Chapter 63
Selective Pick-and-Place of Thin Film by Robotic Micromanipulation

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ABSTRACT

Micro-engineering is increasingly interested in the use of thin films with thicknesses of less than 20nm. Before integrating these promising materials into complex Nano Electro Mechanical Systems (NEMS), their properties must be characterized. They must be transferred onto specific substrates for analysis. Current manipulation techniques are not suitable for the transfer of these thin films as they do not allow selection of the parts of the object that must be manipulated, and the quality of the sample is altered by traces of chemical residues. To perform the transfer of a selected thin film without modifying its properties, this paper presents a novel approach based on local gluing. This method has been validated by experiments performed on graphite films. Successful transfers of thin films of 4.2 × 4.7 μm² to 70 × 12 μm² with an estimated thickness of between 10 and 40 layers have been demonstrated. Limits of this technique are discussed.

INTRODUCTION

With the development of micromechanics and microelectronics the interest in thin films, especially for their numerous physical- properties, is growing (Booth et al., 2008; Lee, Wei, Kysar, & Hone, 2008). These promising materials will be used to make new devices like MEMS or resonators (Bunch et al., 2007). Fabrication processes of thin films are now well known (Geim, 2009; Shukla, Kumar, Mazher, & Balan, 2009). However, in order to integrate them in complex devices it is necessary to characterize their physical properties. In particular, structural characterization

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is a primordial and unavoidable step. Structural characterization, at different scales and levels, can be obtained by various microscopy techniques such as Optical Microscopy, Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM) and Transmission Electron Microscopy (TEM). Some of these techniques require the use of substrates with specific properties (for example, SEM requires conducting substrates, while TEM requires suspended samples).Many possible applications of thin films also encourage the use of particular substrates (e.g., doped silicon is widely used for electronic applications), it is thus necessary to place the area of the thin film that must be analyzed on a specific substrate, to be able to manipulate selected parts of thin films.

An important issue is the reduction of chemical contact during this transfer, as chemical residues can change the properties of thin films (Boukhvalov & Katsnelson, 2009). The understanding of physical-property modifications, by adding chemical materials (e.g., doping), is the subject of much research (Boukhvalov, 2011; Boukhvalov, Moehlecke, Silva, & Kopelevich, 2011; Lahiri & Batzill, 2010; Yazyev & Pasquarello, 2010). Avoiding chemical residues on thin films can ensure a constant quality of analysis. Therefore, analysis of thin- film properties, without chemical residues, allows an additional comprehension of physical properties.

Manipulation of these thin films is challenging since difficulties are due both to microworld properties and the two-dimensional (2D) geometry of the object. In the microworld, surface forces (electrostatic, van der Waals, and capillary forces) dominate compared to volumic force (gravity). Since thin films can be assimilated to planar structures with two dimensions significantly greater than the third one, they present a great ratio surface/thickness hence, a great interaction between the surface of the thin film and the substrate. Furthermore, due to their 2D geometry, they do not offer enough volume for microhandling, and grippers cannot be used. The problem of surface forces must thus be addressed.

Graphene, a monoatomic-thick layer of graphite, is the prototype of 2D crystals (Geim, 2009). Because of its many potential applications in different fields for example, nanoelectronics (Eda & Chhowalla, 2009; Hwang, Acosta, Vela, Haliyo, & Régnier, 2009), or nanomechanics (Bunch et al., 2008; Lee et al., 2008), it is a promising material. To manipulate selected thin films, this paper proposes a strategy based on local gluing. A drop of glue is deposited on a small isolated part, to prevent chemical contact with the rest of the thin film. This method allows the transfer to a specific area of a thin film, selected for its physical properties. This strategy is validated by experiments performed on graphite thin films. Thin films of $10 \times 10\ \mu m^2$ with an estimated thickness of 10 to 40 layers (4 to 16 nm) are transferred.

This paper is organized as follows. The next section presents the thin films used and their particularities. A review of classical solutions for micromanipulation using Microrobotics is made in section State of the Art. Section Materials and Methods describes the setup and the performed experiments. Results are discussed in the last section.

Sample Preparation

The graphitic thin films used in this study are obtained by an anodic bonding technique adapted to the preparation of graphene (Shukla et al., 2009).

This technique consists of sticking bulk graphite onto a Pyrex glass substrate, by simultaneously heating the system (to reach temperatures around 200°C) and applying a high voltage (according to the kV). After mechanical cleavage of the graphite on the Pyrex, the samples present graphitic areas of variable thicknesses, from a few hundred layers down to the monolayer limit. We focus here on the mechanical transposition of graphitic thin films formed by approximately 10 to 40 layers (Figure 1).