A graphene electron lens

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Single atomic layers of graphene show intriguing electronic and transport properties, and in the last few years they have been in the focus of interest for two-dimensional electron devices with high electron mobilities. Although the classical way to produce graphene is by exfoliation from a graphite crystal, supported graphene layers can also be obtained by graphitization of SiC in ultra-high vacuum. It is known that a more homogeneous surface is obtained when the preparation is carried out in argon atmosphere of up to 1 bar, which slows down the graphitization process and results in extended layers of graphene. We studied these graphene layers with scanning tunneling microscopy (STM), which allows direct atomic resolution and the unambiguous identification of possible defects in the graphene layer.

The graphitization of a stepped surface of SiC still results in a continuous graphene layer that then covers the steps of the supporting surface like a carpet. Recently, we have shown that the continuous growth of graphene follows even a stronger relief and grows smoothly on a SiC(0001) surface structured with hexagonal faceted nano holes [1]. Graphene has a very high elastic limit of nearly 30 % which allows to follow the facets of the hole by local straining of less than 1 %. Both the longer geometrical path and the lowering of the group velocity due to the stretching of the graphene at the facets lead to a retardation of the electrons passing across the hole. This arrangement is expected to behave like a focusing lens for the electron waves propagating in the two dimensions of the graphene layer. While the inclination of the facets is in the range of 5° to 7°, the relation between the depth of the hole and its diameter, thus the stretching of the graphene layer, is the parameter that can be used to tune the focal length. Typical holes of a few hundred nanometers in diameter and a depth of some nanometers result in focal lengths in the range of a few micrometers.

We have shown that pre-patterning of the SiC(0001) surface can be performed by focused ion beam lithography or by reactive ion etching through a structured porous alumina membrane [2] in order to obtain lens arrays on larger areas. The change of the electronic structure due to the focusing effect will lead to modifications in the work function of the graphene surface in the vicinity of the focal points, which can be measured with PEEM, Kelvin probe force microscopy or STM, depending on the lateral dimensions of the lens array.
The principle of indirect tailoring of the electronic properties of graphene by variation of strain avoids the problems that are linked to a direct engineering of the graphene layer itself and opens up a way towards a deliberate design of graphene-based high speed electronics.

References

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Figures

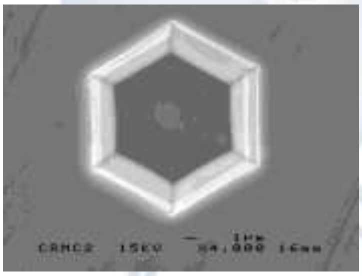

Fig 1. SEM of a hexagonal nano-hole in SiC

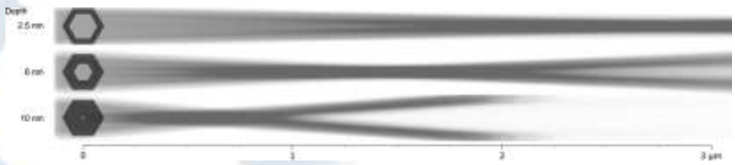

Fig 2. Simulation of the focusing effect of three different hexagonal 2D electron lenses