Patterning Graphene with Nonlinear Laser Lithography

Evgeniya Kovalska
Ihor Pavlov, Coskun Kocabas, Fatih Ömer Ilday

Bilkent University, Ankara, Turkey

ikovalska@bilkent.edu.tr

An incessant interest toward graphene's exceptional electronic properties encourages the scientific community to take further steps in the development of new patterned graphene-based platforms for bioelectrical, electromechanical, optoelectronic, and thermal management purposes. Originally flat graphene due to its semi-metallic nature with a zero band gap make challenges for direct application in semiconductor devices[1]. Patterning of graphene could be one route to tuning transport properties of graphene-based devices as well as the reactivity by increasing of specific surface area and artificial ordering of graphene.

Several methods based on various techniques, as well as laser-based patterning and nanostructuring have been proposed[2]. However, these techniques are either extremely costly, restricted to certain patterns or require complex of steps to obtain a regular pattern.

Here, we propose the use of a new laser-based technique, Non-linear Laser Lithography (NLL) that achieves extremely regular patterning by utilizing nonlinear feedback between the surface being processed and the processing laser beam[3]. NLL is a single-step, low-cost and high-speed method, which can be applied for non-planar objects as well, resulting in metal-oxide or semiconductor-oxide nanostructures with femtosecond pulses[3]. We report on the first implementation of NLL technique for multi-layer graphene (MLG) nanostructuring via Ni substrate pre-patterning. We are able to obtain various patterns, which can then be transferred to a desired substrate. These MLG nanostructures can find applications in optoelectronics, plasmonics, energy storage and biosensors.

References

[1] Lu G., Yu K., Wen Z., Chen J. Nanoscale 5 (2013) 1353.
[2] Feng J., Li W., Qian X., Qi J., Qi L., Li J. Nanoscale 4 (2012) 4883.
[3] Oktem B., Pavlov I., Ilday S., Kalaycioglu H., Rybak A., Yavas S., Erdogan M., Ilday F. O. Nat. Photon. 7 (2013) 897.

Figures

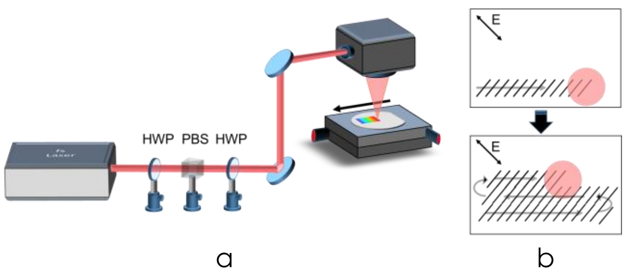

Figure 1: Scheme of the NLL setup. (a) Femtosecond Yb-doped fiber laser system at 1030 nm, galvanometer scanner and motorized 3D-translation stage (z-stage is not shown); half-wave plate (HWP) and polarization beam splitter (PBS) for polarization control. (b) Scanning direction of laser beam over the sample is indicated.

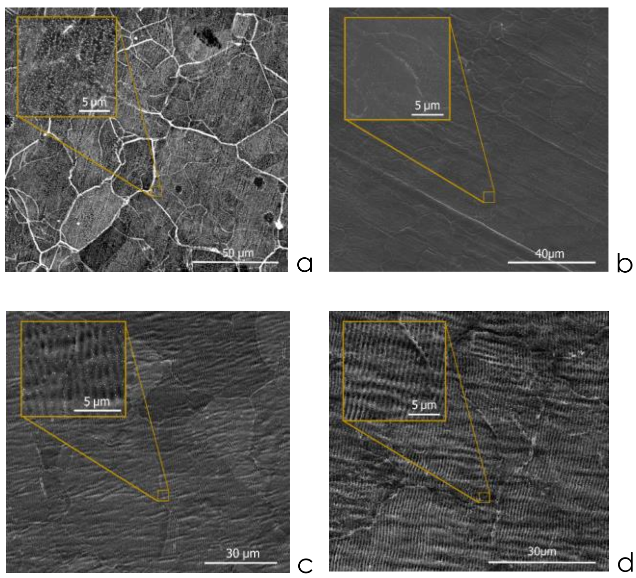

Figure 2: SEM images of (a) Ni foil with 50 µm thickness, (b) MLG on the Ni foil, (c) patterned Ni foil and (d) structured MLG on the Ni foil.