In situ TEM electrical characterisation and patterning of graphene

Thomsen, Joachim Dahl; Gade, Carsten; Bøggild, Peter; Booth, Tim

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

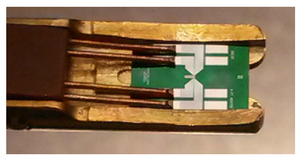
In situ TEM electrical characterisation and patterning of graphene

Joachim D. Thomsen, Carsten Gade, Peter Bøggild, Timothy J. Booth
DTU Nanotech,Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
jdth@nanotech.dtu.dk

Center for Nanostructured Graphene

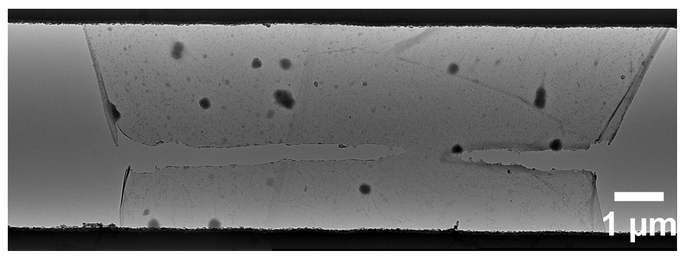
Introduction

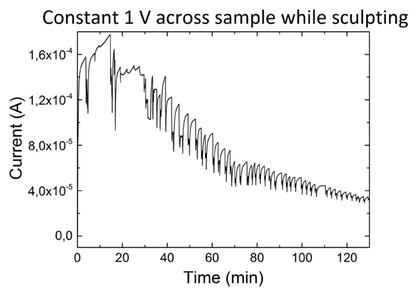
- Transmission electron microscopy is an excellent characterisation tool, able to obtain information about the graphene structure on an atomic scale
- It can also be used to pattern the graphene through (1) knock-on damage from the beam, (2) etching with oxygen (in an environmental TEM), (3) nanoparticle etching
- Here we present our preliminary work with graphene in-situ TEM



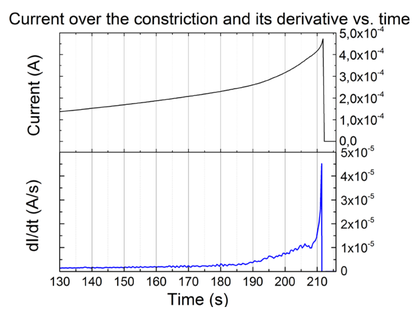
Graphene Constriction

1. Using knock-on damage we can structure the graphene by focusing the beam to a small area as possible, in this case forming a constriction.

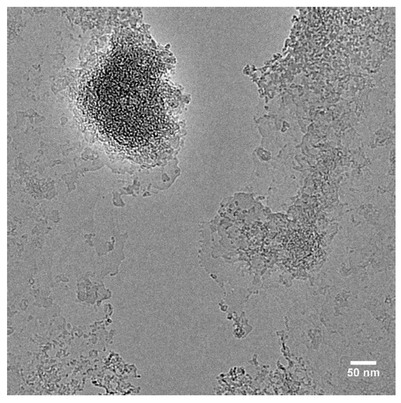




2. After sculpting we swept the voltage until the contriction broke

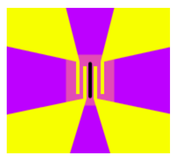


3. High resolution images of the broken area shows indications of heating

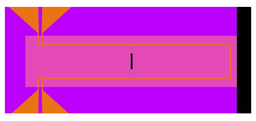


TEM Platforms

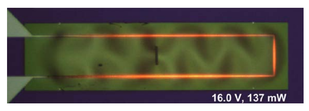
We have fabricated a variety of chips that are able to measure electrical properties and heat up.



Schematic of the 4 point contact chip. Colour code: yellow – metal, purple – nitride surface, pink – freestanding nitride, black – opening in nitride (35 µm long)



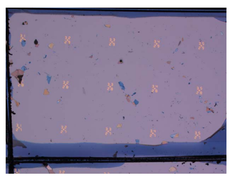
Schematic of the 4 point heater chip. Colour code: brown – encapsulated metal



Chip glowing hot in normal atmosphere

Cross sectional view – graphene on top

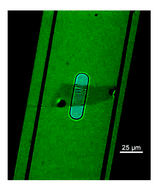
Graphene Transfer



We transfer graphene using the ”wedging” method with cellulose acetate butyrate (CAB). We have reproducibly obtained graphene suspended over 15 µm trenches on our TEM platforms.

