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FABRICATION AND CHARACTERIZATION OF SEMICONDUCTOR LASERS OF $Pb_{1-x}Sn_xTe$

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14. Abstract/Notes

The fabrication and characterization of PbTe homostructure diode-lasers are described. The threshold current density is in the range between 2.5 and 10 KA/cm² and the factors that lead to the device degradation are discussed.

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FABRICATION AND CHARACTERIZATION OF SEMICONDUCTOR LASERS OF $Pb_{1-x}Sn_xTe$

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ABSTRACT - The fabrication and characterization of PbTe homostructure diode-lasers are described. The threshold current density is in the range between 2.5 and 10 KA/cm² and the factors that lead to the device degradation are discussed.

Lead salts semiconductor lasers have been widely used, among other applications, in pollution monitoring[1] and uranium isotope separation techniques[2] due to their high resolution capabilities and to their emission wavelength range between 6 and 16 μm.

The frequency tuning of the emitting diode can be done by varying the alloy composition (x) (Fig. [1])[3] and a fine tuning can be further achieved by small changes in the operation temperature.

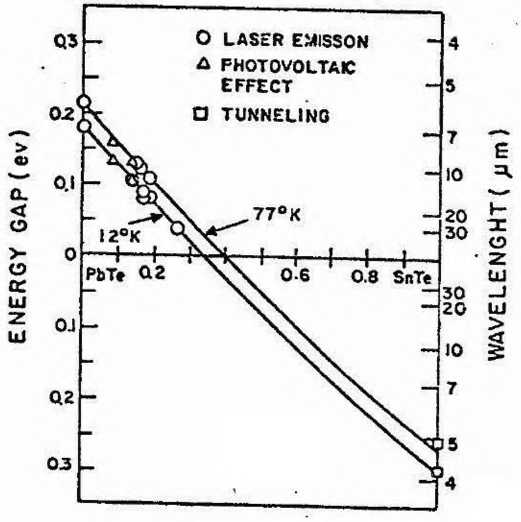

Fig. [1] - Energy gap of the $Pb_{1-x}Sn_xTe$ alloy versus tin atomic concetration (x).

(After J. Melngailis, Ref. 3).

The $Pb_{1-x}Sn_xTe$ alloy is extensively used at our laboratories to fabricate photovoltaic infrared detectors[4] and the aim of this work is to use the available technology in the fabrication of PbSnTe semiconductor lasers.

The technique used to grow the layers for the p-n junction is the Liquid Phase Epitaxy (LPE) that consists in a melt-substrate contact during a period of time in which the system temperature decreases at a constant rate. The layer thickness is controlled by these two factors.

The best layers were obtained with a supersaturated growth (melt-substrate contact at a temperature a couple of degrees below the saturation temperature)[4-5]. The carrier type and concentration are determined by the expansion of the phase diagram, around stoichiometry, as shown in Fig. [2][6].

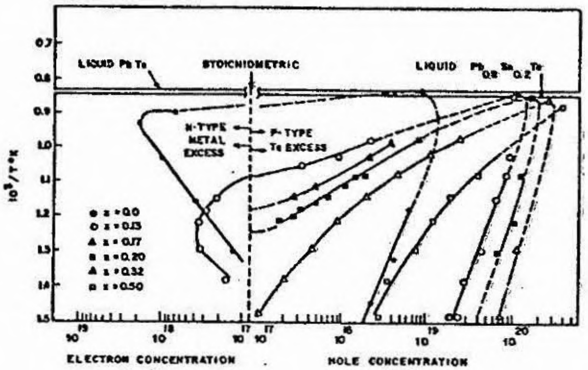

Fig. [2] - $Pb_{1-x}Sn_xTe$ carrier concentration versus growth temperature for several tin concentrations.

(After L.R.Tomasetta, Ref. 6)

The substrates are prepared from PbTe single crystals grown by Bridgman and VMS techniques[7], oriented and polished to achieve a (100) optical surface.

The X-ray Laue diffraction pattern shows that the layers are monocrystalline, following the substrate orientation. Morphological characterization of the layers shows ripples (due to small deviations from the (100) substrate plane), transversal lines (due to substrate preparation) and metallic inclusions (due to the growth temperature).

In this work two types of PbTe homostructures have been grown: $P^+(5\times10^{18}cm^{-3})/N^+(2\times10^{17}cm^{-3})$ and $P^+(5\times10^{18}cm^{-3})/N(1\times10^{17}cm^{-3})/N^+(7\times10^{18}cm^{-3})$.

After the growth process, the next step is to make a stripe to confine the current flow in a well-defined area, reducing the active region width and permitting to work with lower currents. For this a 0.3 μm thick insulant layer of SiO_2 is evaporated by electron beam and stripes of 100 μm long are made using standard photolithographic techniques.

The metal contacts on the P-side are made by Au evaporation followed by In electroplating; on the N-side, In electroplated contacts are used.

Since PbTe is a soft material, the Fabry-Perot cavity (500 μm) is made by polishing two opposites sides to achieve flat parallel mirrors[6]. The individual lasers are then sawed to the final 300 μm width. The final device is shown in Fig. [3].

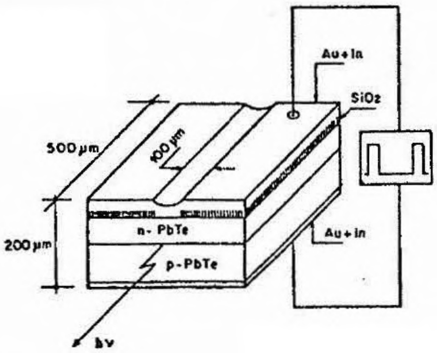

Fig. [3] - PbTe homostructure laser.

