2Dfun: 2D functional MX2-graphene hetero-structures

Main area: New layered materials and heterostructures
Keywords: Hetero-structures with graphene and metal dichalcogenides MX_2, high-k gate stack on MX_2, HfO_2 on MX_2, Al_2O_3 on MX_2, ALD of high-k on MX_2, charge transfer between MX_2 and graphene, ALD of MX_2, surface functionalization of graphene, surface functionalization
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Abstract

The Graphene Flagship has produced many exciting and valuable results so far. One of the main obstacles for real uptake in the industry however is the lack of scalable processes for making large area, high quality layers and hetero-structures of graphene and other 2D layered materials. Moreover, the interfaces in such structures are not well understood; this is critical as these interfaces and how they are modified during processing sequences will govern to a large extend any device functioning and performance. 2Dfun aims at developing a graphene/MX_2/dielectric platform based on low-temperature high-volume production compatible deposition techniques of 2D transition metal dichalcogenides (MX_2) on graphene as well as high-k dielectric layers (Al_2O_3, HfO_2) on MX_2. While high-k growth will be developed based on a conventional Atomic Layer Deposition (ALD) process, we will investigate two novel routes for MX_2 making: i) plasma-enhanced sulfurization of metal or metal oxide layers deposited by ALD, and ii) a direct ALD process based on regular metal and chalcogen precursors. Oxford Instruments (UK) will assist in tool modification for in-situ PE sulfurization. An important aspect is the functionalization of the graphene and MX_2 surfaces so as to create active sites for the subsequent growth process, for which we will develop work with Self-Assembled Monolayers as well as some novel inorganic functionalization approaches. The resulting layers and full graphene / MX_2 / high-k layer structures will be thoroughly analyzed for their structural, chemical, optical and electrical characteristics. Next to more conventional techniques, we will employ some novel approaches such as Second Harmonic Generation for crystallinity and Rutherford Backscattering for quantitative and stoichiometry measurements. We want to understand the detailed structure of 2D/2D (graphene/ MX_2) and 2D/3D (MX_2 /dielectric metal oxide) interfaces, as well as how the functionalization of the surface before growth has influenced the resulting interface. Especially important are aspects of charge transfer (='doping' from device point of view), energy distribution, gap state spectrum and band structure, as well as their stability. To this end, we will employ a few very powerful analysis techniques (dynamic XPS in-operando, Internal Photon Emission and Photoconductivity), in combination with basic electrical approaches (I/V, C/V) and ab-initio atomistic modeling on appropriate test structures (Bilkent University Ankara, KULeuven Physics Dept.). Finally, with this graphene/ MX_2/high-k platform we will build some generic hybrid MOSFET devices (IMEC) for functional exploration and assessment of its electrical quality (standard transistor characterization, in-operando XPS at Bilkent University). This will lay sound foundations for offering this platform for application and further development inside the Graphene Flagship.

Consortium

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