Patterning and tuning of electrical and optical properties of graphene by laser induced two-photon oxidation

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Abstract Graphene has high potential for becoming the next generation material for electronics, photonics and optoelectronics.[1,2] However, spatially controlled modification of graphene is required for advanced applications. Electrical properties of graphene can be modified by tuning its shape or dimension. Narrow ribbons of graphene lead to opening of a band gap due to quantum confinement effect.[3] Graphene oxide (GO) has a band gap, which can be tuned by controlling the degree of oxidation. Laser heating has been used for modification of electrical properties of GO.[4] However, thermal reduction of GO does not fully recover the excellent electrical properties of graphene. So far, laser patterning of graphene has been limited to ablation,[5] which is of limited use.
Here, we report patterning and controlled tuning of electrical and optical properties of graphene by femtosecond laser induced non-linear oxidation.[6] Patterning is achieved by focusing a pulsed laser beam to graphene in ambient air leading to photo-oxidation (See Fig. 1). We use four wave mixing (FWM) for imaging graphene and graphene oxide patterns. FWM produces a strong signal in monolayer graphene and the signal is very sensitive to oxidation providing good contrast between patterned and non-patterned areas. By adjusting the laser pulse parameters, we oxidize graphene without ablation or cutting. Patterning is performed for air suspended graphene as well as for graphene on silicon substrate. By tuning the level of oxidation, electrical (and optical) properties of oxidized regions can be continuously fine-tuned; however, the excellent electrical properties of the non-oxidized regions of graphene are preserved. We show via electrical measurements that gradual photo-oxidation leads to increase of resistance and finally opening of a band gap. We also demonstrate FET operation of photo-oxidized graphene with an ON-OFF ratio better than one order of magnitude, which can be improved in further studies (see Fig. 2). The presented concept allows development of all-graphene electronic and optoelectronic devices with an all-optical method.

References

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Figures

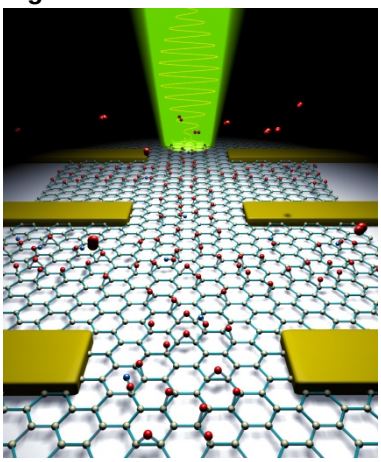

Figure 1.

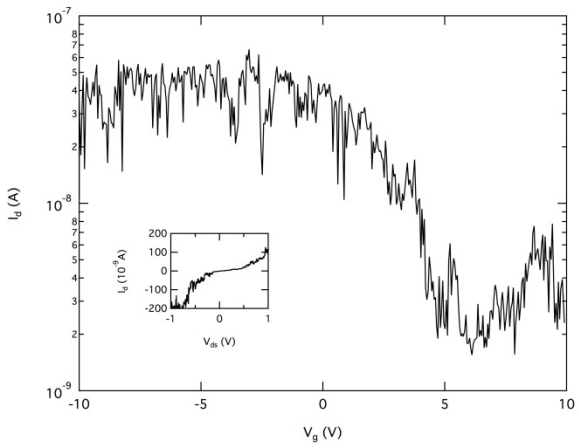

Figure 2.