Si Quantum Dot Formation Process Technology and Optically Coupled MOS Devices

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● Integration of Light and MOS transistor

In the research field of "Nanodevices and Processes", the integration of light and MOS devices is a quite important issue. The conventional MOS integrated circuits have metal interconnection, while implementation of optical interconnection will realize more functionality in MOS devices. In order to realize such idea, we introduced Si nano structure into the gate insalator of MOS transistor.

● Optical input multi-valued memory device using Si quantum dots

We have developed process technology for self-assembling formation of Si quantum dots with the typical size of 10 nm on SiO_2 using SiH_4 low-pressure chemical vapor deposition (LPCVD) method. By the introduction of Si dots, quantum effects such as resonant tunneling have been observed at room temperature. Furthermore, we have observed hysteresis in the I_d-V_g characteristics of MOS transistors utilizing Si quantum dots as the floating gate memory nodes, which indicates multi-valued memory operation. This is due the stepwise injection of electrons to the dots. Based on these results, we aimed stepwise charge injection into the Si quantum dots by means of optical input, which can realize optically

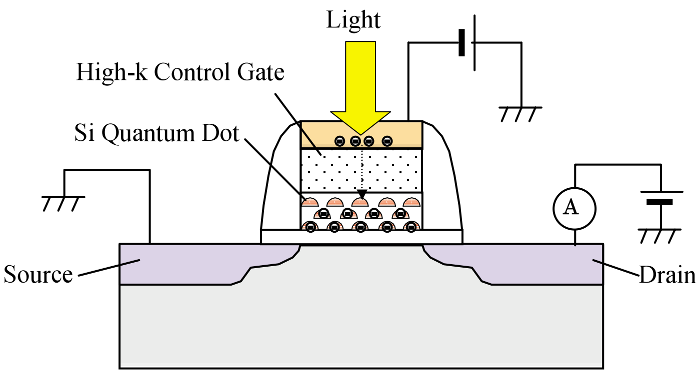


Fig. 1. Schematic diagram of optical input multi-valued memory device with Si quantum dots in the gate insulator, which work as the memory nodes.

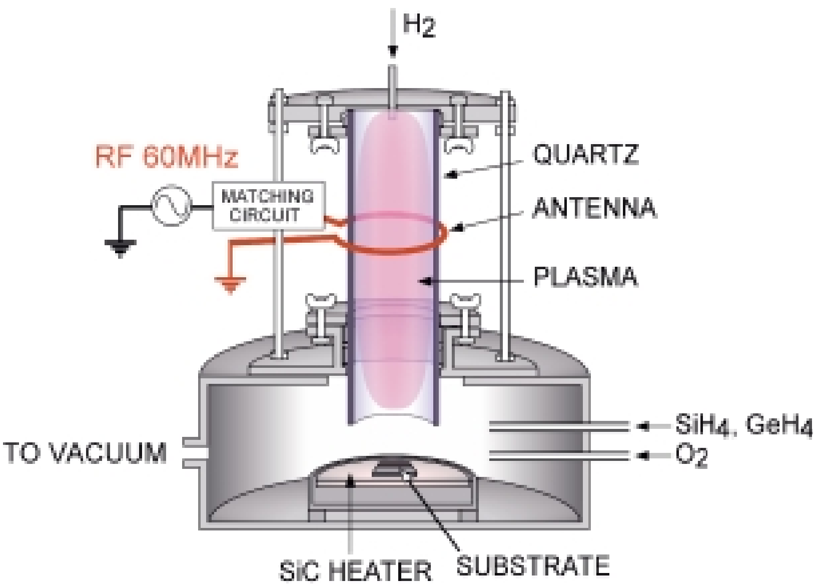
coupled multi-valued memory devices as schematically shown in Fig. 1. Our plan is to develop process technologies that realize such device structure.

● Nucleation control in Si quantum dots formation

In order to realize the Si quantum dots structure as shown in Fig. 1, nucleation control of Si quantum dots on SiO_2 is the key technological issue. It has clarified that the Si-OH bonds at the SiO_2 surface is essentially important for the nucleation of Si quantum dots. In addition, control of surface absorbents on SiO_2 prior to dot formation is also quite important. Based on these results, we try to develop successive dot formation process technologies that can perform in a vacuum chamber. We are developing a LPCVD equipment which has VHF (60 MHz) remote plasma as shown in Fig. 2. We expect hydrogen radicals supplied by the remote plasma can form nucleation sites on the SiO_2 surface. By this technology, formation of nucleation sites and successive dots growth by LPCVD can perform without breaking the vacuum. Furthermore, successive oxidation of dot surface will lead us to vacuum formation of stacked Si quantum dots structure. We have built up LPCVD equipment with remote plasma source and the VHF hydrogen plasma discharge has been achieved. We are proceeding to dots formation experiments.

● Expectations

We expect development of novel semiconductor devices by the approach mentioned above. In addition, we expect the students evolved in the research enjoy the experiment, have unique ideas, and be the leaders of next generation semiconductor electronics field.



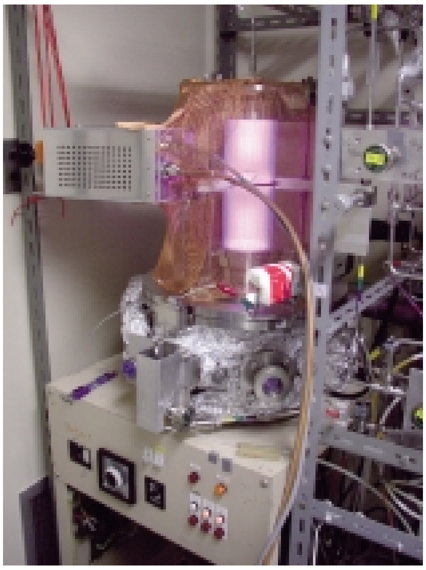


Fig. 2. Schematic diagram of LPCVD equipment with remote plasma source (left) and a photograph of remote hydrogen plasma discharge (right).