The lasers are mounted in a LN_2 Dewar for characterization. The laser base (substrate) is soldered in a Cu-In electroplated block and the other contact (N side) is made by pressure or with a gold wire soldered with In. It was noted that the soldered contact improves the stability of the laser radiation. The i x V characterization shows a series resistance between 1 and 2 mΩ for the lasers tested.

The lasers are drived at a frequency of 200 Hz with pulse of 20 μsec width and the radiation is detected by PbTe photovoltaic detectors also made by LPE[4].

The J_{th} of the lasers tested is in the range from 2.5 to 10 KA/cm² which are typical values of J_{th} for these types of lasers[8].

Laser degradation is shown in Fig. [4]. The first I_L (light intensity) x i (current) curve was taken in the initial operation period showing a J_{th} = 6 KA/cm² and the second curve, taken after three hours of use, shows J_{th} = 15 KA/cm².

Many factors that lead to device degradation such as defects in the mirrors, metallic contacts (series resistance), device package (soldering), thermal coupling, and layer defects will be object of further studies and improved in order to increase the device lifetime.

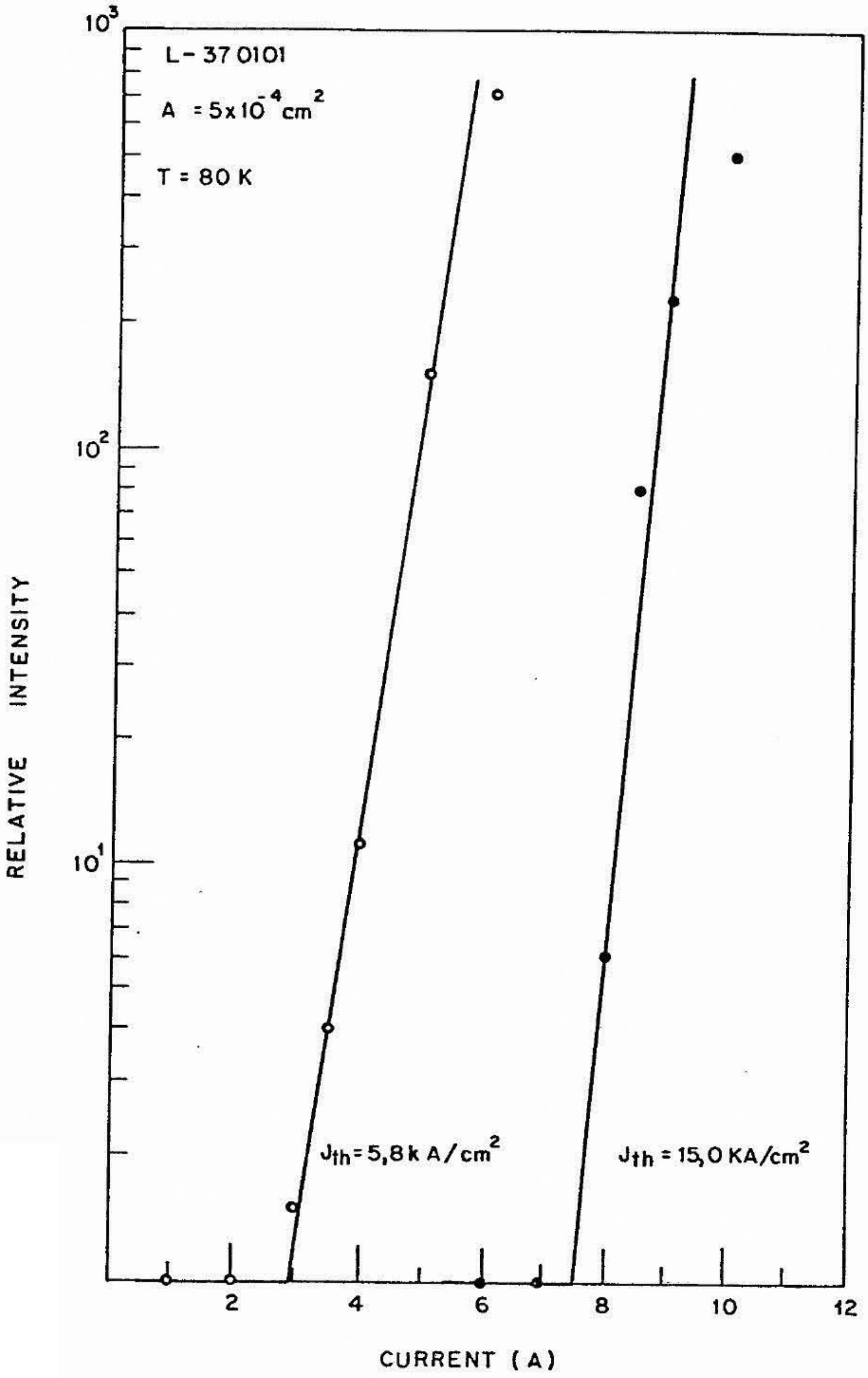

Fig. [4] - I_L x i curves for a PbTe homostructure laser. The left one relates to the first operation and the right one shows the J_{th} degradation after 3 hours of constant use.

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