Program Number: S8.3 **Day / Time:** Thursday, Dec. 1, 2:15 PM - 2:30 PM

Location - Controlled Si Grains via Laser Crystallization of Liquid - Silicon.

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In the flexible electronics, printing is promising as it enables non-vacuum and non-photolithography process hence a low-cost production. Organic semiconductor materials have been investigated for the printing, however carrier mobility and reliability are inferior in comparison with silicon devices. New material, liquid silicon, which is a hydrogenated polysilane in an organic solvent, offers us a chance to print silicon devices on a flexible substrate. Shimoda, et al. [1] succeeded in fabricating polycrystalline Si TFTs with laser crystallization of amorphous-Si precursor formed from the liquid-Si. However the performance is limited by the grain boundaries in the channel because of the random nature of the poly-Si grains. If the location of the grains can be controlled, TFTs can be fabricated inside the grain and performance would reach the crystalline-Si counterpart. This will realize high-speed circuits in the flexible electronics and may alter the fabrication process in ULSI. In this paper, we investigated to control location of each Si grains with laser crystallization of a-Si formed by spin-coated liquid-Si. We have succeeded to form grains with a diameter of 1.5 um at predetermined positions.

We used the micro-Czochralski process [2] to control the position of Si grains. First, a grid of 100nm wide and 700nm deep holes (grain-filter) have been formed in 1.6 micron thick SiO_2 on a crystalline Si substrate. 21-wt% solution of UV-irradiated CPS (liquid Si) was then spin-coated on the structure at a rotation speed of 2000 rpm and baked at 430 °C for 60 min to remove the solvent and to form a-Si. The film thickness was 112 nm. Next the film was pre-annealed in a furnace at 650 °C for 2 hours to dehydrogenate the a-Si film. Finally the sample was crystallized with XeCl excimer laser (308nm, 25ns) at a substrate temperature of 450 °C, with fluences varying from 450 to 700 mJ/cm^2. Hydrogen concentration of a-Si film measured with TOF-SIMS was decreased from 6.7e21cm^{-3} to 2-5e19cm^{-3} after the furnace annealing. Film density, measured by XRR, increases from 1.96g/cm^3 to 2.328g/cm^3, of which the latter is exactly the same as that of the crystalline Si substrate. Upon laser irradiation the Si grains have been obtained and the size increased with the energy density. Ablation, which occurs at an excess energy density, increases from <200 to 1000mJ/cm^2 after the pre-annealing, because of the degassing and densification. With an energy density just below the ablation threshold, we have obtained Si grains with a maximum size of 1.5um. Those Si grains were successfully grown on top of the predetermined positions of the grain-filters. [1] T. Shimoda, et al., Nature 2006 [2] R. Ishihara, et al., Thin Solid Film 2003

Citation: J.Zhang, R.Ishihara, H.Tagagishi, R.Kawajiri, T.Shimoda, K.Beenakker. Location - Controlled Si Grains via Laser Crystallization of Liquid - Silicon.. Program No. S8.3. *2011 Abstract Viewer.* Boston, MA: Materials Research Society