THz Modulators and Detectors Based on Semiconductor Nanowires

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***Abstract*—Semiconductors nanowires have to potential to be building blocks for future nano-optoelectronic devices. We have recently demonstrated high performance THz photonic devices based on GaAs and InP nanowires. These include ultrafast optically switched modulators of THz radiation and single nanowire photoconductive detectors of THz pulses.**

I. INTRODUCTION

Terahertz technologies and applications have developed rapidly over the past few decades, however applicatuions in areas such as high-speed communications are limited by a lack of some components such as very high-speed modulators.[1] We have been expoliting the unique properties of semiconductor nanowires to develop new THz devices including ultrfast THz modulators and detectors.

Semiconductor nanowires of group III-V semiconductors can be grown as defect-free single crystals by molecular beam epitaxy (MBE) or metal-organic vapour phase epitaxy (MOVPE) [2], and hence they possess excellent electronic properties, such as very high electron mobilities, and may be doped precisely [3]. In addition the ~10nm diameters of the nanowires allow unique structures to be formed, such as heterojunctions with lattice mismatched materials, and both axial and radial quatum heterostructures [4].

We have previously developed techniques to characterise and optimise semoconductor nanowires based on optical pump terahertz probe spectroscopy [5]. Based on this work we have now developed nanowires and nanowire devices specifically for applications on THz science and technology.

II. AN ULTRAFAST THZ MODULATOR

GaAs semiconductor of diameter 50nm were grown by MOVPE at the Australian National University using Au-assisted Vapour-Liquid-Solid metthod [2] (as shown in Fig 1b). The nanowires were transferred onto parylene-C films such that the nanowires were arranged in a grid fashion. [6] Layers of parylene with nanowires embedded were laminated to form a flexible active polariser element, as example of which is shown in Fig. 1c. The concept of the THz modulator is shown in Fig 1a. The parylene-nanowire film acts as a wire-grid THz polariser when optically excited but just acts as a dielectric slab when not photoexcited. As the photoconductivity lifetime is very short in GaAs nanowires, the device can be switched on a picosecond timesacle. We previuosly demonstrated this concept with semoconducting carbon nanotubes [7], but he modulation depth was poor.

We utilised an optical pump–terahertz probe spectroscopy system [5] and varied the polarization of the optical pump beam to demonstrate the ultrafast parylene-nanowire THz modulator. The modulatuion switching time was found to be less than 5ps and a modulation depth of -8 dB. We achieved an extinction of over 13% and 4THz bandwidth.

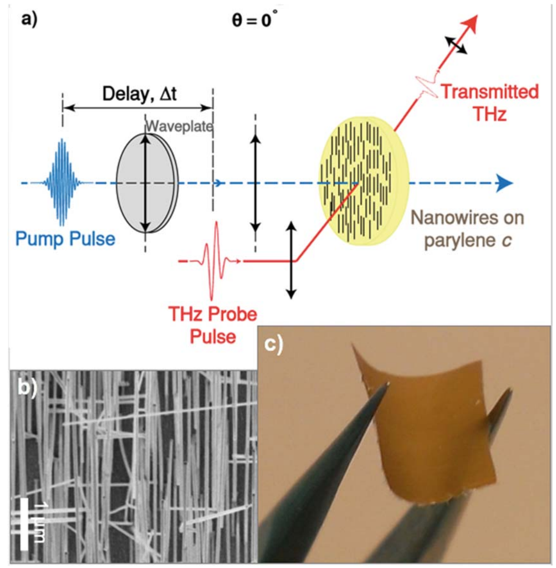

Fig. 1. (a) Schematic diagram showing the concept and experimental set-up of the ultrafast THz modulator. (b) SEM image of GaAs nanowires grown on the GaAs substrate before embedding in parylene (c) Photograph of flexible modulator film consisting of aligned GaAs nanowires embedded in parylene.

III. SINGLE NANOWIRE THZ DETECTORS

We have also recently used selective n-type doping along InP nanowires to improve the design and performance of our single nanowire photoconductive THz receivers [7,8].

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