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The Elimination of Contact Degradation in Lead-Salt Diode Lasers

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Tunable semiconductor lasers of lead-salt materials are finding wide application. Studies on using these lasers for high resolution spectroscopy, air pollution monitoring and combustion specie analysis have been reported.[1] Further applications of these lasers have been limited by the lack of well behaved and reliable devices. In this talk, the mechanisms of degradation and methods of controlling it will be discussed.

Lasers for this study were fabricated from single crystals of $Pb_{1-x}Sn_xTe$ and $PbS_{1-x}Se_x$ grown from the vapor phase.[2-5] Two modes of degradation have been observed. They are catastrophic failure and a slow increase in contact resistance. The former is caused by rapid thermal cycling between cryogenic temperatures and room temperature. This problem has been eliminated by using a newly designed heat sink package. In this design the motion of the laser chip against the heat sink package during temperature cycling is minimized.

Slow degradation (increase of contact resistance) is observed for lasers that have been stored at room temperature, even under vacuum. No degradation has been observed for lasers kept at temperatures below 77 K, even after several hundred hours of cw operation. This is consistent with the finding of Yoshikawa et al[6] that intrinsic degradation related to an increase in deep level, nonradiative recombination centers is virtually nonexistent. Figure 1 shows the I-V characteristic of a laser that has been subjected to life testing. It is evident that degradation occurs during room temperature storage, rather than during cw operation (including thermal cycling).

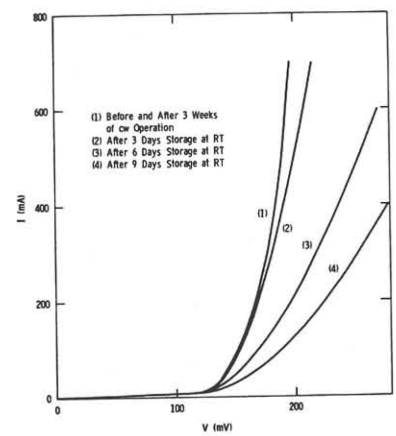

FIG. 1. I-V characteristics of a laser during operation and after storage at room temperature.

The contacts degrade on the p-type side of the laser, where both In-Au and In-Pt have been used for contacts. We found that the increase in contact resistance is caused by the diffusion of In into the surface layer of the p-type side. Figure 2 shows an electron microprobe analysis of In and Pb concentration profiles near the metal-semiconductor interface before and after a laser is degraded. After the contact resistance increased, traces of In were found in the first few μm of the crystal below the contact. Since In is a donor in lead-salt materials, a reduction in hole carrier concentration near the surface is expected. We think this is the reason for the increase in contact resistance.[4]

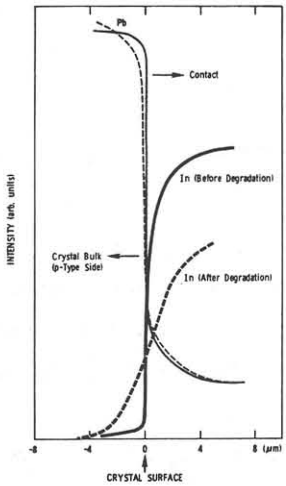

FIG. 2. Electron microprobe analysis of a crystal-contact interface.

Further study reveals that Au or Pt alone cannot form a barrier against In penetration, but a combination of Pt-Au does. A process for the formation of In-Pt-Au contacts on the p-side of $PbS_{1-x}Se_x$ lasers was then developed. In addition, the crystal surface was purposely oxidized before evaporating the first layer of Au. This increases the hole carrier concentration near the surface and tends to stabilize the contact resistance.

Over a period of eight months a group of $PbS_{1-x}Se_x$ lasers (made with this new kind of contact) has been tested for thermal cycling, room temperature storage and cw operation. For up to forty-six thermal cycles and several hundred hours of operation, no sign of degradation in contact resistance, threshold current density or optical properties was observed.

References

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