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

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General introduction and outline

Two research fields meet

A single glance at the title of this thesis might give rise to questions on the focus and scope of the work reported here. Is this thesis a mere aggregation of two separate studies? What is the relation between research on the origin of friction and on the growth of graphene? Why is a theoretical study combined with experimental work?

The key to the answer to these questions can be found in previously reported work that was performed by Dienwiebel *et al.*[1]. In that work, it was discovered that the incommensurability between rotated graphite layers results in ultralow friction, also known as superlubricity. This effect of ultralow friction, measured at the nanometer scale, invites us to investigate the friction of a nanocontact: which parameters are essential to capture an atomic-scale contact in a simple model? Can we describe, understand and predict the behaviour of friction contacts, based on this model?

The results of Dienwiebel *et al.* invite us to think about a scaled-up version: is it possible to reproduce the low-friction behaviour between rotated layers of graphite at the macroscopic scale?

To perform such a macroscopic low-friction experiment, a first requirement is the availability of surfaces that are characterized by atomically flat and defect-free, macroscopic-sized single crystals of graphite or graphene. Can we realize such surfaces? Are there atomic-scale processes that can assist in the synthesis of perfect, macroscopic-sized graphene-covered surfaces?

Part I: On the origins of friction

The research reported in this thesis deals with the two types of questions outlined above. First, we present our studies into the origins of friction. Our approach is to focus on the dissipation of a single-asperity friction contact.

After an introduction of the subject and a brief overview of the current status of the research field on single-asperity friction in the first chapter, we present a bottom-up estimate of the dissipation of a frictional nanocontact in Chapter 2. The result shows that there is a significant discrepancy between our estimate and the typical values assumed in the literature. In order to solve this discrepancy, we present a more physical, but still rather simple method to describe a single asperity.

In Chapter 3, the numerical method to simulate and evaluate our new description of single-asperity friction is presented.

Chapter 4 contains the results of our computations. These results are discussed and compared with experimental results from the literature. This study brings us to a more fundamental understanding of a friction nanocontact. Additionally, it casts new light on the behaviour of sliding surfaces and invites us to speculate about new ways to control friction by manipulation of the contact geometry.

Part II: Graphene growth on Ir(111)

The second part of this thesis is dedicated to the experimental work performed on the graphene-iridium system. Using our high- and variable-temperature STM we studied the behaviour of graphene at nucleation and growth conditions on the Ir(111) surface.

In Chapter 5, the recent literature is discussed and the most relevant aspects of the experimental setup are described in combination with some methods used in our work.

Chapters 6-8 are dedicated to the results of the experiments, focussing on the nucleation, growth and ripening of graphene on Ir(111). Chapters 9 and 10 present some findings on the closure of a graphene film and on the high-temperature impact of iridium steps on the graphene overlayer.

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