Novel strain devices to observe pseudo-magnetic fields in suspended graphene membranes

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The interplay between a mechanical deformation of a graphene membrane and the change in electronic transport gives rise to novel physics, such as the formation of pseudo-magnetic fields, and offers a route to “straintronic” devices, in which the behaviour of the charge carriers can be modified by controlling the amount of local strain [1]. These devices have the advantage of exhibiting a range of conduction phenomena arising purely from the strain pattern within the graphene membrane, without the need to cut the graphene sheet. Furthermore, neighbouring devices on a single substrate can display different transport effects, despite common external parameters such as applied magnetic field.

Pseudo-magnetic fields can be induced by the introduction of non-uniform strain in the membrane and are expected to lead to unusual transport features in the quantum Hall regime, such as the prospect of the quantum Hall effect in the absence of applied field [2,3]. Furthermore, time-reversal symmetry is preserved for lattice deformations, and so the pseudo-magnetic field takes opposite values for electrons in the K and K’ valleys. This enables the valleys to be examined individually. Thus far, only non-uniform pseudo-magnetic fields have been observed in scanning tunnelling spectroscopy measurements in zero external magnetic field, probing the local density of states of highly strained graphene nanobubbles [4,5].

We have fabricated novel devices to produce the required strain configuration to produce uniform pseudo-magnetic fields in metal–graphene suspended structures for conventional two-terminal electron transport measurements. Conventional nanofabrication techniques, such as electron beam lithography, are used to pattern the structures. After partially etching the supporting oxide layer with hydrofluoric acid, the difference in the thermal expansion coefficients within the device structure leads to the metallic contacts selectively deforming upon cooling to cryogenic temperatures, producing the desired non-uniform strain. Finite element modelling was used to develop the contact design, which was verified with prototypes imaged in a low temperature electron microscope. The magnitude of the pseudo-magnetic field in these devices is designed to be ~1 T enabling the effects of the pseudo-magnetic field to be explored in conjunction with an experimentally-realisable external magnetic field. Electrical measurements in the electron-density–magnetic-field plane on these strained devices are on-going.

This work can easily be adapted to produce other strain configurations, providing a route to strain engineering the electrical properties of graphene, an area which has developed a large body of theoretical work but thus far little experimental work.

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