Extended Abstracts of the 1993 International Conference on Solid State Devices and Materials, Makuhari, 1993, pp. 968-969

Electrical Properties of High Mobility Poly-Si TFTs at Low Temperatures

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Poly-Si TFTs are essential for new devices, such as flat-panel displays. Many studies have been conducted on device fabrication, resulting in high mobility poly-Si TFTs, especially those made from laser-annealed poly-crystallized Si films.[1,2] However, the conduction mechanism in poly-Si TFTs is not yet well known, because of the very complex film structure having grain boundaries. Measurements of poly-SiTFT characteristics at low temperatures and magnetic fields are very useful for clarifying the conduction mechanism. This is the first report of poly-Si TFT electrical characteristics measured at low temperatures and in 1.3 T magnetic fields.

N-channel poly-Si TFTs with Hall bars were fabricated from laser-irradiated sputtered Si films and sputtered gate oxide films 100 nm thick. They showed a field effect mobility of 160 cm^2/Vs at room temperature. As shown in Fig. 1, the poly-Si TFT has Hall electrodes (1,2,··6) in addition to gate (G), source (S) and drain (D) electrodes. Channel length L is 110 μm and width W is 20 μm.

Figure 2 shows temperature dependence of conductivity of the poly-Si TFT from room temperature to 4.2 K. Conductivities at gate voltages of 25 V and 30 V increase with decreasing temperatures down to 220 K. This means that the height of the potential barrier at grain boundaries is very low.[3] The conductivities decrease with decreasing temperature below 200 K even at high gate voltages of low potential barrier. Figure 3 shows the dependences of (a) carrier density and (b) Hall mobility on temperature. Carrier density is nearly independent of temperature for all gate voltages. However, Hall mobilities show a similar temperature dependence to the conductivities (Fig. 2). Accordingly, the conductivity is mainly determined by the Hall mobility, that is, by the carrier velocity rather than by the carrier density. This result suggests that the potential barriers formed by carrier trap states at grain boundaries in poly-Si films drastically influences on carrier velocity (not on carrier density).

Below about 40 K, it was observed that temperature dependence of conductivity obeys $\sigma = \sigma_0 \exp\{-(T_0/T)^x\}$ of variable-range hopping between localized states, where x is $\sim$1/3 or 1/2. In the above temperature range, the negative magnetoresistance indicates nearly linear changes with magnetic field strength, as shown in Fig.4. In particular, the negative magnetoresistance is anisotropic which is indicate of a quantum-interference, orbital mechanism.[4] Thus, the experiments demonstrated that the carrier trap states are strongly localized ones, resulting in variable-range hopping between the states.

In conclusion, carrier velocity plays a more important role than carrier density in the electrical characteristics of poly-Si TFTs over a wide range of temperature. Moreover, it was newly found that carrier velocity is greatly affected by strongly localized states at grain boundaries in poly-Si films. Therefore, the strongly localized states are essentially important to clarify the conduction mechanism of poly-Si TFTs.

Finally, the authors would like to thank A. Okamoto and S. Suyama for helping with poly-Si TFT fabrication, and K. Oto, A. Kudou and Y. Tutui for measuring the electrical characteristics.

References:
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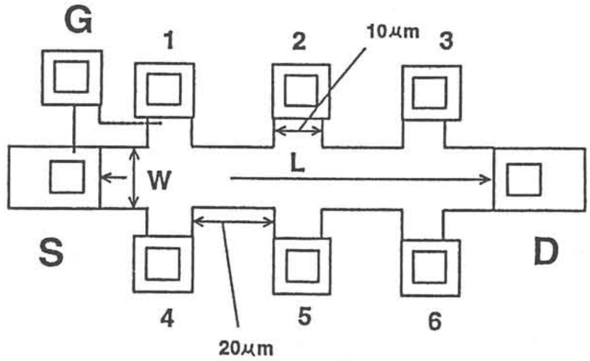

FIG.1: Structure of poly-Si TFTs used for measurements.

