Room-temperature ferromagnetism and fractals in hydrogenated epitaxial graphene

Schoo, R.E.S.
De Vries, N.V., Adriaans, G. P., Najafi, A., Ridene, M.,Flipse, C.F.J.

Molecular Materials and Nanosystems, Eindhoven University of Technology, 5600MB, EIndhoven, Netherlands

R.E.S.Schoo@tue.nl

Thermal decomposition of the Si-face of 6H-SiC provides large sheets of high quality graphene on a substrate compatible with processing methods in the silicon industry [1]. When such epitaxial graphene (EG) is bombarded with atomic hydrogen, the resulting partially hydrogenated graphene exhibits unusual properties. In our group we have established that, at low hydrogen flow and for certain hydrogen coverages, hydrogenated EG becomes ferromagnetic (maximum magnetization of $\pm 27 \cdot 10^{-7}$ emu) [2] as a result of periodically distributed localized electron states on the silicon atoms directly below the graphene layer [3][4]. The spin relaxation length in graphene is large due to the (virtual) absence of spin orbit coupling, which implies that our discovery of ferromagnetic behaviour makes the system a very interesting candidate for the realisation of spintronic devices. Additionally, higher hydrogen flow regimes were identified where special surface structures are formed, approximately 1-2nm high, which have a fractal-like outline. Using electric force microscopy, a variation on AFM, we have established that these fractal structures contain an inhomogeneous and loosely bound surface charge density [5]. On theoretical grounds we believe this corresponds to the hydrodynamic regime of quantum Hall quasiparticles [6]. By extending the hydrodynamic description of quantum Hall quasiparticles to the hydrogenated EG system, we found that the elastic deformation of the graphene sheet by the chemisorption of hydrogen [5] can cause the fractal growth patterns.

References

[1] Emtsev, K. V., Bostwick, A., Horn, K., Jobst, J., Kellogg, G. L., Ley, L., & Seyller, T., Nature Materials, 8(3) (2009) 203
[2] Giesbers, A. J. M., Uhlířová, K., Konečný, M., Peters, E. C., Burghard, M., Aarts, J., & Flipse, C. F. J., Physical Review Letters, 111(16) (2013) 166101
[3] Ridene, M., Kha, C. S., & Flipse, C. F. J., Nanotechnology, 27(12) (2016) 125705
[4] Ridene, M., Najafi, A., Iezhokin & I., Flipse, C. F. J. (to be submitted)
[5] Najafi, A., Knoester, M., Juricic, V., Ridane, M., De Vries, N. V., Schoo, R.E.S., De Morais Smith, C. & Flipse, C.F.J. (submitted)
[6] Agam, O., Bettelheim, E., Wiegmann, P., & Zabrodin, A., Physical Review Letters, 88(23) (2002) 2368011

Figures

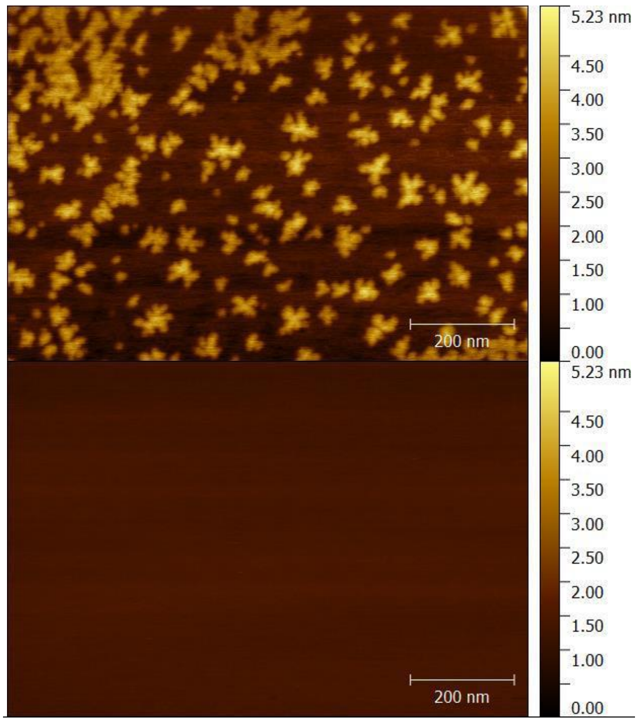

Figure 1: Top: Fractal surface structures are observed in AFM after partial hydrogenation of epitaxial graphene on 6H-SiC. Bottom: before hydrogenation no features appear at this scale. Scan window is 1x0.7μm² in both cases.