

Determination of the Al-induced Surface Charge by AC Surface Photovoltage Measurements in N-Type Silicon Wafers

Hirofumi Shimizu, Masanori Ikeda and Ryuhei Shin

Department of Electrical and Electronic Engineering,
College of Engineering, Nihon University,
Tamura-machi, Koriyama, Japan 963-8642

An ac surface photovoltage (SPV) method [1], in which the excitation source is a chopped photon beam (PB), has been used to identify aluminum (Al) [2] and iron (Fe) [3] as responsible for inducing negative oxide charge in n-type silicon (Si) wafers. This metal-induced negative charge (Q_{mi}) grows with increasing exposure time to air.

One purpose of this report is to measure the ac SPV on n-type Si wafers, which have been treated with an Al-contaminated alkaline RCA (Radio Corporation of America) solution, both as a function of the exposure time to air and the chopping frequency (f). The other is to estimate the Al-induced negative charge density in n-type Si wafers on the basis of a half-sided junction (HSJ) model [1].

An experimental set up developed in-house is shown in Fig.1. A light emitting diode (LED) was used as a light source and the wavelength of the chopped PB was 470 nm. Transparent electrodes used in the set up were made of a glass plate coated with indium oxide. Ac SPVs were measured with a lock-in amplifier tuned to the frequencies of the LED driver. The incident PB power was $3 \mu W$.

The samples were Czochralski-grown Si (100) wafers 125 mm in diameter. These were phosphorus doped (n-type) with a resistivity of $0.2 \pm 0.01 \Omega \cdot cm$. First, the wafers were rinsed in an RCA alkaline solution containing an $Al(NO_3)$ reagent (Al concentration: $10 \mu g/ml$) and then they were exposed in air and the ac SPV was measured as a function of frequency and exposure time.

Fig. 2 shows the ac SPVs of an Al-contaminated n-type Si wafer vs. frequency, as a function of air exposure time. The surface concentration of Al was 9.2×10^{12} atoms/cm². At the start of air exposure, the ac SPV vs. frequency curve showed flat- and $1/f$ -dependency regions. However, the ac SPV gradually increased with air exposure time as a function of frequency and finally proportional to $1/f$ (strong inversion). This indicates that negative oxide charge had grown on the n-type Si wafer surface with air exposure time in the form of proposed network model of (AlOSi)⁻.

The frequency characteristics of the ac SPV is shown as a function of interface trap density (D_{it}) in Fig.3. According to the best fitting on the basis of HSJ model [1], the oxide charge density was obtained for exposure time of 1 h to be $3.65 \times 10^{11} /cm^2$ which shows that about 4 % of the Al concentration in the native oxide acts as negative charge. This oxide charge density increased with exposure time as Table 1 summarizes the other calculated results.

REFERENCES

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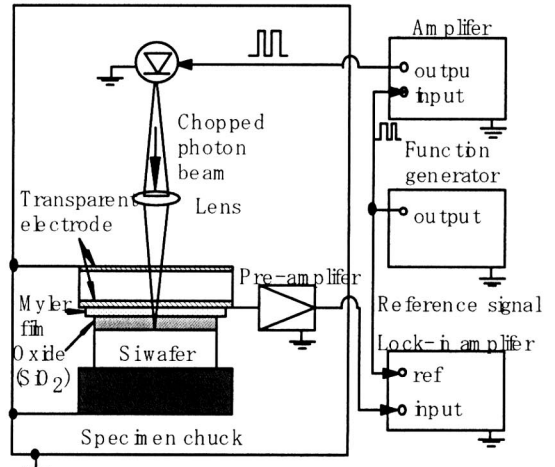


Fig.1. Block diagram of set up for ac SPV.

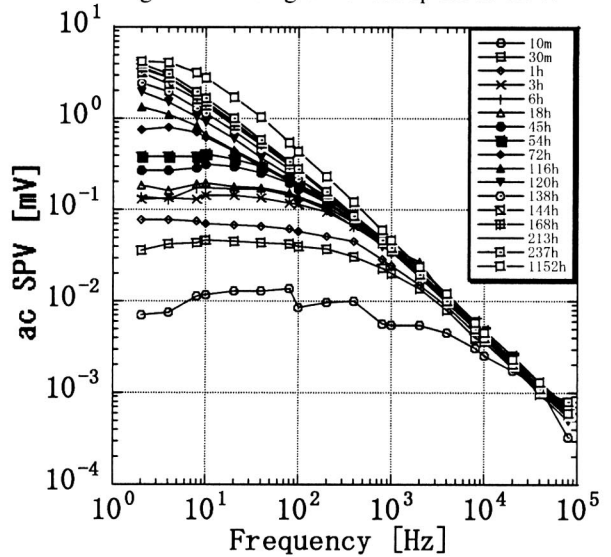


Fig.2. Ac SPV for Al-contaminated Si wafer vs. frequency as a function of air exposure time.

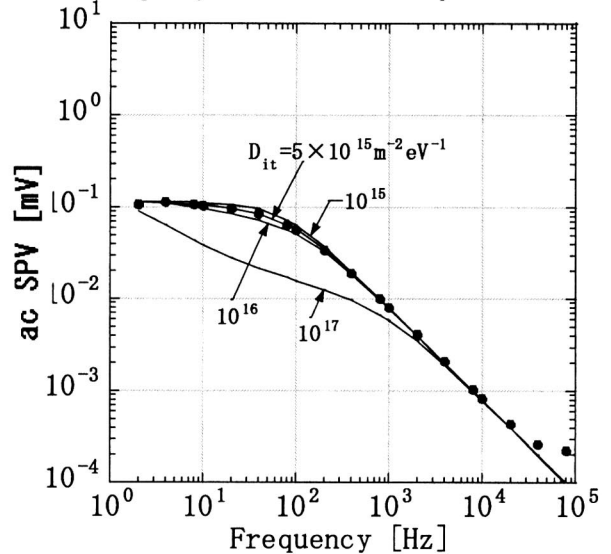


Fig.3. Ac SPV vs. frequency relationship obtained by calculation.

Table1. Calculated results by using the HSJ model [1].

	1 h	2 h
Surface potential: u_s	-15.31	-16.18
Fermi potential: u_f	-14.37	-14.37
Surface Charge: Q_s (C/cm ²)	5.65×10^{-8}	5.82×10^{-8}
Interface trap density: D_{it} (m ⁻² ·eV ⁻¹)	5×10^{15}	1×10^{16}
Interface trap charge: Q_{it} (mC/cm ²)	1.95×10^{-10}	7.52×10^{-10}
Oxide charge: Q_{mi} (mC/cm ²)	-5.84×10^{-8}	-6.57×10^{-8}
Oxide charge density: Q_{mi} (/cm ²)	-3.65×10^{11}	-4.10×10^{11}