# Chemically produced Graphene oxide integrates front-end-of-line at wafer-scale

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**Abstract:**
Graphene based materials so far have demonstrated their potential in next generation electronics, energy-related, catalysis, photo-electronic and sensor applications [1-4]. For the improved performance and advanced functionalities that the Graphene and other two-dimensional (2D) material systems promise, 2D materials technology now invites a reproach for designing sustainable and commercially viable process steps meeting industry requirements [5, 6]. Here easy and robust methods for the production of high-quality Graphene-based and other 2D materials on wafer-scale that may enable routine micro and nanofabrication processes are critical to develop and merge with routine technology [7].

Towards this requirement and demand, we present a holistic approach for scaling up the nanofabrication process for Graphene based materials, which we were developing in our group during past years. So far, we are able to produce high-performance Graphene based thin-films at wafer-scale on arbitrary substrates and combine them with routine lithography processes for front-end-of-line integration for different applications. Our approach first focused on development of efficient chemistry processes for the production of chemically preserved Graphene oxide layers with minimal residues in the final product and established a superior production process as confirmed using state-of-the-art material characterization methods. GO thin-layers are then used as fundamental building block for the realization of thin-films on silicon and glass substrates in a specialized gas-phase surface modification procedure and GO immobilization processes using spin-coating. The process overall yields robust immobilization of GO layers resulting in controllable GO thin-film thicknesses with homogenous physical and chemical properties as discerned from various surface characterization methods such as ellipsometry, XPS, UPS, localized Raman spectroscopy and conductive AFM scanning techniques.

The robust GO thin-films, after going through a suitable annealing process, work as a standard 'Graphene-based wafer' – ready to be used in a routine lithography process for device fabrication. Making an exemplary case in line with our expertise, we have used such thin-films for the production of electrical biosensors for label-free detection of biomolecules such as nucleic acids, prostate-specific antigens and glycan-based biomarkers for prostate cancer. With very low device-to-device variations and high-performance sensing characteristics, our Graphene based thin-film technology developed shows high potential for real applications in the field of electrical and optical biosensors. In addition it may substitute other material-systems as electrically conductive layer in various application areas. Deploying as label-free electrical sensors, we demonstrate label-free detection of prostate-specific biomarkers such as ConA lectin and prostate-specific antigen (PSA) in clinically relevant concentrations from physiological buffers using optical and electrical approaches, respectively.

## Figures

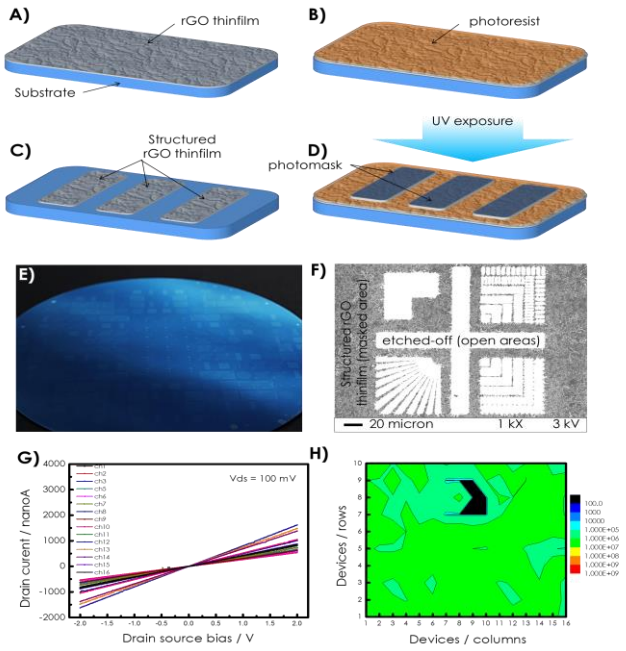


**Figure 1:** (A) realization of Graphene based thin-films on arbitrary substrates, (B, C and D) inclusion of thin-films into routine lithography processes, (E) Graphene based nano-/microstructures shown on the Si wafer, (F) SEM micrograph of the nanostructured thin-films, (G) electrical characteristics of several channels on a sensor chip, (H) a resistance map showing the homogeneity of electrical characteristics over the wafer measured over 160 data-points (devices).

**References:** [1] T. Kuila, A.K. Mishra, P. Khanra, N.H. Kim, J.H. Lee, Nanoscale, 5 (2013) 52-71. [5] M. Peplow, Nature, 522 (2015) 268-269. [6] M. Bianchi, E. Guerriero, M. Fiocco, R. Alberti, L. Polloni, A. Behnam, E.A. Carrion, E. Pop, R. Sordan, Nanoscale, 7 (2015) 8076-8083. [7] R. Lanche, L.E. Delle, M. Weil, X.T. Vu, V. Pachauri, W.M. Munief, P. Wagner, S. Ingebrandt, physica status solidi (a), 210 (2013) 968-974.