Electrical Device Structures Using Fe_2O_3 Nano-Particles Embedded in Polyimide

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We study the electrical properties with temperature variation of Fe_2O_3 nano-particles embedded in polyimide matrix. The metal-oxide nano-particles are fabricated by simple method. After the metal film is grown on a semiconductor or insulator substrate by evaporator, apply spin-coating with polyamic acid which is precursor of polyimide. And then nano-particle is created with 10~30 nm in polyimide after through curing process below 400 °C. We could make several kind of metal-oxide nano-particles by relatively simple method. To control particle condition as density, size or formation, we can modulate metal film thickness, curing temperature, time, etc.

In this experiment, we deposit Fe thin film on the polyamic acid, and spin coat polyamic acid again. After a curing process with 350°C temperature, Fe_2O_3 particles are embedded in polyimide matrix as shown in Fig. 1. Polyimide layer that contain Fe_2O_3 nano-particles in the middle is made on the Si substrate. As then metal floating gate is fabricated on the polyimide, a metal-insulator-semiconductor (MIS) structure is made.

In the measurement of capacitance-voltage (C-V), this structure shows C-V hysteresis (Fig. 2). So, we can think that Fe_2O_3 nano-particles are able to retain electron. This shows possibility to apply single electron memory devices. In our MIS structure with nano-particles, it can be considered that C-V hysteresis curve indicates a charge retaining by nano-particle. Therefore, the total retained charge related with voltage gap in C-V hysteresis as threshold voltage shift is $Q_i = C_i\ dV$. Here, C_i is capacitance of only insulator. Figure 2 shows typical C-V hysteresis shape obtained at room temperature from the sandwich-structure of polyimide/Fe_2O_3 nano-particles/ polyimide. For this structure Fe film is deposited directly on p-type Si substrate. In this structure, the voltage gap is about 8 V and then the charging ratio is estimated about 0.1 electrons per particle. This result shows a feasibility of a memory device such as a floating-gated memory device with semiconductor nano-particles. Figure 3 shows also current-voltage characteristics of MIS with Fe_2O_3 nano-particles as a function of temperature.

The metal-oxide Fe_2O_3 nano-particles are fabricated by using simple and inexpensive method by chemical reaction between polyamic acid and metal films. The charging effect by using polyimide capacitor contained Fe_2O_3 nano-particles of metal-oxide semiconductor, a MIS structure, is measured. It will be discussed also the electron tunneling through nano-particle islands between the nano-electrodes. These results show the feasibility of memory and tunneling devices using the metal-oxide semiconductor nano-particles.

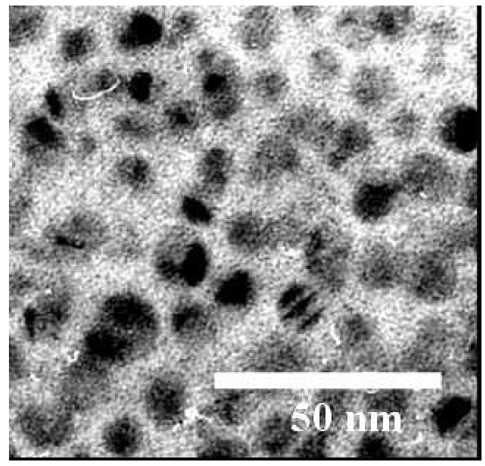

Fig. 1 TEM image of Fe_2O particles with 350°C curing temperature

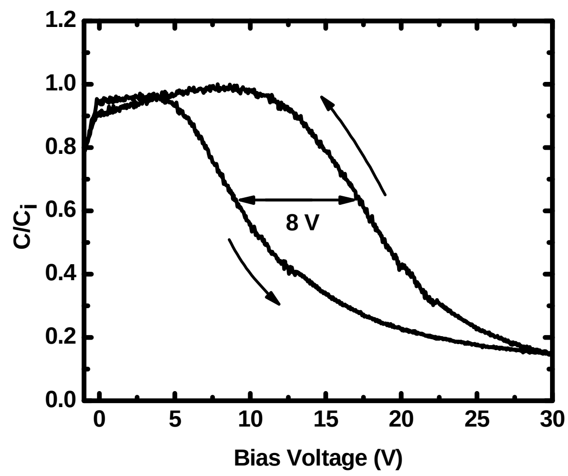

Fig. 2 C-V curve of MIS structure at room temperature

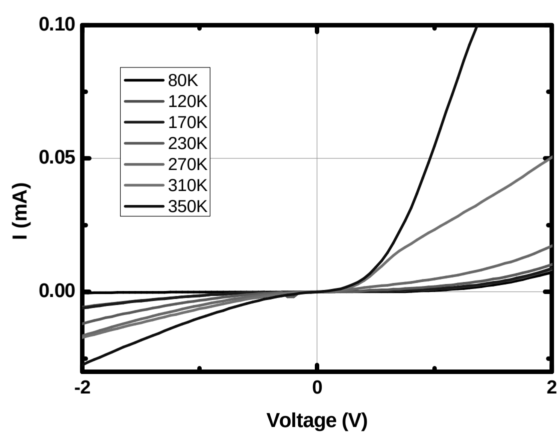

Fig. 3 I-V curve of MIS structure with temperature variation