Mechanical properties of graphene with defects created by ion bombardment

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Abstract

Pristine graphene sheets exhibits superior mechanical properties very promising for applications; they are very light, flexible, stiff, and strong [1]. One of the main challenges for transferring graphene to real application is the large scale production. Currently all the routes to obtain graphene in large scale (CVD, Graphene oxide) produce layers with different kind of defects (grain boundaries, point defects). These defects have been demonstrated to lower the stiffness and strength of the layers [2, 3]. Unfortunately, the fact that these defects are created in a non-controlled manner during sample preparation prevents systematic studies on mechanical properties with defects.

Our approach in this work is to introduce defects in a pristine membrane in a controlled manner by Ar+ ion bombardment, creating mainly atomic monovacancies. For a precise characterization of the defect type and density we use Raman spectroscopy and STM. The stiffness and strength with defect density are then measured by AFM nanoindentations (Fig.1). Counter intuitively, we find that the stiffness of graphene increases with defect content until a vacancy content of ~0.2%, where it doubles its initial value. For higher irradiation doses the elastic modulus slowly decreases with defects inclusion. The initial increase in stiffness can be explained in the framework of statistical mechanics of 2D membranes, where the elastic coefficients are predicted to depend with the momentum of flexural modes [4]. In contrast to the elastic trend, the fracture strength decreases with defect density according to standard fracture continuum models.

References

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Figures

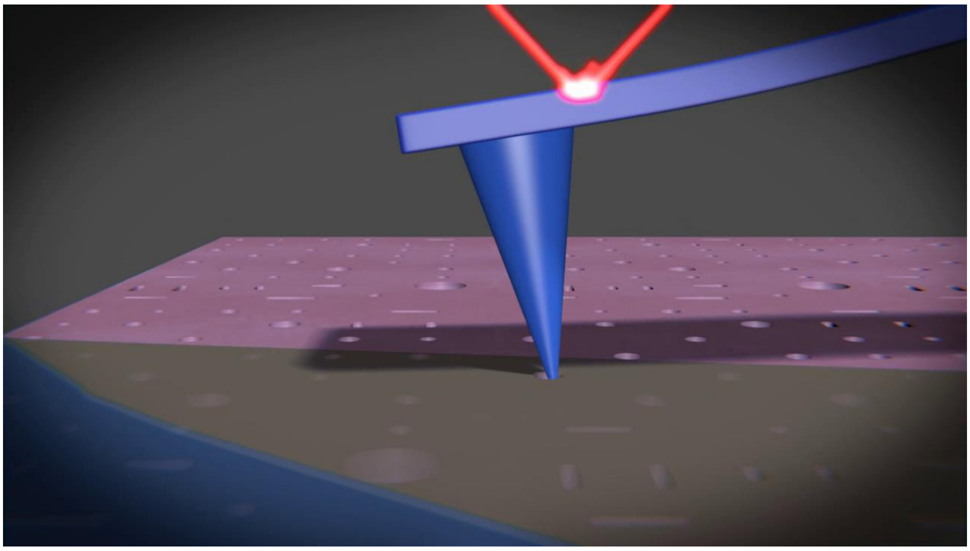

Figure 1. Scheme of a AFM nanoindentation on a free-standing graphene membrane.