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Multi-Tunnelling Junctions of Metal Droplets Formed on CaF2 Stepedges by Self-Assembling Manner

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Single electron devices are interesting for future integrated circuits with high density and low-power consumption. Not only semiconductors but also metals are candidates to form tunnel junctions for these devices. Nowadays, most of them have been fabricated by using lithographic technique skillfully [1, 2]. In this work, one dimensional arrays of metal droplets with high density were fabricated on surface stepedges of epitaxial CaF_2 film in a self-assembling way and a possibility of formation of lateral multi-tunneling junction for single electron devices was shown.

An epitaxial CaF_2 film (20 nm) was grown on a Si(111) substrate at 800°C. After that, Ga was deposited on the CaF_2/Si substrate from a solid source effusion cell with a flux of approximately 1.25 x 10^{14} atoms/cm^2 s. The substrate temperature was varied ranging from 20°C to 500°C and background pressure was less than 6 x 10^{-9} torr during the Ga deposition. The amount of Ga deposited was controlled by deposition time (10 - 110 sec.) and it was monitored *in situ* with a SPA like optical method. The formed Ga droplets were observed by a high resolution SEM. In addition, Al electrodes with a narrower gap were formed by usual PMMA lift-off process for device fabrications.

Figure 1 shows the SEM images of Ga droplets deposited on the CaF_2/Si substrate at (a) 20°C, (b) 300°C and (b) 500°C. Ga droplets are observed along stepedges of CaF_2 at lower temperatures (a), (b) while no Ga droplets are observed at high temperature (c). Especially at 20°C, Ga droplets of which sizes are less than 10 nm were well-ordered along the stepedges with high density. Figure 2 shows the mean droplet size; *d* and the mean distance between two neighboring droplets; *L* depending on amount of Ga deposited at 20°C. The dashed lines show results of Monte Carlo simulation for each quantities under assumption that Ga droplets are grown by coalescence with homogeneous nucleation. We found that *d* and *L* were reduced to a few nanometers as the amount of Ga supplied was reduced, and further reduction of these values is expected from an extrapolation of the experimental results.

Figure 3 shows a SEM image of multi-tunnelling junction diode fabricated in this manner. The droplet size and gap length between droplets are approximately 8 nm and 4 nm, respectively. Electrical characterization is underway now. As well as Ga droplets, we are investigating use of Al as a material to form the droplets which is expected to provide stable tunnel barrier of surface oxide. Characterization of these devices property will be discussed in conference.

References

1) Y. Nakamura *et al.* : Jpn. J. Appl. Phys. **35** (1996) L1465.
2) S. M. Gorwadker *et al.* : Jpn. J. Appl. Phys. **35** (1996) 6673.

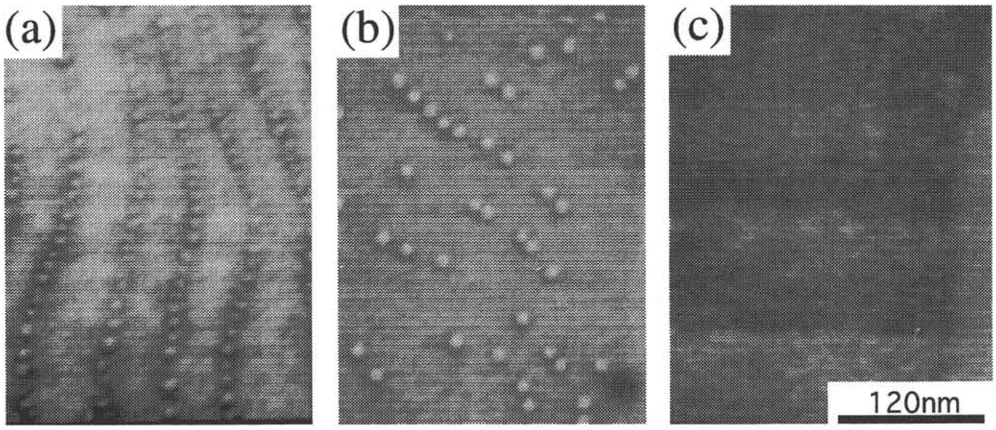

Fig. 1. SEM images of Ga droplets deposited on the CaF_2/Si substrate at (a) 20°C, (b) 300°C and (b) 500°C.

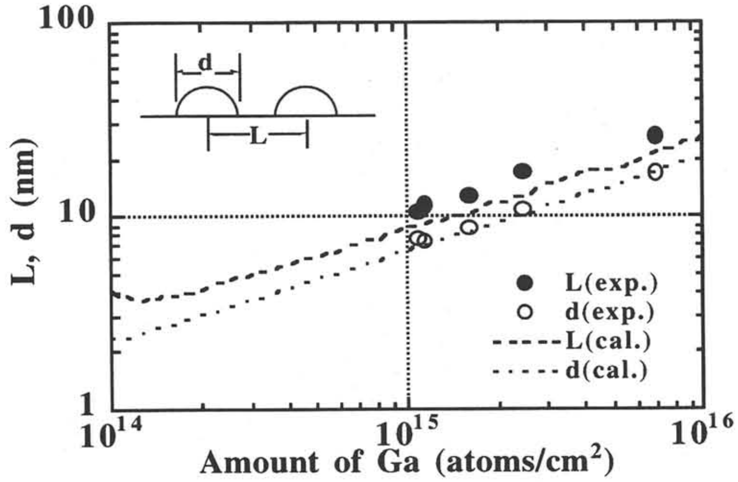

Fig. 2. The mean droplet size; d and the mean distance between two neighboring droplets; L depending on amount of Ga deposited at 20°C. The dashed lines show results of Monte Carlo simulation for these quantities under assumption that Ga droplets are grown by coalescence with homogeneous nucleation.

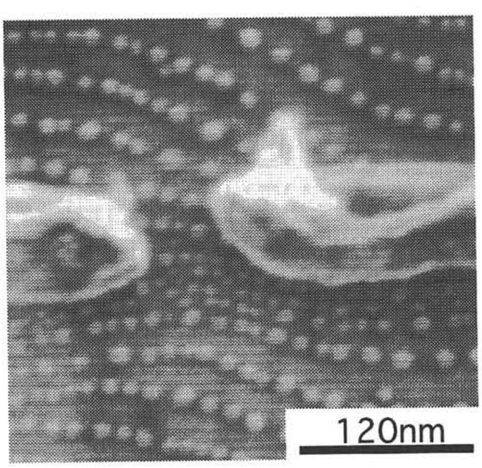

Fig. 3. A SEM image of a multi-tunnelling junction diode fabricated by formation of droplets in self-assembling manner and Al narrow gap electrodes using EB lithography.