Transfer of exfoliated graphene with controlled number of layers to optical fiber faces for Erbium-doped fiber laser mode-locking

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Abstract

Fabrication of CVD graphene samples for rare-earth doped fiber laser and other optical applications has been extensively reported [1-3]. Due to the simplicity of wet-transfer process, CVD grown graphene can be easily transferred, in few steps, to the desired target substrate, such as quartz/silica flat substrates [4] and optical fiber ferrule's end face [5]. However, making CVD graphene samples for optical experiments has some drawbacks, mostly related to samples optical quality, which can compromise experiments reliability and repeatability: polymeric and chemical residues, presence of defects and folded regions on transferred graphene, and the difficulty of unambiguously determine the number of graphene layers.

On the other hand, making samples with mechanically exfoliated graphene, which is layer controllable, low defect, has a challenge that lies on the transfer process. Usually obtained over Si/SiO_2, a non-transparent substrate, exfoliated graphene requires some steps to be transferred to the desire substrate [6]. Previous work successfully transferred graphene directly from scotch tape to fiber face [7], nevertheless achieving non-controllable and non-repeatable number of graphene layers. In this work, we propose a novel technique that unambiguously allows transferring of graphene samples of controlled number of layers directly from the original exfoliation substrate to the final target substrate.

As reported in [8], exfoliated monolayer graphene can be observed and identified depending on the interference conditions between graphene and its substrate. Using a similar analytical model, we determined that glass substrates (1 mm thick) with a PMMA spin-coated layer (300 nm thick) can be a good transparent substrate for exfoliating and identifying graphene, as shown in Fig. 1. As preliminary results, graphene samples with 1and 2 layers, along with multilayer graphene, were obtained in such substrate, and identified by Raman spectroscopy, as shown in Fig. 2.

These samples can be used for transferring exfoliated graphene directly to the polished end face of an optical fiber ferrule. To demonstrate the transferring process, we placed a multilayer graphene sample on a transferring machine setup, as shown in Fig. 2a. In order to soften the PMMA and unstick graphene from it, making graphene adhere to the optical fiber ferrule's face, the area in contact must be heated at ~ 200 degrees C [9], an early point for PMMA thermal degradation. As shown in Fig. 2b and 2c, we successfully transferred multilayer graphene from glass/PMMA substrate to optical fiber face, covering the whole 9 µm diameter fiber's core.

A work on the layer-controlled graphene samples transferring process to optical fiber faces is ongoing, and a study on the influence of graphene number of layers and its related charge-carriers dynamics on the ultrashort pulses generation in graphene mode-locked Erbium-doped fiber lasers is under development.

References

[1] Q. Bao, H. Zhang *et al.*, Nano Res., **4** (2011) 297-307.
[2] M. Zhang, E. J. R. Kelleher *et al.*, Opt. Express, **20** (2012) 25077-25084.
[3] Z. Sun, D. Popa *et al.*, Nano Res., **3** (2010) 653-660.
[4] Y. Wang, S. W. Tong *et al.*, Adv. Mater., **23** (2011) 1514-1518.
[5] Q. Bao, H. Zhang *et al.*, Adv. Funct. Mater., **19** (2009) 3077-3083.
[6] C. Dean, A. F. Young *et al.*, Solid State Communications, **152** (2012) 1275-1282.
[7] Y. M. Chang, H. Kim *et al.*, Appl. Phys. Lett., **97** (2010) 211102.
[8] P. Blake, E. W. Hill *et al.*, Appl. Phys. Lett., **91** (2007) 063124.
[9] M. Ferriol, A. Gentilhomme *et al.*, Polymer Degradation and Stability, 79 (2003) 271-281.

Figures

Figure 1 – a) schematic representation of graphene exfoliation over PMMA/glass substrate. b) graphene-substrate contrast as a function of wavelength, for 300 nm thick PMMA.

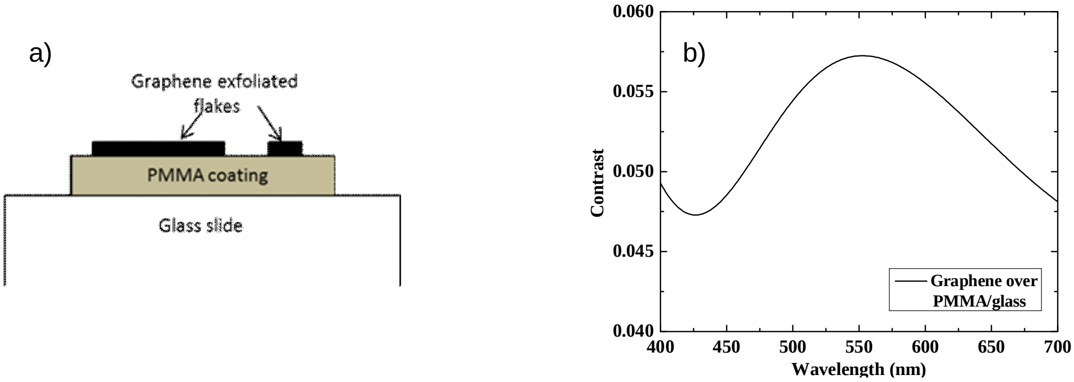

Figure 2 – a) identification of exfoliated graphene over PMMA/glass substrate. b) Raman spectroscopy of regions 1 (monolayer), 2 (bilayer) and 3 (multilayer). c) 2D-band Raman mapping, confirming graphene monolayer on region 1.

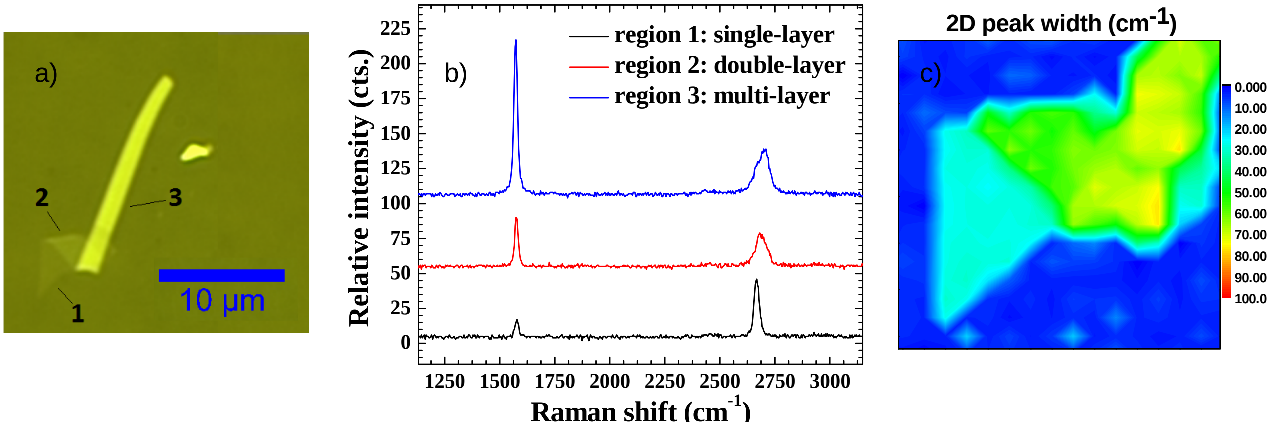

Figure 3 – a) transfer machine representation: glass/PMMA/graphene sample is placed in a XYZ stage, for precise alignment to the fiber core, under optical microscope illumination. b) picture of a multilayer graphene flake transferred to the optical fiber face. c) 2D peak Raman mapping of the transferred graphene. The circle area represents the fiber core, which confirms full coverage.