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Stability Investigation of N-channel MOS-FET Utilizing Alumina Film for Large Scale Dynamic Memory Array

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The unverified stability of n-channel MOS-FET utilizing alumina film has been investigated. The FET is the key element to our dynamic RAM-LSI which consists of both depletion and enhancement-mode FETs.

The extensive study has been done to clarify the reliability problem of enhancement(MAOS) FET. Its gate structure is Al-Al_2O_3(1700Å)-SiO_2(500Å)-Si. Alumina film (Al_2O_3) was grown by hydrolysis of $AlCl_3$ at 900°C. More than several hundreds of samples have been tested by the bias-temperature method for few seconds to 1000 hours at 100°C to 200°C.

The observed V_T shift is sometimes asymmetrical to the polarity of the applied voltage. This origin is traced up to be due to the contamination introduced from contact hole. Contamination free MAOS-FETs fabricated by well-controlled process show the symmetrical V_T shift (Fig.1), which leads us to conclusion that only polarization effect of Al_2O_3 should be responsible for the cause of V_T shift.

The following formula explaining the detailed behavior of V_T shift was obtained,

$$\varDelta V_T=-D.V_{BT}.X_{p\alpha}.\log(t/t_o), \qquad (1)$$

where D is a constant determined from structure (film thickness), V_{BT} is applied voltage, $X_{p\alpha}$ is polarizability of Al_2O_3, t is time and t_o is time constant.

The feature of the formula is that it does not contain large initial V_T shit (low temperature polarization[1),2)]) which is a commonly observed property of conventional MOS-FET utilizing phospho-silicate glass.

The value of polarizability of Al_2O_3 ($X_{p\alpha}$) is 0.07 at 150°C and $X_{p\alpha}.\log(t/t_o)$ is 0.2 for 10 minutes, this value is four times smaller than the value obtained by A. P. Gnadinger[3)] on MAOS capacitor. This smaller value is made possible through the effort to purify $AlCl_3$ as a source of Al_2O_3 and the choice of Al_2O_3 deposition temperature. It was also found that $X_{p\alpha}$ depends on temperature in the form of $X_{p\alpha}=X_{p\alpha o}.\exp(-0.17eV/kT)$ and t_o is independent from temperature (t_o=0.067s) as shown in Fig.2. These are the opposing results to those reported by A. P. Gnadinger[3)] who concluded that it is not $X_{p\alpha}$ but t_o that has temperature dependence as shown in Fig.3.

Our new results mean that smaller V_T shift occurs for the wide range of time and temperature. For example, V_T shift predicted from eq.(1) is -0.07 V for 10 years under operation condition (5 V power supply and 70°C) and -0.48 V for 10 years with 10 V applied at 125°C and so on. These values are at least comparable to those of the conventional p-channel MOS-FET.

From the work mentioned above, fabrication of stable dynamic RAM-LSI becomes possible, and this will be reported elsewhere.

Reference

1) E. H. Snow and B. E. Deal, J. Electrochem. Soc., 113 264 (1966).

2) J. M. Eldridge, R. B. Laibowitz and P. Balk, J. Appl. Phys. 40 1922 (1969).

3) A. P. Gnadinger, Electrochem. Soc., Fall Meeting, Abs. No. 164 (1971).

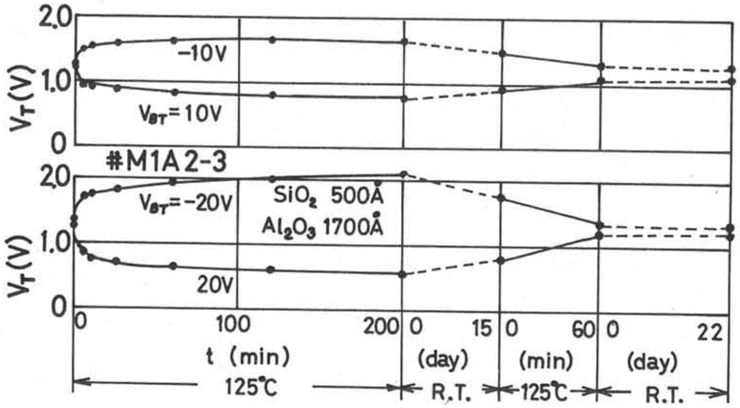

Fig.1 Results of B-T test and annealing

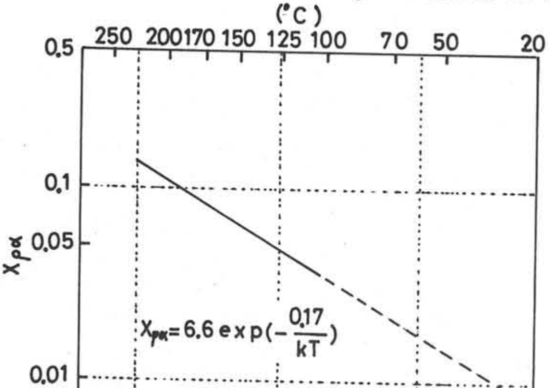

Fig.2 Temperature dependence of poralizability

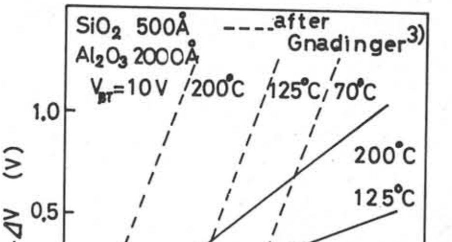

Fig.3 V_T shift predicted by eq.(1)