【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Engineering)

Title of Project : Formation of Self-Aligned Super-Atom-Like Si-Ge Based Quantum Dots and Characterization of their Optical and Electrical Properties

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【Purpose and Background of the Research】

Light emission from Si-based nanostructures including Si quantum dots (QDs) has attracted considerable interest because of its potential advantage in combining both photonics and electronics on a single chip. In this research, we have studied strain- and valency-controlled Si-Ge based QDs, each of which has a pseudo-super atom structure consisting of Si clad and Ge core, to enhance both the carrier injection rate and carrier recombination for light emission. Especially, we focus on study of carrier recombination dynamics in the Si-Ge pseudo-super atom structures for a current injection type Si-Ge based QDs laser.

【Research Methods】

We design and fabricate three-dimensionally (3D) ordered arrays of self-aligned Si-QDs with Ge core with an areal density as high as ~10^{13} cm^{-2} on the basis of our previous achievements (Fig. 1), and study the impact of strain in and valency control of QDs on light emission. Even in indirect-transition semiconductors such as Si and Ge, by downsizing to the nanometer scale and by applying structural strain, pseudo-direct optical transitions can be caused and, as a result, light emission efficiency is expected to be enhanced markedly. Thus, super-atom-like Ge-core/Si-shell QDs structure is thought to be potential for high-efficient light emission.

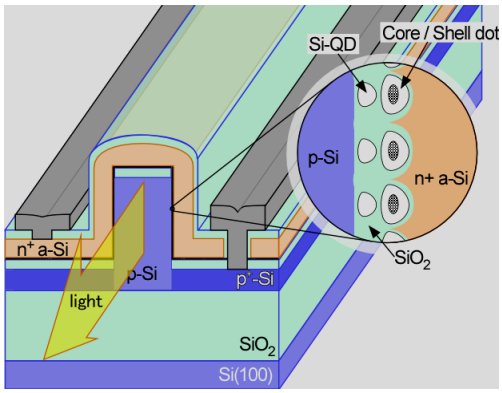

Figure 1 A schematic view of a proposed high-efficient electroluminescence device using self-aligned Si-based core-Si-QDs proposed in this research, we expect that the carrier tunneling probability between upper and lower dots is increased markedly in comparison to the case of random stacked dots structures. In addition, delta-doping of either P or B atoms into the Si-shell or Ge-core will lead us to an increase in the carrier injection efficiency. With a high density formation of self-aligned Ge core Si-QDs on a Si pillar as an optical cavity, we will be able to gain advantages of stimulated radiation and optical amplification at a specific wavelength.

【Expected Research Achievements and Scientific Significance】

We will demonstrate high efficiency light emission from super-atom-like Si-based QDs, and design and fabricate device structures with 3D ordered arrays of self-aligned QDs for lasing operation. The results obtained in this research will lead to the development of current-injection type Si-based laser very compatible with Si-ULSI processing and open up optical interconnection in a chip as for advanced silicon photonics.

【Publications Relevant to the Project】

・K. Makihara, K. Kondo, M. Ikeda, A. Ohta and S. Miyazaki, Photoluminescence Study of Si Quantum Dots with Ge Core, ECS Trans., Vol. 64, No. 6, 2014, pp. 365-370.
・K. Makihara, H. Deki, M Ikeda and S, Miyazaki, Electroluminescence from One-dimensionally Self-Aligned Si-based Quantum Dots with High Areal Dot Density, Jpn. J. Appl. Phys., Vol. 51, No. 4, 2012, 04DG08 (5 pages).

【Term of Project】 FY2015-2018

【Budget Allocation】 152,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.nuee.nagoya-u.ac.jp/labs/miyazakilab/