ADVANCED MATERIALS TECHNOLOGIES

Supporting Information

for *Adv. Mater. Technol.,* DOI: 10.1002/admt.202100137

Efficient Er/O Doped Silicon Photodiodes at Communication Wavelengths by Deep Cooling

*Xingyan Zhao, Kaiman Lin, Sai Gao, Huayou Liu, Jiajing He, Xiaoming Wang, Huimin Wen, and Yaping Dan**

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S1. Capacitance calculation

Given that the boron doping concentration $N_a \approx 10^{21}$ cm^{-3} and the Er/O doping concentration is $N_d \approx 10^{19}$ cm^{-3}, we have the built-in voltage:

$$V_{bi} = V_t \ln\left(\frac{N_a N_d}{{n_i}^2}\right) = 0.0259 \ln\left(\frac{1 \times 10^{21} \times 1 \times 10^{19}}{(1.5 \times 10^{10})^2}\right) = 1.17V$$

The junction capacitance

$$\mathrm{C}' = \left\{\frac{q\varepsilon_s N_a N_d}{2(V_{bi} + V_R)(N_a + N_d)}\right\}^{\frac{1}{2}} = 6.18 \times 10^{-7}\mathrm{F}/cm^2$$

The total junction capacitance

$$\mathrm{C} = \mathrm{C}' * \mathrm{A} = 6.18 \times 10^{-7} * 10e-4 * 100e-4F = 6.18 \times 10^{-12}F = 6.18pF$$

S2. Deep cooling process

The deep cooling (DC) process was performed in an upgraded dilatometer (DIL 805A, TA Instruments, shown in Figure S1a) in which the samples were annealed at 950 °C for 5 minutes by means of copper coil-based electromagnetic heating, followed by a flush of high purity Helium (99.999%) gas cooled in liquid nitrogen (77 K). The deep cooling can reach the limitation of the cooling rate of 1000 ℃/s. Figure S1b shows the schematic of the temperature vs time of the DC (black line) and RTA (red line) process. The deep cooling method has a relatively lower heating rate but a much larger cooling rate.

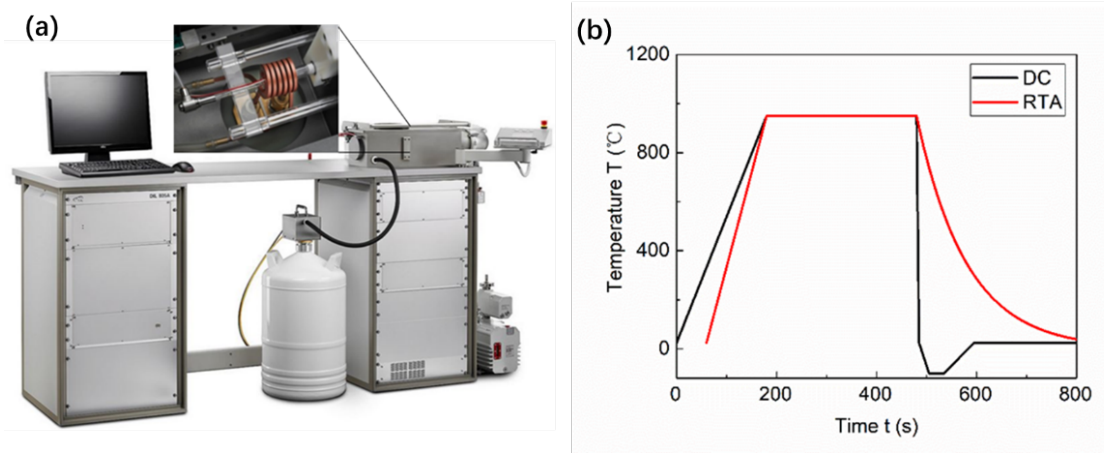

Figure S1 (a) Dilatometer (DIL 805A, TA Instruments). (b) Schematic of the temperature vs time of the DC and RTA process.

S3. Transient measurement

The diagram of transient measurement is shown in Figure S2. The light signal is supplied by a tunable laser Agilent 81640A and coupled to the Er/O waveguide photodiode through the optical fiber and grating coupler. The laser output is periodically on and off under the control of a computer. The Er/O photodiode is under –1V voltage bias sourced by a sourcemeter (Keithley 2400) and the current is measured at the same time. With the laser periodically on and off, the transient current is picked up by a computer.

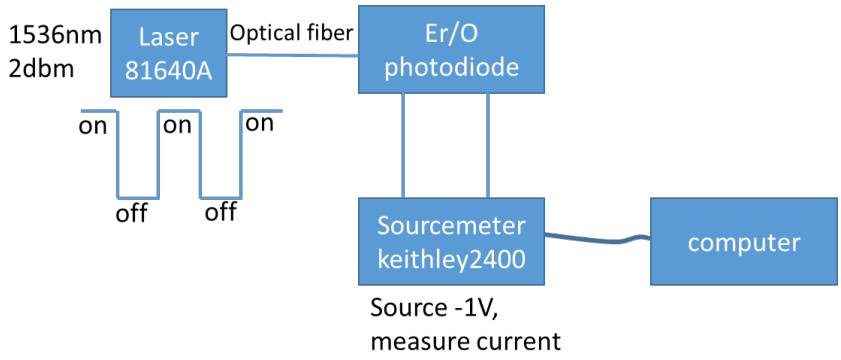

Figure S2 Transient photocurrent measurement diagram.