2-8

Ion Implanted ZnSe p-n Junction Devices

Y. S. Park, Aerospace Research Laboratories, Wright-Patterson Air Force Base, Ohio 45433 and B. K. Shin, Systems Research Laboratories, Inc., Dayton, Ohio 45440.

Various ZnSe p-n junction devices have been fabricated from n-type ZnSe by implanting phosphorus ions at room temperature. Among them are electroluminescent devices, switching and memory devices and backward diodes. Implantation at room temperature was performed at 70 to 400 keV to a dose of approximately 10^{14} to 10^{16} ions/cm.^{2} ZnSe crystals doped with aluminum (10-1000 ppm) having the resistivity values in the range 0.01 to 1 Ω-cm were used. By selecting conductivity of the substrate materials and implantation dosage, and optimizing post-annealing conditions such as temperature, duration and environment, the devices exhibiting specific properties were readily reproduced.

The diodes exhibiting an excellent rectification characteristic with saturation current of 1.3×10^{-12} A were obtained. The substrate ZnSe samples having the carrier concentrations in the range 10^{16} to 10^{18} /cm^3 were implanted to a dose level of 10^{14} to 10^{16} /cm^2 at 70 to 400 keV and annealed for 10 minutes in an argon atmosphere. The I-V characteristics obey the relation $I \propto \exp(eV/nkT)$ with the value of n as low as 1.3. The electrical breakdown in reverse bias at room temperature occurs at about 34 V and the temperature coefficient of breakdown voltage is found to be about 0.05 V/°C.

Good electroluminescent devices were obtained, in general, in the samples having the carrier concentration of ~10^{17} /cm^3, which were implanted at 400 keV to a dose level of 10^{14} /cm^2 and annealed at 500°C for 5 minutes in an argon atmosphere. The devices emit light in both forward and reverse directions. In the forward direction, the diode has an electroluminescence spectrum closely similar to the red photoluminescence spectrum, with a peak at 6300 Å at 300°K. This is a characteristic luminescence due to a phosphorus center in the ZnSe. When biased in the reverse direction, the diode emits light peaking at 5900 Å, which is a self-activated luminescence band arising from transitions between localized states of a center consisting of a zinc vacancy and the impurity.

Switching and memory effects were observed in the diodes when the samples were annealed at 500°C for 5 minutes in air. The samples having the carrier concentration of about 10^{18} /cm^3 were implanted at 90 keV to a dose level of 10^{16} /cm^2. In the forward direction, the switching action takes place from the high-impedance state A at the threshold voltage of about 10 V to the low-impedance state B. The device does not switch from the state B. The low-impedance state B has been maintained for one week at zero bias and can be reproduced until the diode is biased in the reverse direction. In the reverse direction, the switching action takes place from the low-impedance state C at the threshold voltage of about 4 to 10 V to the high-impedance state D. The diode remains in the state D indefinitely.

Backward diodes were obtained when a heavily doped sample (1000 ppm) was implanted to a dose level of 10^{16} /cm^2 at 90 keV and annealed at 600°C for 10 minutes in an argon atmosphere. The I-V characteristic is that of the diode without negative resistance.

Figure Captions

Fig. 1 Semi-log plot of dc current-voltage characteristics of a phosphorus implanted ZnSe diode at room temperature in the dark.
(a) as implanted and (b) after annealing at 450°C for 5 mins.

Fig. 2 I-V characteristics of a phosphorus implanted ZnSe diode measured in the dark at (a) 300°K and (b) 200"K.

Fig. 3 Electroluminescence spectra from a forward biased phosphorus implanted ZnSe diode.

Fig. 4 I-V characteristic showing two switching states in a phosphorus implanted ZnSe diode.

Fig. 5 I-V characteristic of backward phosphorus implanted ZnSe diode.

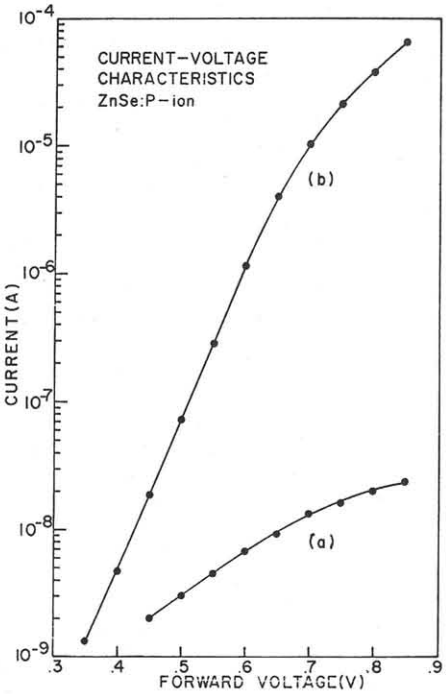

Fig. 1

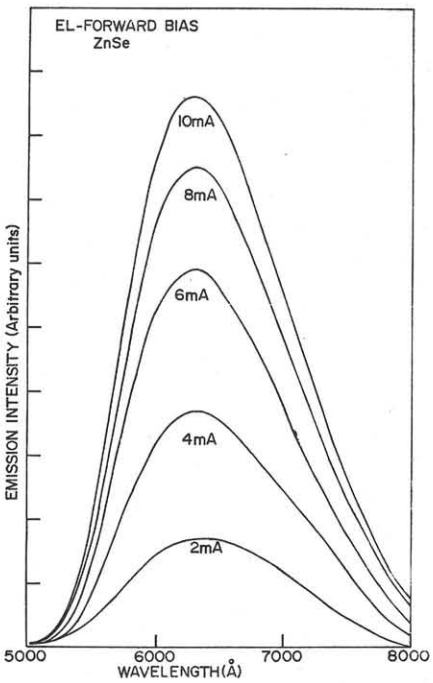

Fig. 3

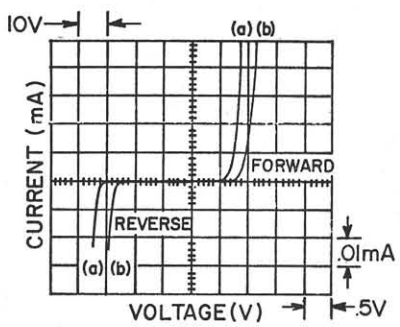

Fig. 2

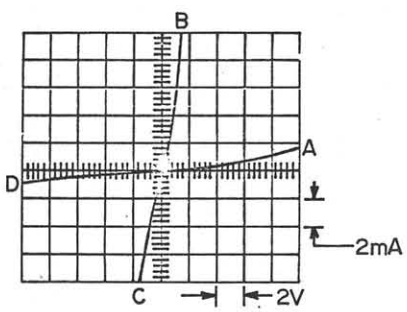

Fig. 4

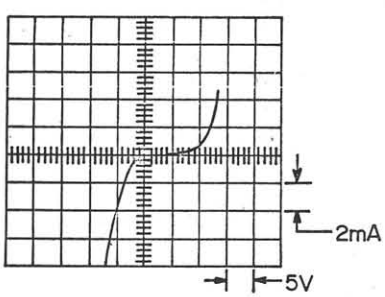

Fig. 5