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## **The origins of friction and the growth of graphene, investigated at the atomic scale**

Baarle, D.W. van

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**Author:** Baarle, D.W. van

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# Stellingen

behorend bij het proefschrift “The origins of friction and the growth of graphene, investigated at the atomic scale.”

## I

At first glance, one would expect that an ideal friction microscope should be equipped with a completely rigid tip. Such a stiff tip will actually not be capable of performing atomic-scale stick-slip motion and hence will not be suitable for the observation of individual atoms.

(Chapter 2 of this thesis)

## II

The extreme mass ratio between the tip apex and the cantilever of a friction microscope makes the momentum dissipation in such an instrument inefficient. Nevertheless, the tip influences the motion of the cantilever significantly due to the hopping character of its own motion. This effect reduces the Q-factor of the cantilever.

(Chapter 4 of this thesis)

## III

The growth mechanism of graphene on iridium is a complex process comprising several intricate steps, which repeat in a fixed sequence under the proper conditions.

(Chapter 7 of this thesis)

## IV

Graphene has the ability to prevent the formation of topological lattice defects during its growth on certain metal substrates by elastic deformation of its lattice.

(Chapter 9 of this thesis)

## V

Friction can arise without explicit dissipation, such as a velocity-dependent friction term in a Langevin equation, as the natural consequence of the dephasing of phonons.

(S.Yu. Krylov and J.W.M. Frenken, *Surface and Interface Science*, 4, Ed. K. Wandelt, Wiley-VCH, 2013, Chapter 30.)

## VI

The application of just a single atomic layer of graphene on the contacting surfaces of two sliding, macroscopic bodies can reduce the friction between these bodies significantly.

(Berman *et al.* *Diamond and Related Materials* **54**, 2015, 91-96)

## VII

Due to the variation in strain, induced by the substrate, the quality of graphene grown on polycrystalline substrates cannot be determined properly by Raman spectroscopy before the graphene is transferred to a different substrate. After transfer a new strain distribution may be introduced that still affects the Raman spectra.

(Wang *et al.* *J. Phys. Chem. C* **112**, 2008, 10637-10640)

## VIII

The lack of fundamental knowledge on graphene growth delays the industrial application of graphene.

(Vlassouk *et al.* *J. Phys. Chem C* **117**, 2013, 18919-18926; Wu *et al.*, *Nature Materials* **15**, 2016, 43-47)

## IX

People who try to protect historic organs by preventing amateur organists to play on them, are a major threat to those organs.

## X

For devices that contain logic elements, safety certification schemes that do not involve cyber security are unsafe.

Dirk van Baarle  
Leiden, 29 November 2016