Influence of passivation layer on graphene properties for optoelectronic applications

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Graphene, due to its remarkable optical properties, has attracted interest for applications in optoelectronics, including single-layer electro-absorption modulators (EAM) [1,2]. However, devices with unpassivated graphene show sensitivity to the environment and to surface adsorbates, exhibiting temporal changes of important graphene properties, such as doping and carrier mobility [3]. In order for graphene devices to operate reproducibly under ambient conditions, graphene passivation is required. The passivation layer should protect the devices from aging, prevent mobility degradation and inhibit hysteresis effects, but also preserve the natural p-doping in graphene. The p-doping characteristic is ideal for electro-optical modulation, because it allows to operate the device at low voltage DC bias [2].
In this work, we test different passivation layers (HSQ, SOG, HfO2 and Al_2O_3) by sweeping the back gate voltage from -35 V to 35 V on electrical test structures fabricated with passivated graphene. The back gate oxide is made of 90 nm SiO_2. We then analyse the effect of such layers on graphene properties, such as the graphene neutrality point, hysteresis and aging. Passivation with Al_2O_3 is found to be preferable among the four passivation films studied, because it preserves the p-doping characteristic in graphene and reduces hysteretic behaviour, while also preventing mobility degradation and doping variations over time (Table 1). At last, we fabricate single-layer graphene EAMs, with 5 nm SiO_2 gate oxide and (Si)/Al_2O_3 as graphene passivation layer. We show that the Al_2O_3 passivation layer results in hysteresis-free electro-optical response, while preserving the p-doping characteristic of unpassivated graphene. A second measurement repeated after 2 months' time shows no significant degradation in the device response, indicating that the passivation layers protects graphene from environmental variations (Fig.1).

Table 1 Values of mobility (μ), contact resistance (R_C), Dirac voltage (V_{Dirac}) and hysteresis (ΔV_{Dirac}) for the graphene devices fabricated with Al_2O_3 passivation layer measured after fabrication and after 1 month time.

	HSQ		Al_2O_3	
	t = 0	**t = 1 month**	**t = 0**	**t = 1 month**
μ (cm^2/Vs)	2818	2458	2948	2984
$\mathbf{R_C}$ (Ω μm)	774	921	908	981
$\mathbf{V_{Dirac}}$ (V)	13.4	24.6	3.1	4.2
$\mathbf{\Delta V_{Dirac}}$ (V)	7.6	4.5	3.0	8.8

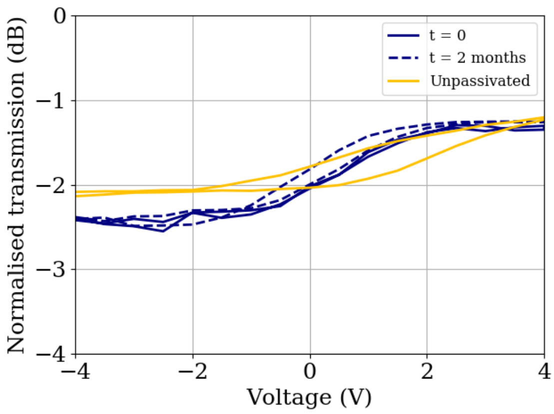

Fig.1 Transmission as a function of applied voltage bias measured with a double voltage sweep on a graphene EAM with L= 25 μm and 5 nm SiO_2 gate oxide. The yellow curve indicates a reference EAM with same characteristics but without passivation layer.

References
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