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Conductivity of nanoporous InP membranes investigated using terahertz spectroscopy

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Abstract
We have investigated the terahertz conductivity of extrinsic and photoexcited electrons in nanoporous indium phosphide (InP) at different pore densities and orientations. The form of electronic transport in the film was found to differ significantly from that for bulk InP. While photo-generated electrons showed Drude-like transport, the behaviour for extrinsic electrons deviated significantly from the Drude model. Time-resolved photoconductivity measurements found that carrier recombination was slow, with lifetimes exceeding 1 ns for all porosities and orientations. When considered together, these findings suggest that the surfaces created by the nanopores strongly alter the dynamics of both extrinsic and photoexcited electrons.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Since the discovery of the luminescent properties of electrochemically etched nanoporous silicon [1], porous semiconductors have become the focus of intense research [2–6]. This is due primarily to the significant differences between the properties of porous semiconductors and their bulk counterparts [7], and to the potential new applications that these properties afford. For example, recent studies have reported porosity-induced birefringence in GaP with potential applications in optoelectronics [8, 9], luminescence in porous III–V and II–VI semiconductors [10–12], the ability of porous III–Vs to support Fröhlich-type surface vibrations [13, 14], and a porosity-induced blueshift of photoluminescence in CdSe [15]. There have also been studies of terahertz emission from porous InP [16].

In order to exploit the potential of nanoporous materials it is important to develop an understanding of how nanoscale structure influences the dynamics of charge carriers. An ideal tool for accomplishing this is the technique of terahertz time-domain spectroscopy [17]. Terahertz pulses are well suited for the purpose of probing semiconductor carrier dynamics because their low energy is non-resonant with the bandgap, and carrier scattering rates and plasma frequencies typically fall in the terahertz range. An additional advantage of terahertz spectroscopy over electrical conductivity measurements is that it is not necessary to fabricate Ohmic contacts, which is particularly a problem for fragile porous membranes.

The frequency-dependent terahertz conductivity has been examined for a variety of bulk semiconductors [18] and nanostructures [19–21], and for some of these systems, the conductivity has also been measured as a function of time after the photoexcitation of carriers by a pulsed laser beam. The time-dependent conductivity yields insights into carrier recombination dynamics, where carrier lifetimes can be significantly shortened by the presence of surface defects [20, 22].

In this paper we report on the conductive response of carriers in porous InP films using terahertz time-domain

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