Nanocrystalline Si dot assembly based on the Langmuir-Blodgett method

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The bottom-up approach to form nanometer-scaled silicon structures is attracting more attentions as an alternative way of developing future quantum nanoelectronics devices since maintaining the conventional top-down miniaturization trend is getting harder due to fundamental physical and technological limitations as well as of the economical limitation. Nanocrystalline silicon (nc-Si) quantum dots [1,2] are particularly a promising material and various new device applications have been explored based on their unique electronic and photonic properties In this paper we report on a new bottom-up technique of high-density assembly of the nc-Si quantum dots based on Langmuir-Blodgett (LB) technique. We previously studied preparation of nc-Si dot dispersion solution using various kinds of solvent. We also demonstrated high-density assembly of the nc-Si dots based on drop and evaporation of the dots solutions [3]. At the same time, however, we learned the drop and evaporation method is very sensitive to temperature, humidity, and vapour pressure of the solvent, and it is difficult to control all these parameters precisely. We therefore need a more efficient method that enables to realize higher-density assembly of the nc-Si dots. In the present work we examined applying the LB technique which has been used widely for assembling various kinds of nanoparticles.

Nanocrystalline Si dots with a diameter of 8 nm were deposited on the Si substrates by using VHF plasma decomposition of pulsed SiH_4 gas supply. The samples were put into a solvent immediately (within one minute), and ultrasonic treatment was conducted for 30 minutes. The solvent consists of chloroform ($CHCl_3$, main solvent to spread on water), HMDS ([(CH_3)3Si]2NH, a silane coupling agents for covering the nc-Si dots both for preventing the reaction with pure water and for making the dots float). Next, remaining HMDS were removed by using the two-phase separation technique with pure water. After these processes, the nc-Si dots solution was dropped and spread on pure water, and the nc-Si dots were then assembled by using the LB method (Fig.1). Figure 2 shows the SEM image of the assembled nc-Si dots. We could achieve the areal dot density of approximately 1.8 x 10^{12} cm^{-2} which is fairly close to the close packing of the spheres with a diameter of 10 nm.

References

[1] T.Ifuku, M.Otobe, A.Itoh, and S.Oda, *Jpn. J. Appl. Phys.* **36**, 4031 (1997).
[2] K.Nishiguchi, S. Hara, and S. Oda, *Mat. Res. Soc. Symp. Proc.* **571**, 43 (2000)
[3] A.Tanaka, Y.Tsuchiya, K.Usami, H.Mizuta, and S.Oda, AMN-2, February 2005

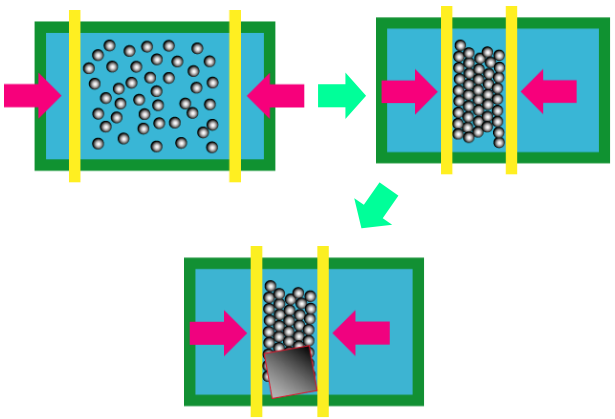

Fig. 1 schematic image of LB method

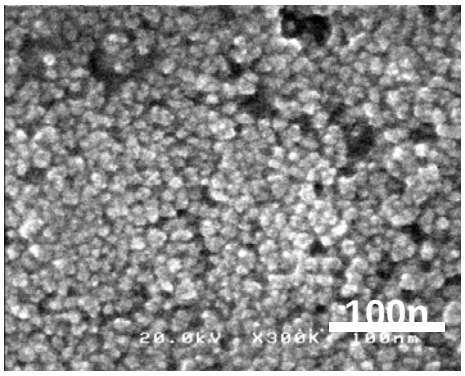

Fig. 2 SEM image of assembled nc-Si dots obtained by LB method