GLOBAL RESEARCH IMMERSION PROGRAM FOR YOUNG SCIENTISTS

GOLD-PATTERNED SUBSTRATE FOR EXFOLIATION OF BULK CRYSTALS AND ELECTRICAL MEASUREMENTS

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Introduction

Ever since the discovery of graphene, which is a single, two-dimensional layer (monolayer) of graphite, it has been observed that 2D materials display remarkable physical properties, which make them a great subject matter for the study of atypical quantum phenomena and electronic applications. However, the fabrication process of high-quality thin layers faces many challenges. One of the most common methods to create thin layers is exfoliation, which consists of applying mechanical forces to exfoliate a bulk crystal until we are left with a thin layer. The exfoliation is widely done by metal-assistance, which makes use of the strong adhesion between metals and the crystals to enhance the process. Despite obtaining large-area thin-layer flakes, this method still poses difficulties to subsequently isolate the samples from the metal without contamination. Recently, a gold-template-assisted exfoliation method was developed, which makes use of a SiO_2 substrate with gold patterns. The gold allows for enough adhesion for the exfoliation but the fact that it is patterned enables the presence of the thin layer directly in contact with the SiO_2 surface. Therefore, the sample is exfoliated directly onto the substrate, without the need to transfer or isolate it. In this work, we focus on reproducing the aforementioned technique and later improve it in order to make electrical measurements.

Research objectives

The objective of our research is to reproduce and improve the gold-template-assisted exfoliation by designing a new pattern for the gold, in such a manner that there will be two gold electrodes. These electrodes in the substrate will allow subsequent electrical measurements of the sample, such as transport and STM measurements. Therefore, this platform will provide a simple and efficient way to exfoliate the sample directly onto the substrate and immediately make measurements, without the need to transfer the samples.

Methods

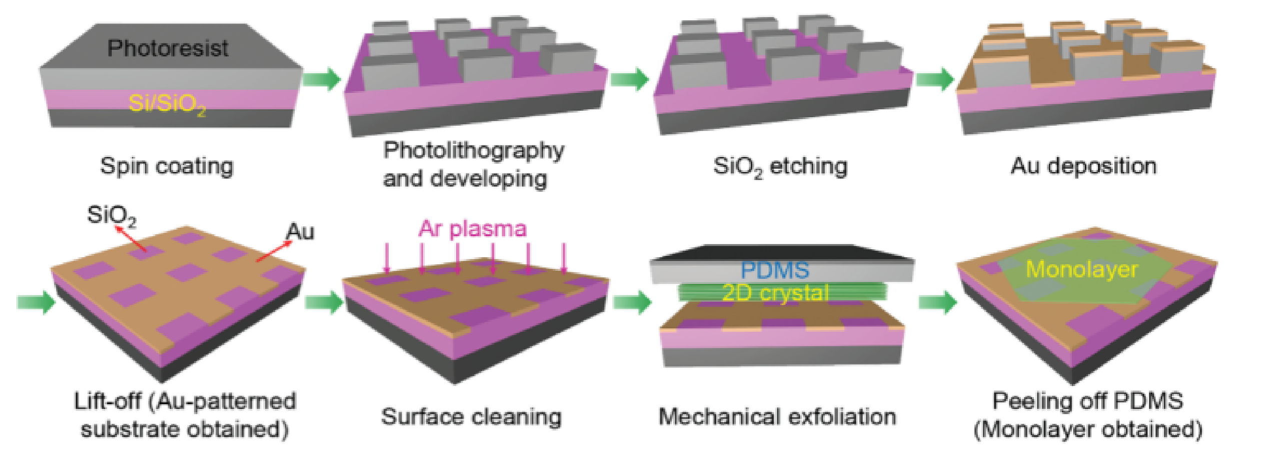

Figure 1: Schematic depiction of the Au-template-assisted mechanical exfoliation method used in the original paper.

The first step to achieve our objectives was to reproduce the literature results of the Au-template-assisted mechanical exfoliation, which is illustrated in figure 1. The process of fabricating the substrate consists of using photolithography to produce the template on a SiO_2 wafer, which is a technique that utilizes light to form patterns on a surface. Gold is then evaporated onto the wafer and, as a result of the photolithography, the pattern is formed. Next, a few different surface cleaning procedures were tested to note which offered the best subsequent exfoliation results, which include chemical and ultrasound treatment as well as plasma exposure. Finally, the substrate is taken to a glove box with inert gas where the bulk crystal is stored. Though the original paper used a polymer (PDMS) to peel a thinner sample from the bulk crystal, here Scotch tape was used. The tape containing the sample is pressed and rubbed onto the substrate and left to rest for a few hours. After the tape is peeled, it is expected to find large-area thin flakes on the substrate. An optical microscope is used to investigate the presence of mono- or few-layer samples.

Figure 2: Patterns used on the substrate. On the left, the original pattern, on the right, the new design pattern with two electrodes (not to scale).

After obtaining the reported results, the new pattern for the gold was designed containing the two electrodes, as represented in figure 2. Different parameters, such as the width of the gold lines, should be tested to evaluate the corresponding yields.

