

Fabrication of SnO₂/Si Heterostructures Using the Laser-Plasma Deposition Method: Optical and Electronic Properties

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Recently, heterojunctions based on metal-oxide nanostructures and silicon have attracted significant scientific interest due to their potential wide range of applications in photo-sensors, telecommunication systems, robotics, and biomedical devices. Among oxide semiconductors, particular attention is devoted to SnO₂ (n-type, $E_g \sim 3.6$ eV, high chemical stability in contact with silicon). For the deposition of tin films (10–30 nm) onto silicon wafers, a pulsed YAG:Nd³⁺ laser (model LS-2137, manufactured by Lotis-TII, Belarus-Japan) with a wavelength $\lambda = 1064$ nm and a pulse duration $\tau \sim 20$ ns (full width at half maximum) was employed. The laser pulse repetition rate was 5 Hz, and the power density of the incident laser radiation on the target was 3.8×10^8 W/cm². The experiments were conducted under vacuum conditions with a residual gas pressure of $\sim 10^{-4}$ Pa. Temporal current variations on the substrate were monitored using a Tektronix TDS 2022B oscilloscope. A detailed schematic of the experimental setup is presented in our previous work [1]. Subsequently, the deposited tin films on silicon wafers

were annealed in air using two-step thermal treatment. The first annealing step at 200 °C ensured oxygen saturation of the tin film and the formation of oxide phases. The second step at 500 °C was employed to crystallize the oxidized layers. Based on the results of structural investigations, it was established that after the two-step thermal treatments, a crystalline SnO₂ phase with tetragonal symmetry and space group P4₂/mm is formed. The lattice parameters were found to be $a = 4.716$ Å and $c = 3.155$ Å. Figure 1a shows the photoluminescence spectra of ultrathin (20 nm) SnO₂ layers on silicon. The spectra consist of a set of narrow bands in the ultraviolet (UV) region (365–400 nm) and a broad band with a maximum in the blue-green region (500 nm), which is attributed to defect states. The luminescence of this broad band is observable even at room temperature. The narrow UV bands exhibit energies lower than the bandgap width of SnO₂ ($E_g = 3.596$ eV), indicating an impurity-related nature of the luminescence—namely, conduction-band-to-acceptor and/or donor-to-valence-band transitions [2].

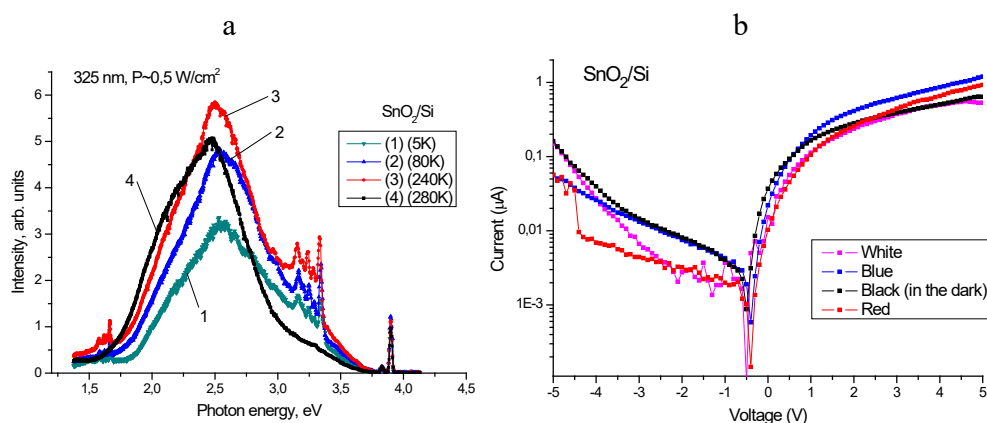


Figure 1: Photoluminescence Spectra (a) Measured at Various Recording Temperatures and Current-Voltage Characteristics (b) for the SnO₂/Si Heterostructure

From electrophysical measurements, it follows that the current–voltage characteristics of the SnO₂/Si heterostructure (Figure 1b) exhibit a pronounced diode-like behavior, which is consistent with the n-type conductivity of the SnO₂ film on p-type silicon. The current–voltage dependence across the SnO₂ layer surface between metal contacts is nearly linear in the range from –5 V to +5 V. The average sheet resistance was found to be 245.27 kΩ. The electrical conductivity of the SnO₂ film is 54.36 S/cm, which corresponds to a charge carrier concentration on the order of 10¹⁶–10¹⁷ cm^{–3}, depending on their mobility.

References

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