Micro four-point probe characterization of nanostructured graphene

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The typical approach for investigating the electronic properties of graphene involves several mutually aligned lithographic steps to define the shape of the graphene and for metallic contacts [1-3]. Lithography must be aligned manually to micromechanically cleaved graphene, although graphene from chemical vapor deposition (CVD) and epitaxial growth are less restrictive. The lithographic steps are usually time consuming and it is difficult to avoid contamination of the graphene with resist residues, or damage to the graphene, which modifies the properties with respect to pristine graphene [4-5].

In this work [6], we present electrical measurements on single and few-layer graphene cleaved from naturally occurring large flake graphite onto silicon dioxide (SiO_2), using repositionable micro four-point probes (M4PP), and compare with results obtained through standard lithographic techniques. The electronic properties measured in this way are comparable to those obtained with lithographic electrodes, yet M4PP allow for fast characterization of as-fabricated graphene without exposing the graphene to chemicals or electron beam irradiation, or modifying the graphene after production. Moreover it provides the possibility of mapping the graphene surface with high spatial resolution.

In M4PP measurements we observe a hysteresis in the charge neutrality point depending on the rate of the gate sweep, which we ascribe to charge trapping in the SiO_2 [2-3,7-10], with a maximum in the observed hysteresis at 0.8 V/s. The graphene appears to be very resistant to mechanical scratches from the probes; however, as expected, near the critical current densities [11] of graphene at the point shaped electrodes will lead to irreversible damage, typical at 10^8 A/cm^2. For measurements on nanostructured graphene, micromechanical cleaved graphene is etched in a Hall bar geometry, and measurements on the sample with both fixed electrodes and M4PP are performed. In common with previous reports, [12-15] the nanostructuring of the graphene leads to a measurable perturbation of the electronic properties with respect to the pristine graphene.

The micro four-point probes can be used to perform local, non-destructive measurements on graphene in a far shorter timescale than using fixed lithographic contacts. The sample size is only limited by the probe pitch, and characterization is possible between many process steps. Micro four-point probes can therefore be used as an in-line verification tool for process monitoring in graphene production, as well as providing a unique possibility of probing and mapping the electronic transport properties of graphene.

References

[1] Novoselov K S, Geim A K, Morozov S V, Jiang D, Zhang Y, Dubonos S V, Grigorieva I V, Firsov A A, Science, **306** (2004) 666-9
[2] Lafkioti M, Krauss B, Lohmann T, Zschieschang U, Klauk H, Klitzing K, Smet J H, Nano Lett. **10** (2010) 1149-53
[3] Lohmann T, Klitzing K, Smet J H, Nano Lett. **9** (2009) 1073-9
[4] Jacobsen A, Koehler F M, Stark W J, Ensslin K, New J. Phys. **12** (2010) 125007
[5] Ishigami M, Chen J H, Cullen W G, Fuhrer M S, Williams E D, Nano Lett. **7** (2007) 1643-8
[6] Klarskov M B, Dam H F, Petersen D H, Hansen T M, Löwenborg A, Booth T J, Schmidt M S, Lin R, Nielsen P F, Bøggild P, Nanotechology, **22(44)** (2011) 445702
[7] Dan Y, Lu Y, Kybert N J, Luo Z, Johnson A T C, Nano Lett., **9** (2009) 1472-5
[8] Joshi P, Romero H E, Neal A T, Toutam V K Tadigadapa S A, J. Phys: Condens. Matter, **22** (2010) 334214
[9] Liao Z, Han B, Zhou Y, Yu D, J. Chem. Phys., **133** (2010) 044703
[10] Wang H, Wu Y, Cong C, Shang J, Yu T, ACS Nano, **4** (2010) 7221-8
[11] Murali R, Yang Y, Brenner K, Beck T, Meindl J D, Appl. Phys. Lett., **94** (2009) 243114
[12] Bai J, Zhong X, Jiang S, Huang Y, Duan X, Nat. Nanotech., **5** (2010) 190-4
[13] Sinitskii A, Tour J M, J. Am. Chem. Soc., **132(42)** (2010) 14730-2
[14] Safron N S, Brewer A S, Arnold M S, Small, **7(4)** (2011) 492-8
[15] Liu L, Zhang Y, Wang W, Gu C, Bai X, Wang E, Adv. Mat. **23(10)** (2011) 1246-51

Figures

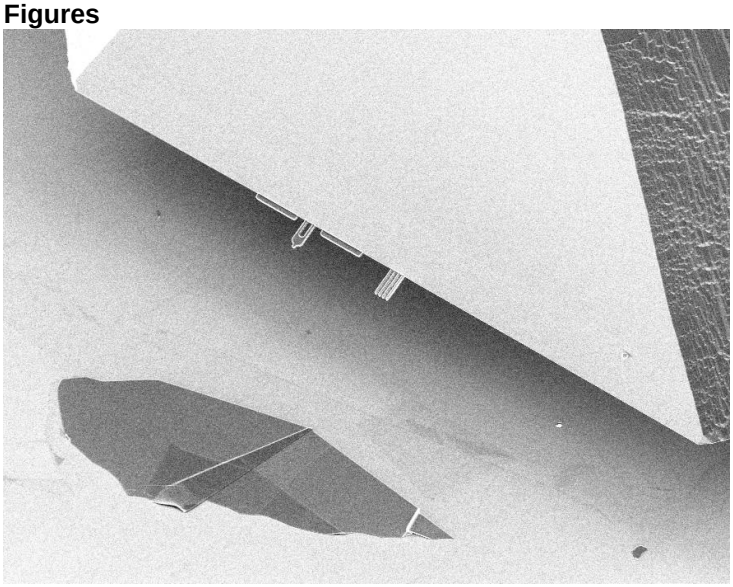

Fig. 1. Scanning electron microscope image of a micro four-point probe approaching graphene and graphite on silicon dioxide.

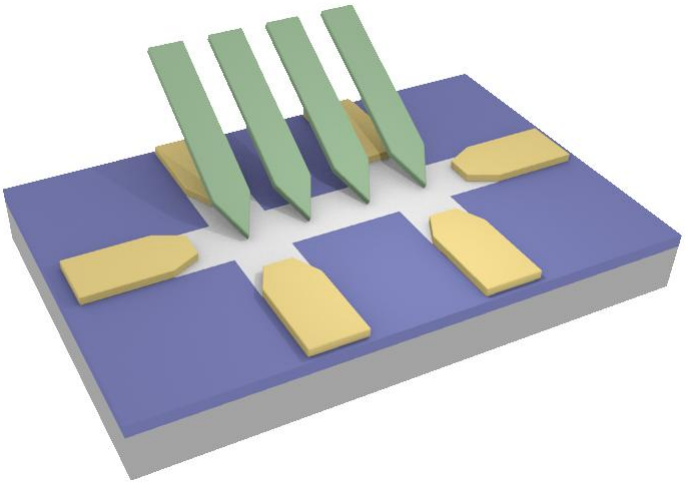

Fig. 2. Schematic for measurement on nanostructured graphene, which includes a comparison of fixed and micro four-point probes measurements on the same graphene sample.