Graphene transistors for biosensing: optimizing the microfabrication process

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Electrolyte-gated graphene field-effect transistors (EG-GFETs) have been explored for biosensing applications with promising results [1] for a variety of biomolecules such as, proteins, nucleic acids and hormones [1]. However, most of the results never go over the proof-of-concept stage mainly due to reproducibility and scalability issues. The main goal of this work is to develop a process for wafer-scale fabrication of high electronic quality graphene devices for biosensing applications. Our process overcomes two main issues: dielectric passivation of metallic contacts and removal of surface residues after graphene transfer and patterning.
Dielectric passivation of metallic contacts was optimized considering the need to use strong solvents (e.g., DMF) when functionalizing graphene [2] and recurrent exposure to saline solutions. A protective coating consisting of a stack of five alternated SiO_2 and SiN_x thin-film layers with a total thickness of 250 nm was designed. To achieve full protection of the passive areas of the chip with sub-device resolution (the active channel area for biosensing is defined at this stage), the protective layer is applied after graphene transfer and subsequently dry-etched. This requires the use of a protective layer for the graphene itself, to allow patterning of the dielectrics by RIE.
CVD graphene is normally transferred to the final substrate using a temporary polymeric substrate. Although it is the best method for large-scale transfer, it brings about challenges due to surface contaminants (PMMA, metal residues) [3], often overlooked in the biosensing field, which hinder functionalization and promote non-specific binding of biomolecules in undesired areas [4]. To avoid the adherence of transfer-borne residues to the EG-GFETs critical surfaces (e.g., in-plane gold gate electrode) graphene transfer assisted by lift-off methods was successfully explored in layouts with low device density. For denser designs, however, a protective metallic layer was added on top of the gold contacts leaving only the graphene-receiving areas exposed. The protective layer endures multiple wet-transfer and full-wafer processes and survives all steps required for graphene patterning. In the end, the protective layer is easily removed by mild chemicals, providing a fast and safe way to avoid residues on the final surface of the devices.
Electrical characterization of the devices shows good coverage of graphene and process uniformity. A statistical study of the channel resistances showed that the value of the channel resistance depends critically on the quality of the graphene transfer step.

REFERENCES

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FIGURES

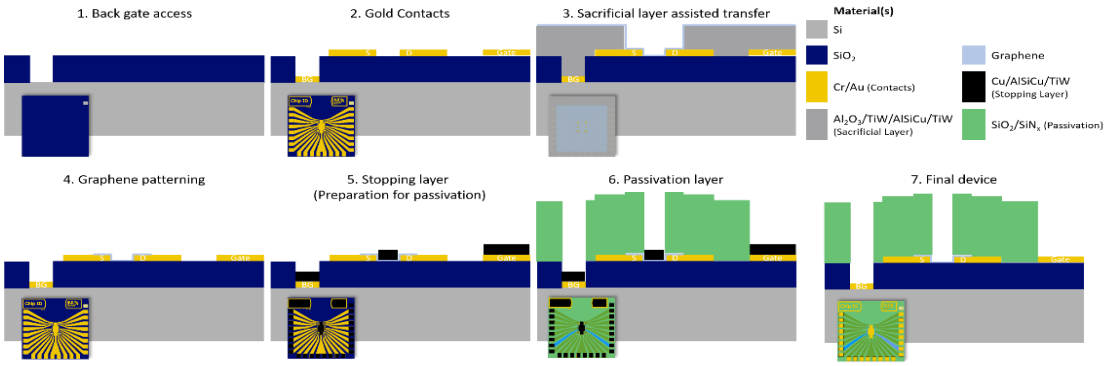

Figure 1: Graphical overview of the optimized fabrication process for wafer-scale production of EG-GFETs for biosensing.