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Ion-implantation Study of HgCdTe

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The alloys of mercury cadmium telluride (HgCdTe) are important semiconductors for infrared applications. In the past 10-15 years, the development of HgCdTe devices has concentrated on n-type photoconductors because of the unusually high mobility ratio $\left(\frac{\mu_e}{\mu_h} \gtrsim 200\right)$ of these materials. Detectors have been made that operate at 77K with response out to 30 μm. However, these photoconductor detectors are low impedance ($\lesssim 100\ \Omega$), and therefore preclude the realization of large focal planes where excessive power consumption is undesirable.

Photovoltaic devices, on the other hand, are inherently superior to photoconductors because the development of photovoltaic HgCdTe is a recent emerging technology; the performance of individual diodes and arrays has been reported.[1-5] These diodes are made mostly by ion-implantation. For long wavelength applications, the low junction impedance of these diodes has limited their application in advanced electro-optical systems.

This paper reports on a comprehensive study of ion-implantation in narrow bandgap HgCdTe. Specifically, characteristics of implanted species such as B, Al, P, In, Ga, Hg, Cl, F, I, Br, Ag, As, N, H. Na, K under various implant and annealing conditions will be discussed.

Current work on B, Al, In and P ion-implantation in HgCdTe (8-14 μm spectral range) has produced n^+-p (B, Al, In) and p^+-n (P) junctions. The implants are performd at energies from 60 to 400 keV and at doses from 10^{10} to $10^{15}/cm^2$. Thermal annealing is subsequently carried out under various conditions by adjusting temperature, time, capping techniques and ambient atmosphere. Depth profiles of implanted species in as-implanted samples, as well as the redistributed profile in post-implant annealed samples, have been obtained by secondary ion mass spectroscopy (SIMS) techniques using a CAMECA ion probe. The profiles of the composition versus depth can be obtained over a few microns with an accuracy of $\lesssim 5 \times 10^{14}/cm^3$ ions. To compare the results of as-implanted depth profiles with theoretical predictions, Gaussian profiles have been calculated from theoretical estimates of the range parameters[6]. An example of experimental and calculated depth profiles of boron implanted HgCdTe is shown in Figure 1. The as-implanted profile is in good agreement with the calculated Gaussian profile.

After implantation, thermal and pulsed-laser annealing have been used to anneal the implant damage in HgCdTe and to electrically activate the dopant species. For example, Figure 2 shows boron depth profiles of a ZnS-capped sample which was isothermally annealed for two different annealing times; the as-implanted profile is also included for comparison. No significant redistribution of boron-implanted region occurred after annealing in either case. For a longer annealing time, however, two peaks in boron distribution occur; these are reproducible and have been observed for different doses. There also is a tail in the boron distribution. For samples that are annealed for a long time, however, this tail is often masked by the residual boron background in the sample. The boron depth profile of non-capped samples also has two peaks, similar to those shown in Figure 2; however, in this case the first peak (~0.03 μm from the surface) is much stronger than the second one(~ 0.25 μm from the surface), presumably due to Hg out-diffusion during annealing.

In summary, this paper provides a detailed discussion of the redistribution process due to annealing (thermal and laser induced). In addition, results from the radiation damage study using the $^{4}He^{+}$ backscattering technique[7,8] (for important dopants such as B, Al and P) and the junction depths as determined by electron beam induced current (EBIC), as well as the carrier concentration profiles and the estimated dopant activation efficiences will be reported.

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