A Study of the Surface Properties of Epitaxially Grown Indium Phosphide using Photoluminescence

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Abstract

Surface recombination of photogenerated minority carriers is one of the loss mechanism in p-n junction solar cells. Optically excited photoluminescence (PL) was used as a means of inferring the surface recombination velocity (SRV) of doped crystalline indium phosphide, which has been grown by current-controlled liquid phase epitaxy. By monitoring the PL intensity induced by two excitation wavelengths, the bulk diffusion length and surface recombination parameters may be obtained under suitable experimental conditions.

Various surface treatments were performed to attempt to reduce the SRV losses. These treatments included chemical etching and thin film formation/deposition. It was observed that some treatments may result in a reduced SRV, but the effect was unstable under atmospheric exposure.

Introduction

With the current use of InP as solar cells, a study of its surface properties is of interest for improving the efficiency and a better understanding of the surface recombination velocity. The SRV has been investigated for heavily doped n-type and p-type InP [2] and it was shown that the SRV depends strongly on the surface treatment. Surface recombination is nonradiative and thus, competes with bulk radiative recombination for the excess carrier densities. We examined the PL radiation emitted from the bulk, due to optically excited electron-hole pairs, the excitation wavelengths having energy \( hv > E_g \), the bandgap energy. At room temperature the radiation will have a spectral peak near \( E_g \). Treating the surface to reduce the SRV will increase the radiation intensity, since SRV is non-radiative [1]. The SRV is then interpreted from PL measurements before and after surface treatments.

Experimental Approach

Under the condition \( S/D \gg 1/L \) and \( L \gg 1/\alpha_e(\lambda_e) \), the photoluminescence intensity (PLI) is given by [2,3]:

\[
\text{PLI} = K\left[\frac{1}{\alpha_e} + \frac{D}{S}\right]
\]

where \( S \) is the surface recombination velocity, \( D \) is the minority carrier diffusion coefficient, \( L \) is the minority carrier diffusion length, \( \alpha_e(\lambda_e) \) is the absorption coefficient at the excitation wavelength \( \lambda_e \), and \( K \) is a system constant. Thus, by performing measurements at two wavelengths the \( D/S \) ratio can be calculated if \( \alpha_e(\lambda_e) \) is known.

The measurement system was implemented with an argon ion and a helium-neon laser as the excitation sources. A power meter/stabilizer was used to provide a known incident power. The transmitted integrated PLI was detected with a silicon photodiode placed in close proximity to the back of the InP sample. This DC detector signal was amplified by a current amplifier. In the alternate direct PL mode the surface radiated PLI was collected by a lens system and focussed into a spectrometer-detector system. The laser beam was chopped and a lock-in amplifier detector system was used. The transmitted PLI method seems to be more reproducible with respect to removal and replacement of the sample as was done when the surface treatments are performed. The samples with acceptor concentration in the \( 10^{17} - 10^{19} \text{ cm}^{-3} \) range were prepared by current-controlled liquid phase epitaxial growth of Mn-doped InP layers on InP substrates. After growth the back surface of the sample was chemically-mechanically polished to reduce the surface attenuation of the transmitted PLI signal.

The results of PLI measurements after various wet chemical etching and thermal surface treatments on InP will be presented.
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References

