Digest of Tech. Papers The 13th Conf. on Solid State Devices. Tokyo

A-4-7 Process Characterization of MOS devices by Scanning Electron Microscopy with 0.5-1 KV electrons

N. Hashimoto, H. Todokoro, S. Fukuhara and K. Senoo
Central Research Laboratory, Hitachi Ltd.,
Kokubunji, Tokyo, JAPAN

Introduction The performance of the MOS LSI has been improved through structural miniaturization and new device technologies. The complexity of this LSI requires a new approach to process characterization, e.g. optical microscope can not inspect an LSI using 1 μm geometry. The scanning electron microscope (SEM) provides the only means for non-destructive inspection beyond optical limits.

This paper reports on using a low acceleration voltage SEM. MOS devices, after processing, are examined without any radiation damage and with negligible charge-up effects. Thus, in-process inspection of fine patterning can now be done.

Low acceleration voltage SEM A high resolution, low acceleration SEM has been developed and is shown in Fig. 1. The microscope uses a new electron gun with a field emission cathode. Resolution is 20 nm. In contrast, resolution is approximately 1 μm for a tungsten thermionic gun operating at 1 KV.

Electrons emitted from the field emission cathode are decelerated by a three-anode type static lens, which control the focal length and improves the current efficiency of the system.

Experimental A conventional SEM is operated at an acceleration voltage of about 20 KV to obtain sufficient resolution. However, the radiation level at this voltage causes degradation of MOS device characteristics. Figures 2 and 3 show the effects of electron dose on V-I characteristics and Vth shifts in an MOS FET, respectively. In normal observations, with magnitude between 1000 and 10000, the electron dose is 10^{-4}- $10^{-2}/cm^2$. As a result, to obtain a Vth shift of less than 0.01 v, which does not cause any variation in the MOS LSI, 1 KV observation is required.

Further, there are radiation problems when examining in-process wafers. In order to define these problems MOS devices were irradiated in a dry vacuum after definition of the polycrystalline Si gate. It was found that the Vth of an irradiated active MOS FET is equal to that of a non-irradiated device and MOS capacitor breakdown is energy dependent.

A passivated short-channel MOS FET has been inspected in geometric and electrical tests using an SEM, as shown in Fig. 4. The channel length of the MOS FET was measured to be 2.1 μm. The MOS FET was electrically operated in the SEM which a triangle wave (G-input) of $1V_{P-P}$ biased with 1.5V DC is applied to the gate electrode. The secondary electron signals, SE SIG. (D) and (G), showed voltage contrast corresponding to the conditions on the drain (D) and gate (G). Output signal, SE SIG. (D), using a voltage contrast mode, suggests quantitative estimation of a MOS LSI circuit, without radiation damage, is possible.

Thus, observation using a low acceleration SEM in a clean vacuum provides a new inspection technique for in-process wafers and the voltage contrast mode can promote LSI process charactrization.

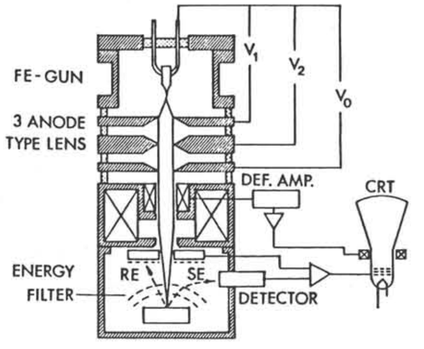

Fig. 1 Schematic diagram of a low acceleration SEM.

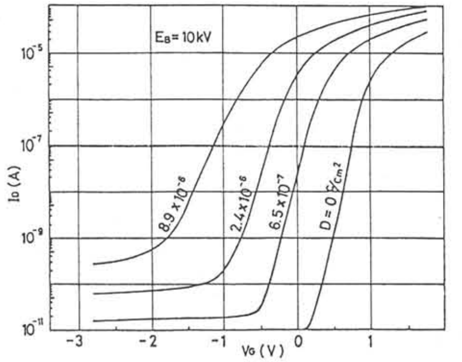

Fig. 2 Effects of electron radiation on subthreshold current of an n-channel bar-type MOS FET. Acceleration voltage, E_B, is 10 KV.

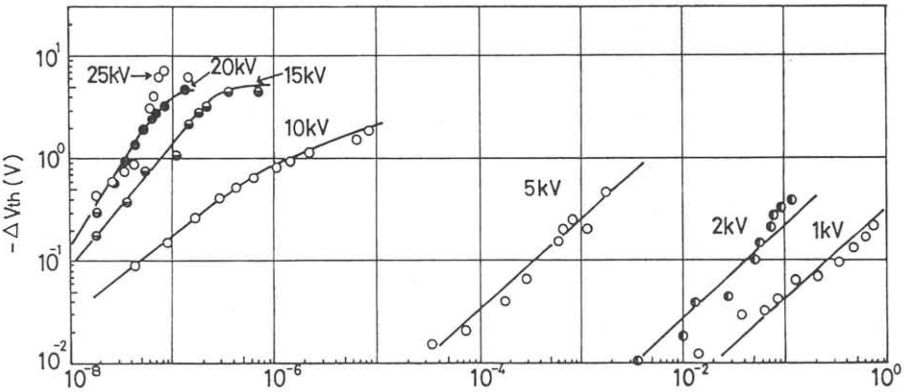

Fig. 3 Vth shift (ΔVth) versus electron dose (D) for various acceleration voltages.

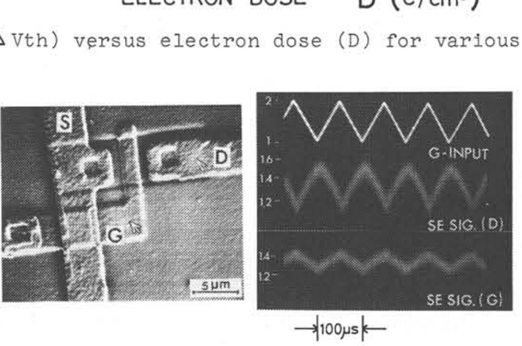

Fig. 4 Example of geometric and electrical tests at 1 KV.