Field effect of fixed negative charges on oxidized silicon induced by AlF$_3$ layers with fluorine deficiency

D. König$^a$, D. R. T. Zahn$^b$ and G. Ebest$^b$

$^a$ Institut für Physik, Technische Universität Chemnitz, 09107, Chemnitz, Germany
$^b$ Institut für Elektrotechnik, Technische Universität Chemnitz, 09107, Chemnitz, Germany

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Abstract

We recently discovered that in an AlF$_3$/SiO$_2$/Si structure extrinsic electrons are trapped at fluorine (F) vacancies in AlF$_3$ at the interface with SiO$_2$, generating a high sheet density of fixed negative charges.

p- and n-Type Si substrates were oxidized using rapid thermal oxidation (RTO) or furnace oxidation (th); some samples were passivated in hydrogen (H$_2$). AlF$_3$ was deposited onto oxidized Si wafers by a modified PVD process, leading to a F deficiency (AlF$_{x}$). Samples were characterized by mercury probe (Hg) CV and microwave photo conduction decay ($\mu$W-PCD), determining charge and trap densities and effective carrier lifetime $\tau_{\text{eff}}$, respectively. An effective charge density of up to $|Q_{\text{eff}}| = -6.9 \times 10^{12}$ cm$^{-2}$ is reached due to electrons tunneling from Si into AlF$_3$, occupying F vacancies. Lifetime scans of p-type float zone (FZ) Si samples with 1.5 nm RTO and 20 nm AlF$_3$ show an increase in effective minority carrier lifetime by a factor of 8.4 compared to samples with 1.5 nm RTO only. The fixed negative charge density increases with exposure time to sunlight or at simulated ageing by a 24 h anneal at 200 °C in air.

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Corresponding author. Tel.: +49 371 531 3089; fax: +49 371 531 3004.