Nanowires in Terahertz Photonics: Harder, Better, Stronger, Faster

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Abstract—**By virtue of their quasi one-dimensional geometries, III–V semiconductor nanowires present unique capabilities for terahertz photonic devices. Ultrafast terahertz polarisation modulators and miniature terahertz photoconductive detectors are two examples of such nanowire-based devices. By the same token, terahertz methods such as terahertz conductivity spectroscopy offer unparalleled insight into the electronic processes that dictate the performance of nanowire-based devices.**

I. Introduction

III–V semiconductor nanowires (Fig. 1a and b) combine the superior (opto)electronic properties of their constituent III–V materials with the advantages of the nanowire geometry. These advantages include tunable charge carrier lifetimes coupled with high charge carrier mobilities [1, 2], pronounced polarisation anisotropy [3], Young's moduli and yield strengths exceeding those of their bulk counterparts [4], waveguiding effects, the ability to combine highly lattice-mismatched and thermal expansion coefficient-mismatched materials without dislocations, and the occurrence of unusual crystal phases [5]. These properties are beneficial for a wide variety of applications spanning photonic integrated circuits, ultra-thin solar cells and terahertz photonics.

II. Contact-free Characterisation

Somewhat paradoxically, the quasi one-dimensional geometry that gives rise to nanowires' remarkable properties also makes nanowires challenging to characterise using conventional contact-based electrical measurement techniques (e.g. Hall effect). Optical pump–terahertz probe (OPTP) spectroscopy overcomes these challenges and enables the contact-free electrical characterisation of nanowires, including their ultrafast properties. For example, OPTP spectroscopy has revealed the nature of surface recombination in GaAs nanowires, which occurs on picosecond timescales [1]. OPTP spectroscopy has also been instrumental in identifying suitable surface passivation protocols [6] as needed for highly efficient optoelectronic devices.

III. Terahertz devices

High charge carrier mobilities, tunable charge carrier lifetimes and polarisation anisotropy make III–V nanowires ideal components for terahertz photonic devices. For example, arrays of aligned GaAs nanowires have been employed as switchable terahertz polarisers (Fig. 1c) that feature broad bandwidth, high modulation depth, low insertion loss and can be modulated on timescales of a few picoseconds [3].

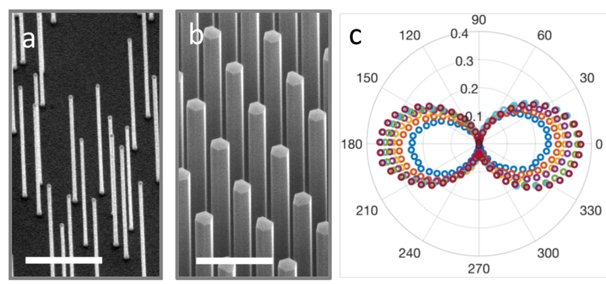

Fig. 1 (a, b) SEM images of (a) GaAs nanowires and (b) InP nanowires grown by metalorganic chemical vapour deposition for integration into terahertz polarization modulators and terahertz receivers, respectively. The scale bar in (a) and (b) is 1 μm. (c) Polar plot obtained from terahertz polarization modulators showing extinction of terahertz pulse as a function of polarization of photoexcitation pulse relative to the nanowire long axis, for photoexcitation fluences between 6 $\mu J/cm^2$ and 20 $\mu J/cm^2$.

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