Preliminary results

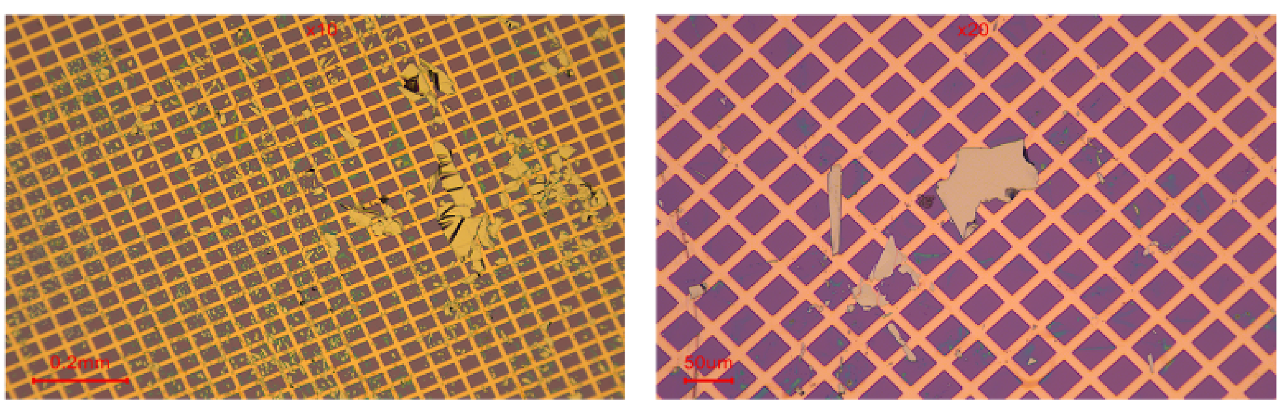

Figure 3: Optical images of the substrates after peeling the sample. On the left, substrate was treated with oxygen plasma, on the right, it was treated with argon plasma.

Figure 3 contains optical images of the substrates with the original pattern after the peeling, each cleaned with different plasma gases. Both results show the presence of thick, mostly small-area flakes, instead of large-area thin ones. The exfoliation yield, that is, the ratio between the original area of the sample and the area of the thin samples on the substrate, is also low. The reason for this is the presence of a high boundary between the SiO_2 and the gold, as shown in the AFM measurements in figure 4. Thus, the lack of a flat surface hinders the exfoliation. It is also possible that, for the oxygen plasma, gold oxide was formed, lowering the stickiness of the gold.

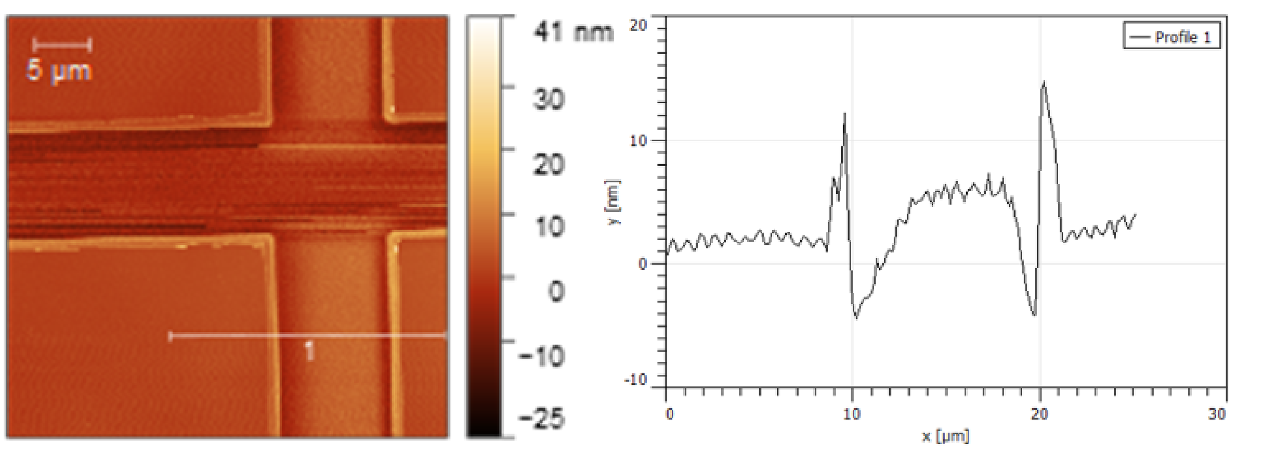

Figure 4: AFM measurements of a substrate treated with argon plasma for 3 minutes. On the left, the AFM image, on the right, the vertical profile of the boundary between SiO2 and gold.

Discussion

There was a difficulty regarding the reproducibility of the methods used in the original article, therefore it is important to change a few parameters in order to achieve good results. So far, the use of argon and oxygen plasmas for cleaning the substrates have not yielded satisfactory exfoliation results, preventing the research to move onto testing the new pattern.

Conclusion

Though this research faced obstacles, it has been able to achieve important conclusions: the use of plasma must be tuned to produce clean and flat substrates, otherwise, the exfoliation won't be successful. The presence of a high boundary between the gold and SiO_2 has prevented us from achieving the reported efficiency of this method. Therefore, further research is needed to accomplish the two electrodes-pattern.

References

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