Stress relaxation mechanism in the Si-SiO_2 system and its influence on the interface properties

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It is known that internal mechanical stresses (IMS) due to the differences in the thermal expansion coefficients between films and substrates and lattice mismatch appear in the Si-SiO_2 system during the process of its formation and that point defects (PD) generation and redistribution could be used to reduce partially the surface stress. However, this process on the atomic scale is till not studied. The goal of the present report is to investigate the stress relaxation mechanism in the Si-SiO_2 system using EPR, IR absorption spectroscopy, scanning elektron microscopy (SEM) and samples deflection measurements. PD density and stresses in the Si-SiO_2 system were varied by oxidation condition (temperature, time, cooling rate, ambient) and by Si_3N_4 deposition on SiO_2. Different sign of the thermal expansion coefficient of the SiO_2 and Si_3N_4 on Si allow to modifay the IMS at the interface. It has been found that samples deflection decreases or increases simultaneously with EPR signal intensity depending on the oxidation condition (temperature).

At oxidation temperature 1100^0C the deflection of the samples(h) decreases with the increase of EPR signal intensity (vacancies),while at a oxidation temperature 1200^0C EPR signal (I) and deflection increase simultaneously. Those allows to suggest that at lower oxidation temperature PD (vacancies) reduce the tensil IMS in Si, while at higher oxidation temperature compressive IMS created PD in SiO_2 (E' centers).At an intermediate oxidation temperature tensil stresses in Si and compressive stresses in SiO_2 may bee equal and compensate each others. It has been find that at oxidation temperature 1130^0C IMS at the Si-SiO_2. interface are lower than at 1100^0C and 1200^0C. Lower defect dencity on samples crossection microphotos obtained by SEM and PD dencity diminishing.in samples oxidized at 1130^0C confirmed thise suggestion.In Fig,2 the EPR signal and IR absorbtion line-width dependence on the oxidation time is shown. It can bee seen ,that EPR signal and IR absorbtion line-width at 1100 cm^{-1} dependence on the oxidation time (oxide thickness) is nonmonotonous and depended on the cooling rate .In slowly cooled samples the increase of the EPR signal is accompanied by the decrease of $\Delta\nu$ but,in fast cooled samples EPR signal and $\Delta\nu$ increase simultaneously with increase oxidation time.

Absent of the cooling rate influence on the PD density and $\Delta\nu$ dependence on the oxidation time at I(t) and $\Delta\nu(t)$ dependence intersection points show, that IMS by an appropriate choice of the SiO_2 film thickness dissapear. The obtained results may bee explained by the PD generation kinetic model in the Si-SiO_2 system proposed by T.U.Tan and U.Gösele [1] and confirmed experimentaly in. [2].

References

[1]..T.Y.Tan, U.Gosele,J.Appl.Phys.A37(1985)1.
[2].D.Kropman,S.Dolgov,T.Kärner.J.Appl.Phys.A62(1996)469.

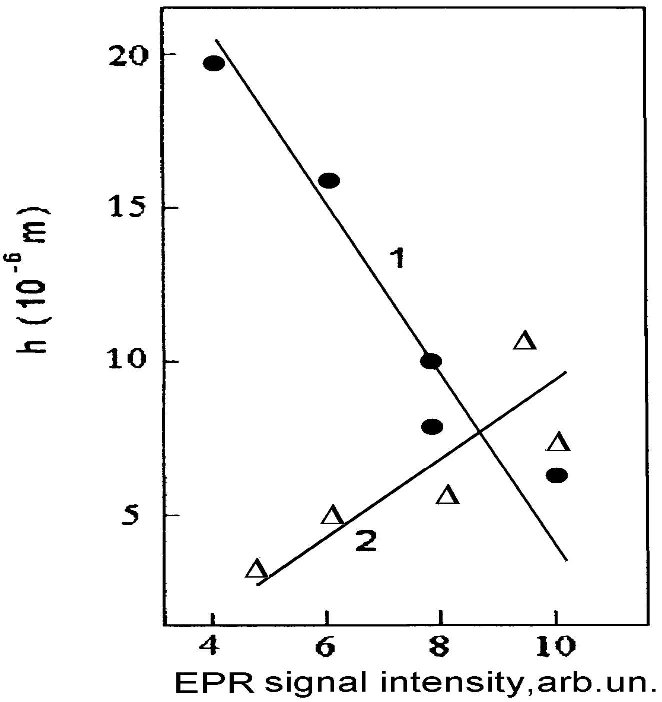

Fig.1.Interdependence between samples deflection and EPR signal at different oxidation temperature: 1100^0C(1) and 1200^0C(2).

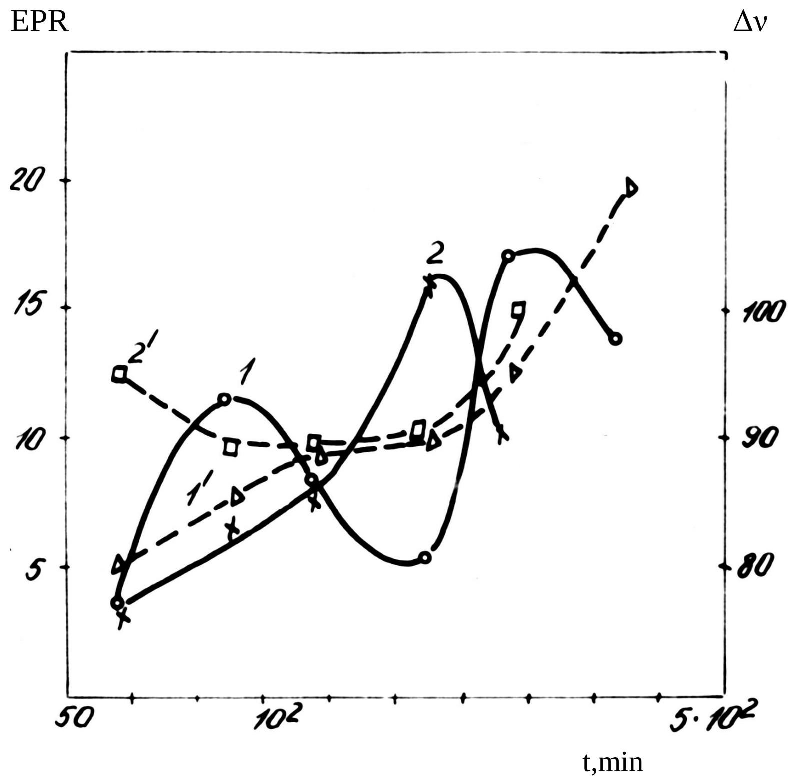

Fig.2. Dependence of the EPR signal (1, 2) and the line-width of SiO_2 IR absorption at 1100 cm^{-1} (1', 2') on the oxidation time, cooling rate 25 (1, 1') and 3^oC/sec. (2, 2')Oxidation temperature 1200^0C.