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Electroluminescence from MOS Capacitors with Si Implanted Oxide on p-type and n-type Si Substrate

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1. Introduction

A device with Si rich gate oxide has attracted interests as a potential structure of Si-based light emitting devices that can be integrated into Si LSI technology for intelligent displays in portable systems[1,2]. We reported visible electroluminescence (EL) from MOS capacitors with Si implanted SiO_2[3,4]. In this work, we demonstrate blue EL from Au/SiO_2/Si MOS capacitors with Si implanted oxide on both p-type and n-type Si substrate. The EL spectra have been analyzed by Gaussian distributions (G_i). The center wavelengths of G_i decomposed from the spectra are independent of Si-dose, V_G and the substrate type.

2. Experimental Procedures and Results

Fig. 1 gives a schematic cross section of a MOS capacitor with Si-implanted gate SiO_2. The 50 nm thick SiO_2 was thermally grown on a p-type (n-type) (100) Si substrate. Si ions were implanted into the SiO_2 by energy of 25 keV, followed by N_2 annealing at 900°C for 30 min. The aluminum film was formed on the backside for ohmic contact. Finally, 15 nm thick Au film was evaporated on the SiO_2 as a transparent electrode. Samples with three kinds of Si dose of 3x, 5x and 10x10^{16} cm^{-2} and reference samples without implantation were fabricated for both p-type and n-type Si substrates (Fig. 1). Fig. 2 shows profiles of implanted Si atoms in SiO_2 calculated by LSS theory. The projected range R_P of Si implantation locates around the center of the SiO_2. The EL measurement system consists of a monochromator and a CCD camera cooled at -45°C. The EL spectrum data were corrected for the total wavelength response curve of the system.

Fig. 3 shows gate current $-J_G$ versus gate voltage $-V_G$ characteristics under the negative gate bias conditions. $-J_G$ increases with Si dose, which introduces traps in SiO_2 and interface layers. The difference of p-type and n-type substrate scarcely affects the gate current characteristics. Hysteresis curves in capacitance vs. gate voltage (C-V) characteristics are also observed for Si implanted capacitors. As only the negative gate bias conditions can cause EL photoemission for both p-type and n-type substrate, electron injection from Au electrode into the gate oxide is important for the photoemission process in this device structure. Fig. 4 shows measured EL spectra for p25-3 and n25-3, which are very similar. It suggests that the photoemission is caused by radiative traps or nano crystals in the Si implanted oxide independently of the substrate type. Fig. 5 shows the measured EL spectra (open squares) of (a) p25-3, (b) n25-3 and (c) n25-5. The spectra can be decomposed into several wavelength components, given in Fig. 5 as the curves (solid lines) fitted by five Gaussian distribution functions of (G_1~G_5) photoemission;

$$G_i = M_i \exp[- (h\nu - h\nu_i)^2 / 2(\Delta h\nu_i)^2]$$

where M_i, $h\nu_i$ and $\Delta h\nu_i$ are the maximum EL intensity, the center photon energy and HWHM (half width at half maximum), respectively. $h\nu_1 \sim h\nu_5$ for $G_1 \sim G_5$ correspond to 1.25, 1.6, 1.9, 2.4 and 2.8 eV, respectively. Although M_i values depend on Si-dose, $h\nu_1 \sim h\nu_5$ are independent of Si-dose, V_G and the substrate type. A ratio of G_5 component in each spectrum decreases as Si dose becomes large. The measured data are successfully reproduced by the fitting curves except the both edge region.

