Passivation effects of 3D Array of Si-nanodisks Fabricated with Bio-template and Neutral Beam Etching Process for Photovoltaic Application

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We proposed and have been researching the formation of quantum nanodots of less than 10 nm in size by means of a top-down process using a low-energy neutral beam capable of defect-free processing. An advantage of the top-down process is that it can form nanostructures with an arrangement that can be uniformly controlled no matter what combination of materials is used. Instead of photolithography, we used a bio-template as proposed by Yamashita et al.[1)] as an etching mask with dots of a few nm in size. The biological super-molecule (protein), ferritin has a diameter of 12 nm, and 7 nm internal cavity. There is a negative charge inside this cavity, and when ferritin is put into a solution containing dissolved Fe ions, these Fe positive ions are introduced into the cavity of ferritin molecules to form iron oxide cores. These iron cores are 7 nm in diameter. Ferritin molecules containing these iron cores are selectively placed in a two-dimensional arrangement on a silicon oxide film, and the protein is then removed by UV/ozone or heat processing, leaving behind the 7 nm iron cores on the substrate for use as an etching mask.[2)] Finally, Cl_2 based neutral beam that can anisotropically etch any kind of surface materials using the etching mask of 7 nm iron cores was used to etch the poly-Si followed by isotropic etching of surface SiO_2 by NF_3/hydrogen radical treatment. After that, 2D iron core array was removed by hydrochloric acid solution. We are using this process to develop quantum-effect devices with a quantum nanodisc structure. A nanodisc is a nano-scale cylindrical structure whose height (thickness) is smaller than its diameter. The sub-10-nm quantum nanodiscs are formed in an array configuration with uniform spacing. The 3D array of Si-NDs consisting of 4 stack layers of 2~6 nm thick Si-ND layer and 2 nm SiC interlayer being deposited alternately onto P-type Si-substrate with the density of ~7×10^{11} cm^{-2} (Fig.1). In this study, we passivated the side walls of the nano pillars by a thin layer (~2nm) of atomic layer deposited aluminum oxide (ALD-Al_2O_3) to eliminate the interface defects in between SiC interlayer and QD to minimize the carrier recombination that hampers the photovoltaic performance. Conductive atomic force microscopy (C-AFM) measurement was carried out to investigate the current leakage between QDSL and its substrate. From the current voltage (*I-V*) relationship in Fig. 2, it is clearly evidenced that the current leakage is drastically minimized to zero when the QDSL is passivated with ALD-Al_2O_3. Based on these results, size effects of 3D Si-NDs (2~6 nm) with SiC (2 nm) interlayer in QDSL structure will be discussed.

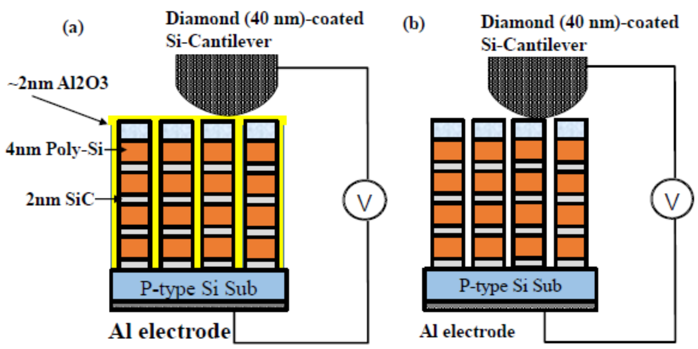

Fig.1. Schematic structure of QDSLs with (a) ALD-Al_2O_3 passivation and (b) without passivation.

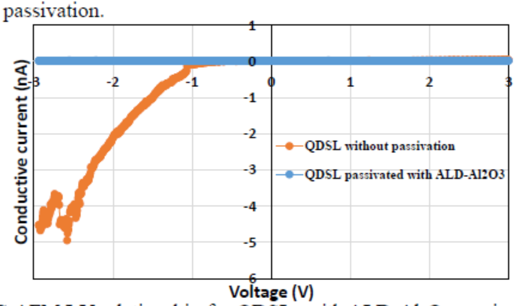

Fig.2. C-AFM I-V relationship for QDSLs with ALD-Al_2O_3 passivation and without passivation.

[1] I. Yamashita, Thin Solid Films **393** (2001) 12.

[2]. C. Huang. M. Igarashi, R. S. Horita, M. Takeguchi, Y. Yraoka, T. Fuyuki, I Yamashita, S. Samukawa, Japanese Journal of Applied Physics **49** (2010) 04DL16.