Digest of Tech. Papers The 14th Conf. (1982 International) on Solid State Devices, Tokyo

## C-4-2 (Invited)

Amorphous-Silicon Transistors and Integrated Circuits

## Masakiyo Matsumura

Department of Physical Electronics, Tokyo Institute of Technology

Oh-okayama, Meguro-ku, Tokyo 152, Japan

Although it has been only 3 years since the first report<sup>1)</sup> on amorphous-silicon field-effect transistors (a-Si FETs) was published, many researchers have shown great interest in a-Si FET. This is because the FET seems to be the best non-linear device for active-matrix-addressed large-area panel-displays and image-sensors. In this presentation, I would like to review our recent theoretical and experimental results on a-Si field-effect devices and its integrated circuits.

Transistor characteristics were analyzed<sup>2)</sup> by assuming that the localized state density (LSD) distribution in a-Si takes an exponential form with respect to energy. The result indicates that the slope of log  $I_D$  - log  $V_G$  curve is a function of a characteristic temperature  $T_G$  of LSD distribution. This feature coincides with experimental results as shown in Fig.1. The two-folded lines which approximate the experimental data indicate that LSD distribution in a-Si has two  $T_G$  values of about 750K and 320K. In order to increase the on-current, it is especially important to decrease LSD with  $T_G$ =320K, while in order to improve the on-off transition it is especially important to decrease LSD with  $T_C$ =750K.

From the experimentally obtained linear  $I_D-V_D$  characteristics of the FET with SiON<sup>3)</sup> as a gate insulator, which was deposited by arc-discharge deposition method<sup>4)</sup> of a SiH<sub>4</sub>, CO<sub>2</sub> and N<sub>2</sub> mixture, we evaluated the field-effect mobility, by using a simple MOSFET equation, as high as  $1.9 \text{cm}^2/\text{Vs}$ , which is about one order in magnitude larger than the one reported to date. This excellent result will be brought about by the improved interface characteristics which resulted from the successive depositions of a-Si and SiON within one-pumpdown and by high quality a-Si film deposited in weakfield plasma. However, further studies to clarify the origin of these results and to identify the ultimate mobility value must be carried out. The present high-mobility a-Si FET with channel length of 10 µm and supply voltage of 5V is calculated to have a transit time  $\tau$  of about 100ns. Thus the dynamic logic circuit will be able to operate at about 1MHz. To obtain such a high speed operation, however, the self-alignment technology<sup>5)</sup> must be achieved. This technology will also be important from an economical view point, because it decreases one of critical steps in a-Si FET fabrication as in MOS IC fabrication.

Electrons trapped in localized states also affect the dynamic performance. The analytical result<sup>6)</sup> is shown in Fig.2. It indicates that if  $T_{G}$ =600K, more than 90% of electrons stored under the gate while the gate voltage is high, will be released within 50T after the gate voltage turns to zero. Since the residual electrons are removed rapidly, it seems possible to construct charge-coupled devices (CCDs) by using a-Si. Figure 3 shows a proposed cross-sectional view of the device<sup>6</sup>. The device operates either in the thermal equilibrium state or the accumulation state. Electrons are transferred across the a-Si film from the surface near one gate to the opposite surface near the

-137-

next gate. This electrode configuration solves the problem in a-Si CCD that the field penetration depth in a-Si is very short. The proto-type CCD with 3 transfer electrodes operated and a transfer efficiency of 70%-95% per transfer was measured.

Another application of a-Si field-effect devices is for three-dimensionally integrated circuits<sup>7)</sup>, because high-quality a-Si film can be deposited on various substrate materials at relatively low temperatures. The proto-type integrated inverter whose cross-sectional view is shown in Fig.4, operated successfully. The result indicated that the threshold-voltage-shift of the a-Si FET is important to eliminate mutual coupling between the FETs. Such a circuit seems to be especially useful for large-area two-dimensional image-sensors where the switching FETs are constructed on a varied layer under the upper a-Si photo-sensitive-elements.

In conclusion, the a-Si field-effect devices reviewed in this presentation, are potentially useful. However, various problems remain. The most serious one is the instability of the electrical characteristics, which must be eliminated in the near future.

The author would like to express his thanks to Profs. S.Furukawa, K.Takahashi and my co-researchers of TIT for their support of this work. A part of this work is supported by the Ministry of Education, Science and Culture of Japan with Grant-in-aid for Scientific Research and by Hoso-Bunka Foundation.

