Persistent photoconductivity in a InP:Fe single layer structure at room temperature

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Measurements of current in the dark and under illumination were carried out at room temperature on samples of semi-insulating (SI) InP:Fe, on which a layer of low resistivity InP:Fe was deposited. A voltage of 25 mV was applied. After the illumination was switched off, a remaining current was observed, for at least one hour, higher than the current before the illumination. This phenomenon is known as persistent photoconductivity (PPC) and, according to the suggested models, is due to the barriers separating electrons and holes and preventing their recombination.

Key words: semiconductors; photoconductivity; recombination and trapping; photoelectron spectroscopy

1. Introduction

In many semiconductor structures, a change in electric conductivity under illumination persists some time after switching off the light. This phenomenon is called persistent photoconductivity (PPC) and has been studied extensively during the two last decades. Measurements of the relaxation and decay of photocurrent have been carried out on the surfaces of epilayers of pure InP [1], n-InP/GaInAs [2], and Ga0.5In0.5P/InP:Fe [3]. Two prevailing theoretical models for the interpretation of PPC have been adopted up to date [4].

The first model is based on a spatial separation of photocarriers (electrons and holes) due to microscopic potential barriers, which are in turn due to zone bending on surfaces, interfaces, junctions, or around inhomogeneities (induced by implantation). If these potential barriers are high enough compared to the thermal potential $kT/q$, the

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lifetime of the remaining electrons and holes becomes very high. The other theoretical model accepts microscopic (atomic) energy barriers in centres with large relaxation times (DX centres). Another theoretical model, which is an extension of the first one [5], refers to the existence of clusters of faults (defect clusters). These clusters are local inhomogeneities, where the density of faults is much higher than the impurity density in the other parts of the crystal. Deep levels in the cluster are charged by electrons trapped from the surrounding material. In this way, a charge of opposite polarity is created around the cluster and consequently an overall potential barrier, separating the photocarriers and resulting in the appearance of the PPC.

In the present work, SI InP:Fe samples were used, with low resistance InP:Fe epilayers, (carrier concentration of $10^{16}$ cm$^{-3}$, and thickness of 0.5 μm). In our samples, the relaxation photoconductivity (PP) was measured as a function of the illumination time (photon dose) and the decay of PP as a function of time after switching off the light at the temperature of 300 K.

### 2. Experimental

Measurements were carried out on two SI-InP:Fe samples (carrier concentration $n = 2.68 \times 10^8$ cm$^{-3}$ and resistivity $\rho = 1.0 \times 10^7$ Ω·cm), on which there was an InP:Fe layer of low resistivity and concentration $10^{16}$ cm$^{-3}$ and with the thickness of 0.5 μm. Two orthogonal Au:Ge ohmic contacts were made, their separation amounting to 5 μm. The samples were placed in a cryostat, the window of which was closed with a Mylar sheet 25 μm thick.

The illumination system consisted of a small 250 W halogen lamp with an external elliptical mirror and a small computer controlled Oriel Optics Co monochromator. The illumination beam stroke incided vertically onto the surface where the contacts were made. For sample 1, light with the wavelength of $\lambda = 925.4$ nm was used, which corresponds to its energy gap, while for the sample 2 the wavelength of $\lambda = 850$ nm was used, which corresponds to the energy higher than the energy gap.

The photocurrent was measured with a Keithley electrometer at room temperature ($T = 300$ K).

### 3. Results and discussion

Before the PPC measurements, the specimens were heated in the dark to a temperature of 400 K in order to ensure that some of the photocarriers, created during the installation of the specimen in the cryostat, recombined. The photocurrent as a function of time for sample 1 is plotted in Fig. 1.

During the second hour of illumination, the photocurrent increased quickly to a maximum, at which the illumination was switched off. After the illumination was
switched off, the current was measured for an additional hour, and its value remained higher than the dark current before illumination.

Fig. 1. Sample 1, current versus time: a) first hour, before any illumination, b) second hour, under illumination with $\lambda = 925.4$ nm, c) third hour, after illumination was switched off

Fig. 2. Sample 2, current versus time: a) first hour, before any illumination, b) second hour, under illumination with $\lambda = 850$ nm, and c) third hour, after illumination was switched off

The photocurrent decay presents an obvious PPC, which can be attributed to the fact that electrons, excited by the substrate layer, are separated from their holes due to the presence of an internal electric field of the junction of the semiconductor layer
and high resistance semiconductor (substrate) [1]. A similar behaviour was observed for sample 2 (Fig. 2).

References


Received 23 September 2004
Revised 20 May 2005