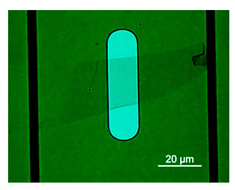
CAB cut

Transfer CAB to TEM chip



Bake to at least 135 °C

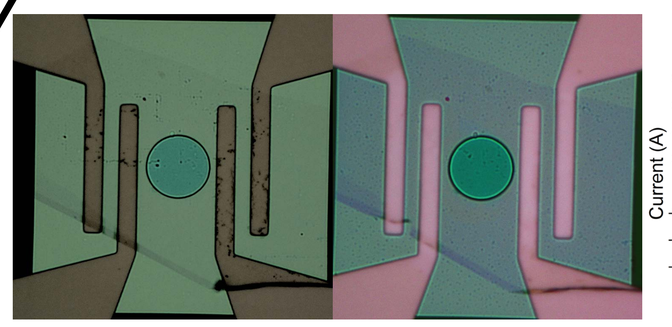
Dissolve CAB



Critical point drying

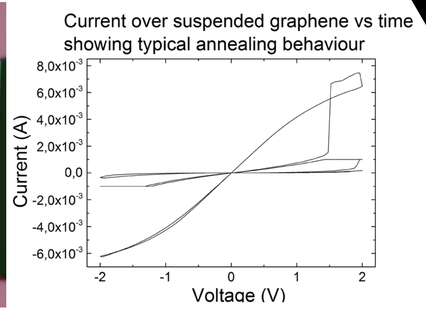
Cleaning Graphene

Current annealing in normal atmosphere

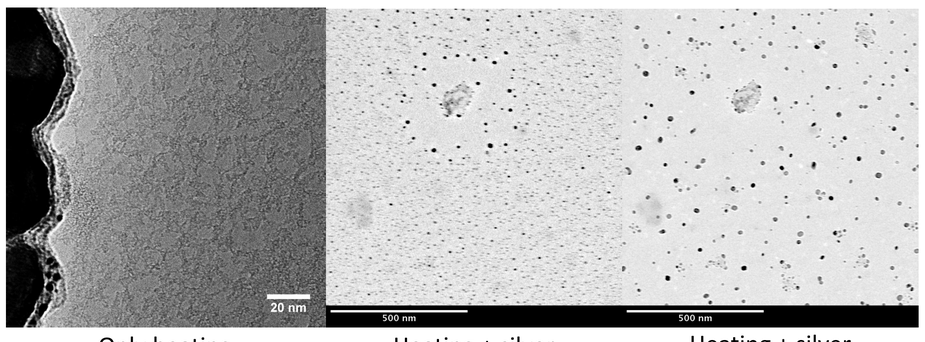


Before annealing

After annealing



In-situ TEM by the on-chip heater



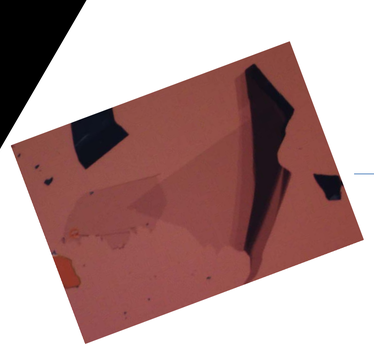
Only heating

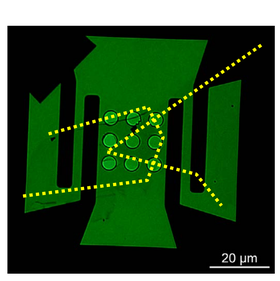
Heating + silver nanoparticles start

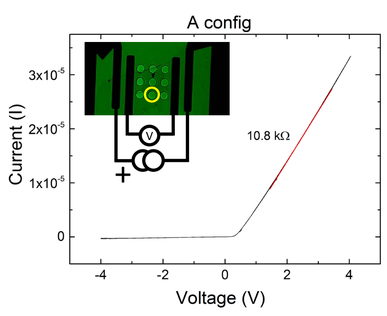
Heating + silver nanoparticles finish

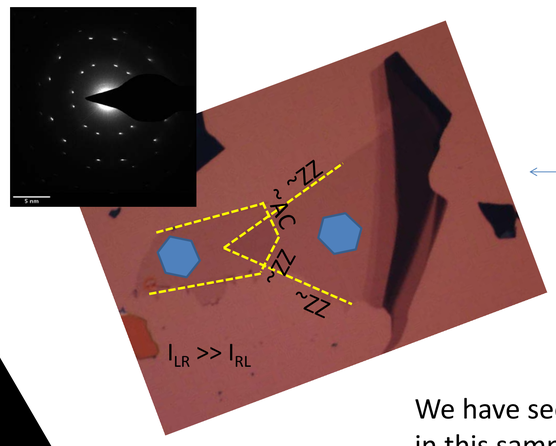
Twisted Bilayers

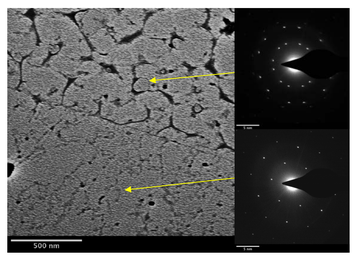
We have fabricated samples of stacked incommensurate monolayers (”twisted bilayers”) using wedging transfer to place a graphene flake on top of another. The stack is then transferred to the TEM platform.











We have seen a diode-like behavior in this sample with straight edges

The work leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° FP7-604000

Technical University of Denmark

DTU Nanotech
Department of Micro- and Nanotechnology