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Chemical vapor deposition of graphene and aligned graphene nanoribbons with controlled edges

It is possible to transform graphene from a semimetal into a semiconductor if it is confined into nanoribbons that are narrower than 10 nm with controlled crystallographic orientation and smooth armchair edges. However, the scalable synthesis of nanoribbons with this precision directly on insulating or semiconducting substrates has not been possible.

In this talk, we demonstrate the direct, scalable synthesis of graphene nanoribbons via chemical vapor deposition (CVD) on Ge(001). Low energy electron diffraction (LEED) and scanning tunneling microscopy (STM) show that the ribbons are self-orienting ±2.9° from the Ge[110] directions and are self-defining. The nanoribbons have predominately smooth armchair edges that give rise to electron interference patterns indicative of high quality edges. By tuning the precursor flux, growth time, and growth temperature, the ribbon anisotropy and growth kinetics can be tailored to yield ribbons with controlled width < 10 nm and aspect ratio > 60. Compared to previous low aspect ratio crystals of graphene obtained on Ge, we find that in order to realize high aspect ratio nanoribbons, it is critical to operate in a regime in which the growth rate is especially slow, on the order of 5 nm/h in the width direction.

This work is important because unlike continuous two-dimensional graphene, which is semimetallic, one-dimensional graphene nanoribbons can be semiconducting, allowing for the substantial modulation of their conductance and enabling their application in semiconductor logic, optoelectronics, photonics, and sensors. Moreover, the direct synthesis of ultranarrow and smooth graphene nanoribbons on Ge demonstrated here provides a scalable, high throughput pathway for integrating semiconducting graphene directly on conventional large-area semiconductor wafer platforms that are compatible with planar processing.

References

[1] Jacobberger et al. Submitted (2015).

Figures

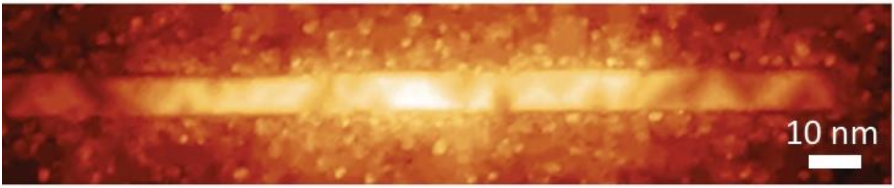

Figure 1: STM image of graphene nanoribbon grown directly on Ge(001).