**Novel technique of multilayer graphene nanostructuring**

**for biosensing and optoelectronic appliances**

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An appropriate candidate in sensing systems (as an electrode) is graphene[[1]](#endnote-1) or other 2D materials[[2]](#endnote-2). The large surface area and superior electrical conductivity of graphene make it an excellent «electron wire» between the redox centers of an interested molecule and the electrode’s surface. Owing to the extraordinary electronic transport property and high electrocatalytic activity of graphene, the electrochemical reactions of analyte are greatly promoted on the graphene film, resulting in an enhanced voltammetric response. Graphene is now a more mature technology, it can be produced in a cost-effective way, in large scale and in a short time, it shows good biocompatibility, and the source material is abundant and inexpensive[[3]](#endnote-3). Graphene is extremely stable to the environmental conditions and does not degrade with time, which makes it an ideal material for stable sensor performance. It also has a range of surface chemistry which can be used to modify the graphene surface[[4]](#endnote-4),[[5]](#endnote-5) and make it amenable to detecting different (bio)markers. Thus, graphene is a promising candidate for advanced electrode materials which has found its way into a wide variety of sensing schemes[[6]](#endnote-6).

Herein we report new laser-assisted patterning of graphene films which can selectively enhance certain sensory and (opto)electronic capabilities of graphene-based devices and can offer its progress of the next generation for energy storage, photonics, and bioelectronics[[7]](#endnote-7),[[8]](#endnote-8). Basically, device's advanced multifunctionality (sensitivity, selectivity, reactivity) is driven by exerting the periodicity and forming active centers on the surface of graphene electrodes. Therefore, we represent the new approach of multilayer graphene (MLG) patterning employing nonlinear laser lithography (NLL) which is contamination-free, rapid and low-cost pattern replication technique. Via patterning, we demonstrate tuning of chemical and electro-optical properties of MLG due to laser power adjustment (310 – 380 mW). We control the hydrophobic/hydrophilic properties which define multifunctionality of graphene-enabled devices due to the graphene surface (dis)organizing, and consequently, a formation of reactive oxygen-based functional groups. Distinct graphene structure alignment (which prevents defects appearance) assisting by strongest laser power (380 mW) contributes to patterned MLG electro-optical changes (sheet resistance decreasing and optical transmittance enhancement) as well.

In conclusion, we discuss the great promise of fabricated devices with supercapacitor and battery designs by using as an electrically reconfigurable medium NLL-assisted graphene patterning. The patterned MLG-based supercapacitor testing results reveal two times transmittance value rising (in comparison with MLG-based supercapacitor) caused by light interaction with patterned structures where its thickness is reduced. Meanwhile, the patterned MLG-based battery indicates long-life viability (500 charging/discharging cycles) with 0.01% capacity-loss per cycle.

We anticipate a proposed NLL-assisted approach for MLG patterning demonstrates a new avenue to advance graphene for multifunctional device engineering particularly in energy storage, wearable electronics, and biosensorics.

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