Analysis of A-DLTS spectra of MOS structures with ultrathin NAOS SiO_2/Si layers

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The nitrid acid (HNO_3) oxidation of Si (NAOS) is unique method for preparation ultrathin silicon dioxide (SiO_2) layers with excellent electrical characteristics by immersion of Si in nitric acid solution. The chemical SiO_2 layers formed in HNO_3 were found to have the lowest interface state density. When postoxidation annealing (POA) or postmetallization annealing (PMA) treatment is preformed in a hydrogen atmosphere after the aluminum (Al) deposition, the leakage current density of the NAOS oxide layer is further decrease [1].

Acoustic version of Deep Level Transient Spectroscopy (A-DLTS) is high-frequency ultrasonic method based on analysis the acoustoelectric response signal (ARS) produced by MOS structure interface when a longitudinal acoustic wave propagates through a structure after applied bias voltage steps to the structure. The ARS is extremely sensitive to external conditions of the structure and reflects any changes in the charge distribution connected with charged traps [2]. The temperature dependence of ARS that reflects relaxation processes is investigated and the activation energies obtained form Arrhenius plots of A-DLTS spectra and some other parameters of traps at the insulator – semiconductor interface layer are determined.

Because sometimes we can not use the standard method of evaluation A-DLTS spectra applying the Arrhenius plot procedure (some rate windows don't provide necessary information for low signal) we applied the method of modelling one rate window (RW) of measured acoustic spectra. To determine the basic parameters of traps at the insulator – semiconductor interface for discrete levels we used mathematical fit the measured A-DLTS spectra for the various rate windows Δt. The activation energies E_a determined from this modelled spectra expressed by the relation

$$\Delta U_{ac}^{0}(T) = \sum_{j=1}^{n} U_{j0}\left(\exp\left(-\frac{t_1}{\tau_j}\right) - \exp\left(-\frac{t_2}{\tau_j}\right)\right) \qquad (1)$$

can be compared with the activation energies calculated from Arrhenius plots.

Fig. 1(a) shows A-DLTS spectra of sample POA7 of the set of MOS structures (p-Si(100), thickness SiO_2 ~ 10nm, oxide layers were formed by immersing Si wafers together with polysilazane specimens spin-coated on Si wafers in 70 wt% HNO_3 aqueous solutions at 120°C, samples were prepared in ISIR, Osaka University). The illustrated spectra that contain

main broad peak, corresponding to one interface state, were measured at bias $V_G = 0.4V$ with pulse voltage $\Delta V_G = -2.6V$ and at the various rate windows. The activation energy $E_a = E_t - E_v = (0.24 +/- 0.02)\ eV$ above the valence band and the corresponding capture cross-sections $\sigma = 2.64x10^{-19} cm^2$ were determined from the Arrhenius plots (inside Fig. 1(a)) constructed for individual peaks. Using the Eq. 1 for the discrete level we simulated the main peak of measured spectra for the time $t_1 = 15\ ms$ and $t_2 = 30\ ms$ (1st RW). We found the energy level $Ea' = 0.26\ eV$ (Fig. 1(b)), which is very close to the activation energy calculated from Arrhenius plot (inside Fig. 1(a)).

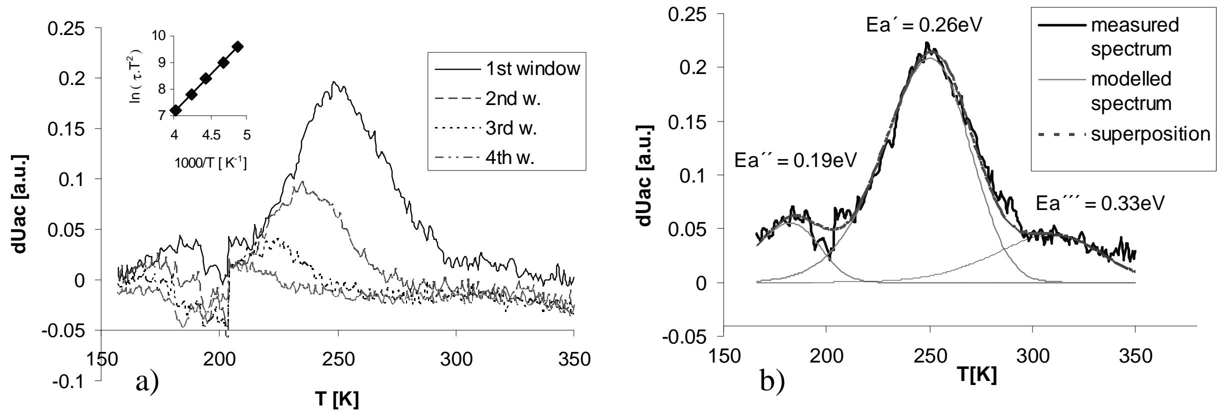

Fig. 1 (a) A-DLTS spectra of the sample SiO_2/Si structure POA7 for the relaxation time τ = 9.1, 18.4, 36.8 and 73.6 ms at V_G = 0.4 V and ΔV_G = -2.6 V and Arrhenius plot constructed from the positions of the peak maxima of the A-DLTS spectra, **(b)** The simulation peak of A-DLTS spectra of sample POA7 obtained for the relaxation time 9.1 ms

Using the modelling method we simulated the whole measured spectra and we could find other possible traps with the energy levels $Ea'' = 0.19\ eV$ and $Ea''' = 0.33\ eV$ (Fig. 1(b)).

The results obtained form A-DLTS measurements including their modelling using mathematical procedure can be compared with the results obtained by different techniques. Both acoustic deep-level transient spectroscopy and another acoustic methods ($U_{ac} - U_g$ curves) connected also with electrical characterization are useful tools for determination of the traps at the Si–SiO_2 interface in the MOS structures with ultrathin SiO_2 layers prepared by nitric acid oxidation [3].

References

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