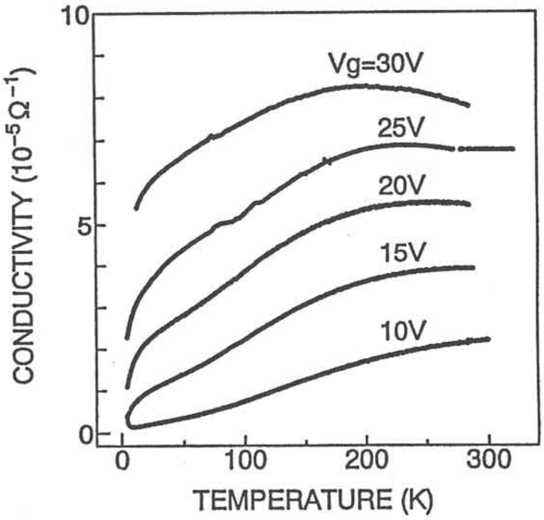

FIG.2: Dependence of conductivity on temperature.

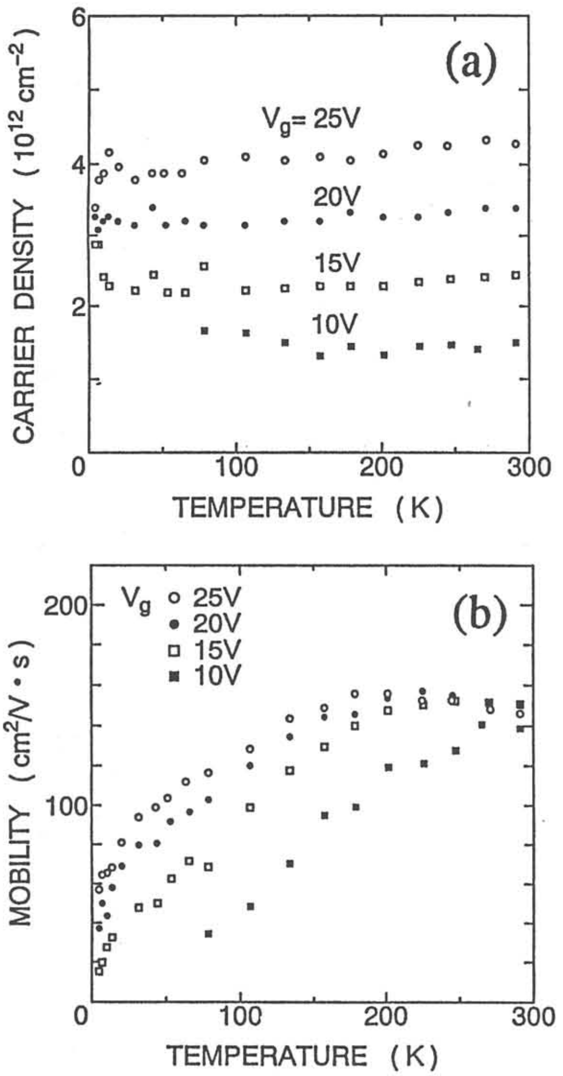

FIG.3: Dependences of (a) carrier density and (b) Hall mobility on temperature.

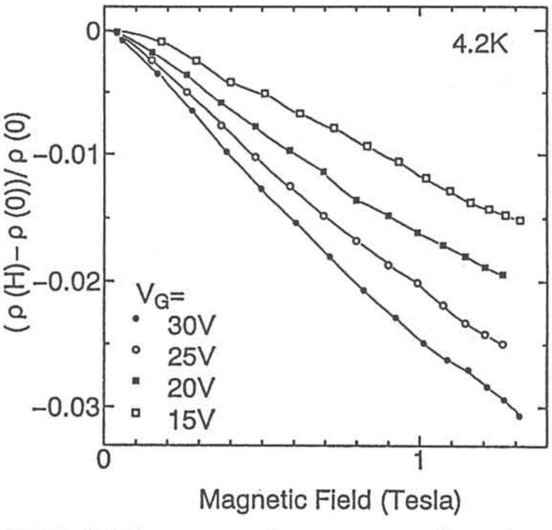

FIG.4: Magnetoresistance as a function of magnetic field strength at 4.2 K.