High-performance method for functionalizing the graphene-based channel of field-effect transistors for the fabrication of biosensors

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Abstract

Electric field-assisted local oxidation (LAO) has been carried out by applying a voltage between a sharp probe and a material almost exclusively at the nanoscale, using atomic force microscopes. The operating conditions of this procedure are set to ensure condensation of water from the atmosphere within the narrow gap between the probe tip and the material. This is known as the water meniscus paradigm and has been widely accepted as a primary explanation for most of LAO results at the nanoscale over the past three decades. This paradigm is adequate to explain, for example, the increase in oxidized spot size with applied voltage. However, it fails to elucidate the evolution of these spots over time. Furthermore, operation with scanning nano-probes suffers from low throughput (few μm^2 per hour), those cantilever-based systems show poor tolerance to chemical contamination, and the resulting features being too small to introduce certain characterization techniques such as, for example, conventional X-Ray photoelectron spectroscopy. In this work, we present both, a first-principles model to explain the evolution of the oxidation of 2D materials over time, that overcomes the previous water paradigm, as well as a custom-built instrument capable of performing local anodic oxidation of 2D materials, such as graphene, at the macroscale (ranging from tens of μm^2 to mm^2) in a remarkably short span of time. Thus, working at speeds 10^4 times faster and over areas 10^7 times larger than those operated by nano-probes, we can functionalize areas of 1 mm^2 in few minutes, so previous drawbacks are overcome. This system has been adapted for use in the functionalization of graphene-based channels of commercial field-effect transistors (FETs) intended for biosensors (Figure 1). Typically, FET channels are tens of µn long, as large areas are required to enhance sensitivity.

References

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Figures

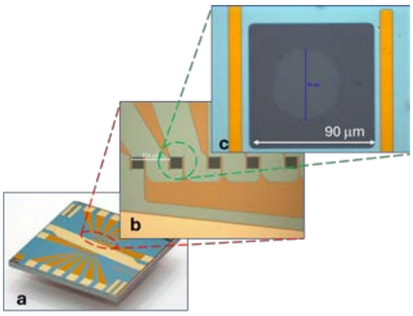

Figure 1: a) S20 layout from Graphenea Foundry, including 12 field-effect transistors with 90 µm-long graphene channels. b) Zoom displaying 5 transistors in the upper region of the chip. c) Detail of the graphene-based transistor channel with a single oxidized circular region of 50 µm diameter, performed with our system in contact mode and exposure time of 150 ms.