated in the world.

3. Research Summary

3.1 Clarification of the nature and origin of DX center in AlGaAs.

An AlGaAs alloy system had attracted much attention in the field of high-speed and opto-electronic devices because it forms high-performance selective doped hetero-structures. The problem was the formation of deep-level defects called “DX center”, which degrade device performance, with increasing Al concentration in the alloy. The nature and origin of the DX center were not known and subject of controversy. A group led by Prof. Kukimoto clarified, for the first time, the origin of the DX center was due to the change of band structure, through the experiment of hydrostatic pressure applied to GaAs. [1] Based on this discovery, research activities of hetero-structure devices such as high-speed transistors and semiconductor lasers were expanded significantly throughout the world. As a consequence, high-speed wireless communication systems and optical communication systems were

commercialized, and information and communication technology society were established.

3.2 Preparation of low-resistivity p-type ZnSe films by MOVPE.

ZnSe is a wide-bandgap semiconductor and is useful for a short-wavelength light emitter. Many researchers tried to form pn-junction devices. The problem was that deep level defects were formed when acceptor impurities were doped, resulted in p-ZnSe with high resistivity, not useful for device applications. A group led by Prof. Kukimoto successfully prepared low-resistivity p-ZnSe epitaxial films, for the first time, by using newly developed Metalorganic Vapor Phase Epitaxy method. [2] They also prepared pn-junction diodes based on ZnSe and observed blue light electroluminescence.

This work led extensive researches of thin-film crystal growth of high-quality wide-bandgap semiconductors. As a consequence, low-power consumption light sources were commercialized and spread throughout the world.

3.3 Fabrication of ZnS blue LEDs by deep level defect control.

Professor Kukimoto started research on blue light-emitting-diodes much earlier. It was difficult to dope n-type impurities in ZnS because of the formation of deep level defect of Zn vacancy. His group prepared ZnS single crystals from the melt under high-pressure. The as-grown high-resistivity crystals were fired in a molten mixture of Zn and Al, and they were quenched immediately in water. This treatment reduced the resistivity by 10^{10}. They successfully prepared ZnS blue-light-emitting-diode with an external quantum efficiency of 5×10^{-4}, the highest value at that time. [3]

4. Remarks

Professor Kukimoto resigned Tokyo Institute of Technology in 1996, two years before the retirement age, and joined Toppan Printing Co Ltd. as a board member, then became a Vice President in 2003. He showed strong leadership in research and new business area developments. As an engineer, his goal is not limited within academic research, but should be achieved by industrialization.

5. References

[1] M. Mizuta, M. Tachikawa, H. Kukimoto and S. Minomura, “Direct evidence for the DX center being a substitutional donor in AlGaAs alloy system, Jpn. J. Appl. Phys. Vol, 24, L143 (1985).

[2] T. Yasuda, I. Mitsuishi and H. Kukimoto, “Metalorganic vapor phase epitaxy of low-resistivity p-type ZnSe”, Appl. Phys. Lett. Vol. 52, 57 (1988).

[3] H. Katayama, S. Oda and H. Kukimoto, “ZnS blue-light-emitting diodes with an external quantum efficiency of 5×10^{-4}”, Appl. Phys. Lett. Vol. 27, 697 (1975).

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