Considering published references[4], we interpret origins of $G_1 \sim G_5$ as shown in Fig. 6; (1) G_1 ($h\nu_1$ ~1.25 eV) is Si-nanocrystal origin. (2) G_2 ($h\nu_2$ ~1.6 eV) corresponds to the radiative traps generated by Si-implantation. (3) G_3 ($h\nu_3$ ~1.9 eV) is due to the radiative defects in thermal SiO_2. (4) G_4 ($h\nu_4$ ~2.4 eV) is caused from oxygen deficient defects. (5) G_5 ($h\nu_5$ ~2.8 eV) is due to the traps generated by Si-implantation located at E_t ~ 3.0 eV as observed in PL analysis. Fig. 7 shows an example of EL color image. Blue light emission can be observed as expected in Fig. 5(a).

3. Conclusions

The clear and smooth EL spectra have been measured for the Au/SiO_2/Si MOS capacitors with 50 nm Si-implanted SiO_2. Blue EL was observed and the measured data are successfully fitted by the Gaussian curves for EL mechanism analysis.

References

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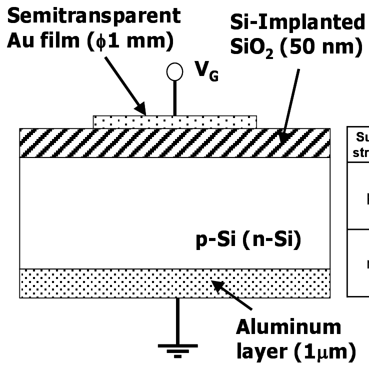

Sub-strate	Sample No.	Implantation Energy (keV)	Dose of Si ion ($\times 10^{16}$ cm^{-2})
p	p25-3	25	3
	p25-5	25	5
	p25-10	25	10
n	n25-3	25	3
	n25-5	25	5
	n25-10	25	10

Fig. 1 A schematic cross section of a MOS capacitor with Si-implanted gate SiO_2.

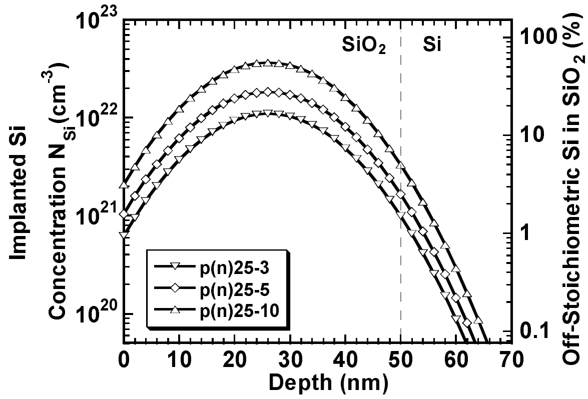

Fig. 2 Profiles of implanted Si atoms in SiO_2 calculated by LSS theory.

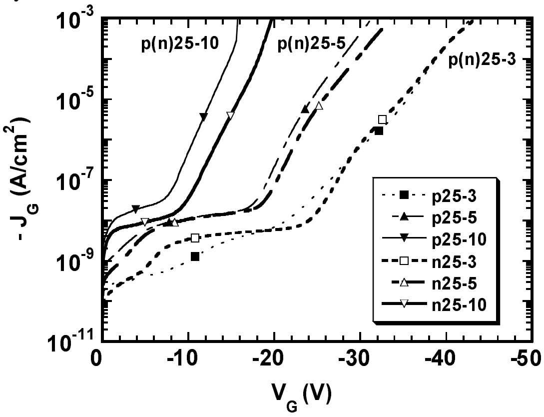

Fig. 3 shows gate current $-J_G$ versus gate voltage $-V_G$ characteristics under the negative gate bias conditions.

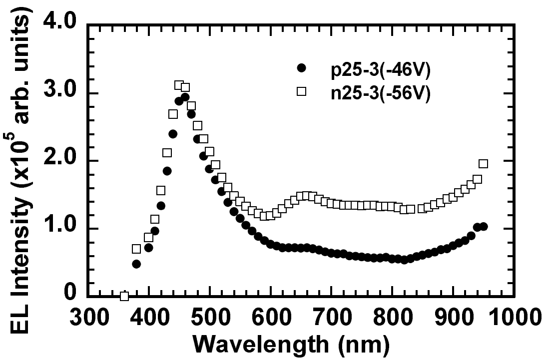

Fig. 4 Measured EL spectra for p25-3 and n25-3.

