Investigation of Slow/Fast Interface States of Al_2O_3/Si MOS system using Deep Level Transient Spectroscopy

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As high-k dielectric materials have been focused as gate oxide for deep sub-micron devices, the characterization of high-k oxide/Si interface become more important topic. Therefore the interface states of Al_2O_3/p-Si(100) system have been investigated using deep level transient spectroscopy (DLTS).

The DLTS signal can be obtained by the difference of the transient response measured at two delay times, t_1 and t_2. The emission time constant (τ_{it}) of interface state is $(t_2-t_1)/\ln(t_2/t_1)$. The interval of t_1 and t_2 was set to be 200ms to measure “slow” interface states that have a long τ_{it} (~1s) and 1ms for “fast” interface states of short τ_{it} (~ms). The fabrication of Al_2O_3/Si MOS capacitor was described in previous report.[1]

Figure 1 showed the $N_{ist}(E)$ and $D_{it}(E)$ dispersions of Al2O3/p-Si MOS syste with different interval time of t_1 and t_2. The N_{sit} was larger than the D_{it} below 0.3eV and the crossover occurred at 0.3eV.

The DLTS spectra for the emission of “slow” interface states were shown in figure 2. When the gate voltage (V_g) increased, an unknown peak was shown up above V_g=1.3V and became larger and larger. The activation energies (Ea) of each peak were 0.569, 0.509, 0.411 and 0.349eV, respectively, with certain V_g’s. Because the V_g corresponding to zero surface potential ($\phi_s=0$) was ~1.2V, the large peak could be seen when the MOS system was in inversion state. The more the MOS system was toward strong inversion, the larger peak could be obtained. This peak was also detected in DLTS spectra for the emission of “fast” interface states. It was reported that the large peak was result from a minority carrier capture process.[2] When V_g increased, the surface Fermi level (E_{FS}) was moved toward the conduction band edge of Si band gap. The Ea of the large peak was related to the energy for electron to capture in the interface at the near of E_{FS}. Therefore the Ea decreased with the increase of V_g.

Figure 3 showed the difference of Ea with the correlation τ_{it} of 866ms and 20ms, respectively. The reason why ΔEa (0.22~0.27eV) occurred with different τ_{it} is not well understood. However if we assume that the “slow” interface states are spatially located in oxide and near the interface, the Ea can be considered separately into two parts. One is for electron to capture from conduction band to the interface (Ea_1). The other is to move from interface into oxide near the interface (Ea_2). In the case of the “fast” interface states, the Ea_1 may equal to Ea. From the above, the ΔEa was thought to be Ea_2.

In summary, the “slow” and “fast” interface states and their activation energies were investigated from DLTS spectra. The difference of activation energy was related to the process for electron movement between the interface of Al_2O_3/Si and oxide trap near the interface.

Acknowledgement

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Reference

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[2] M. Schulz, N. M. Johnson, Appl. Phys. Lett. **31** (1977) No. 9, 297.

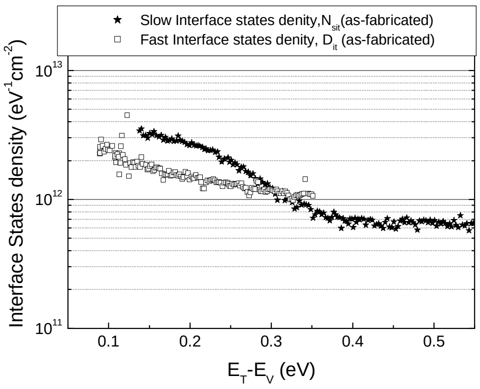

Figure1. $N_{sit}(E)$ and $D_{it}(E)$ dispersions of Al_2O_3/Si MOS system (from DLTS)

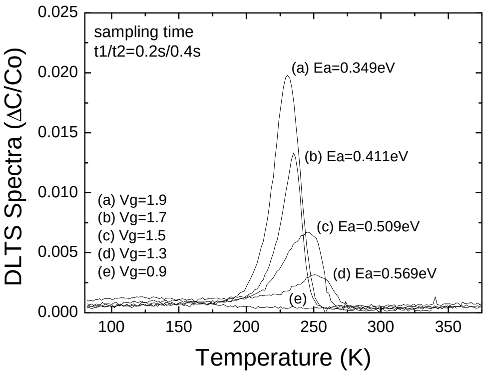

Figure 2. DLTS spectra of Al_2O_3/Si MOS system with the variations of Vg.

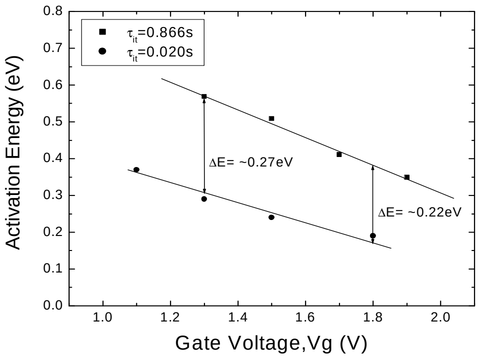

Figure 3. The activation energy with the correlation emission time constant (τ_{it}) of 866ms and 20ms, respectively.