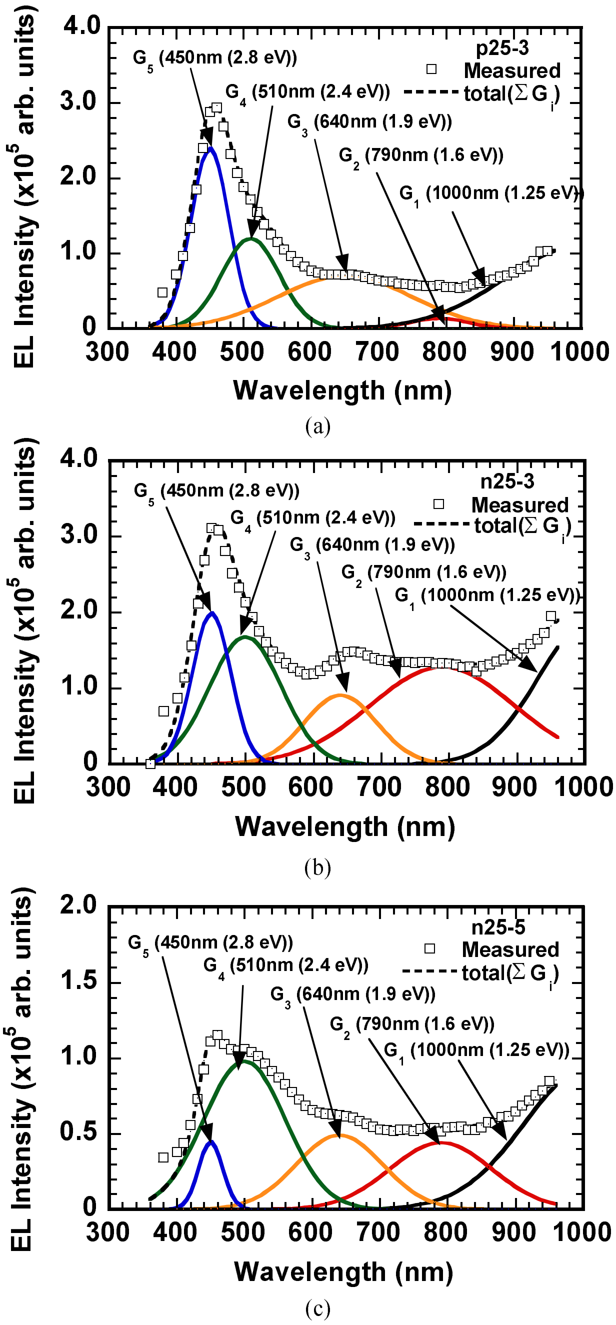

Fig. 5 Measured EL spectra (open squares) of (a) p25-3, (b) n25-3 and (c) n25-5, and calculated curves (solid lines) fitted by five Gaussian distribution functions of (G_1～G_5) emission.

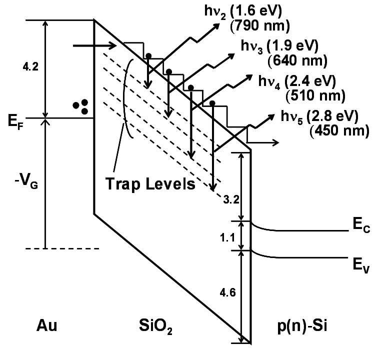

Fig. 6 Energy band diagram illustrating photoemission model.

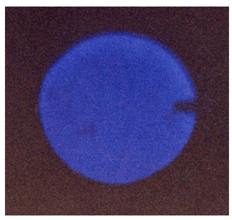

Fig. 7 Microphotograph of EL color image (p-25-3).