P. Alpuim[1,2]
B. Sompalle[1,2], C.D. Liao[1], F. Cerqueira[1,2], J. Borme[1], A. Capasso[1]
[1]INL - International Iberian Nanotechnology Laboratory, Braga, Portugal
[2]CFUM - Center of Physics, University of Minho, Braga, Portugal

pedro.alpuim.us@inl.int

Photodetectors based on CVD-grown 2D materials in a van der Waals heterostructure

2D van der Waals heterostructures have great potential for optoelectronic applications [1,2]. High-quality, atomically thin layers are essential for high performance optoelectronics because of their very high responsivity under illumination, due to high excitonic binding energy and Van Hove singularities in the density of states that increase absorption, and photogating effects from careers trapped in localized states that increase carrier concentration by local gating [2]. In this context, $ReSe_2$ is a promising transition-metal dichalcogenide (TMDC), which has a weakly layer-dependent bandgap (it increases from 1.29 eV to 1.31 eV when passing from bulk to atomically thick layers) but a high photo-responsivity when in few-layer form [3]. Here, we report on the fabrication of a $ReSe_2$-based photodetector with high photosensitivity (~10^6 photo-to-dark conductivity ratio, see Fig.1d) and fast switching time. The device has a planar architecture (Fig.1b) based on high-quality CVD-grown 2D materials that are van der Waals stacked. The contacts to the absorbing layer are millimeter-sized graphene single crystals (Fig.1a). The crystals are obtained by controlling the nucleation density (<600 nuclei/cm^2) on $FeCl_3$/HCl pretreated and ultrasonically cleaned Cu foils inserted in a confined graphite reaction box with narrow slits that effectively suppress Cu sublimation during growth, for reduced substrate roughness and diffusion-limited growth kinetics. The surface oxygen in the partially oxidized substrates not only passivates the Cu active sites to diminish the graphene nucleation density, but also lowers the surface reaction barrier to accelerate its growth rate.
Hexagonal boron nitride serves as an insulating substrate for the device, which is built using a deterministic transfer set up to place the TMDC flake centered on the gap defined by two graphene single crystals that were previously transferred onto a glass cover slip covered with hBN, as shown in Fig. 1c. Metal (AlSiCu) contacts were pre-patterned to the graphene crystals by use of a hard mask, before $ReSe_2$ transfer. This configuration is ideally advantageous to couple the photodetector with light-emitting molecules (fluorophores) or to integrate it with microfluidic devices, in view of biosensing applications.
We also report a direct van der Waals growth of large-scale Graphene/hBN vertical bilayer. CVD grown $MoSe_2$ is then stacked using the same all dry visco elastic stamping setup on to the graphene/hBN vertical bilayer. The direct growth of high-quality van der Waals junctions is an important step toward high-performance integrated optoelectronic devices and systems.

References

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Figures

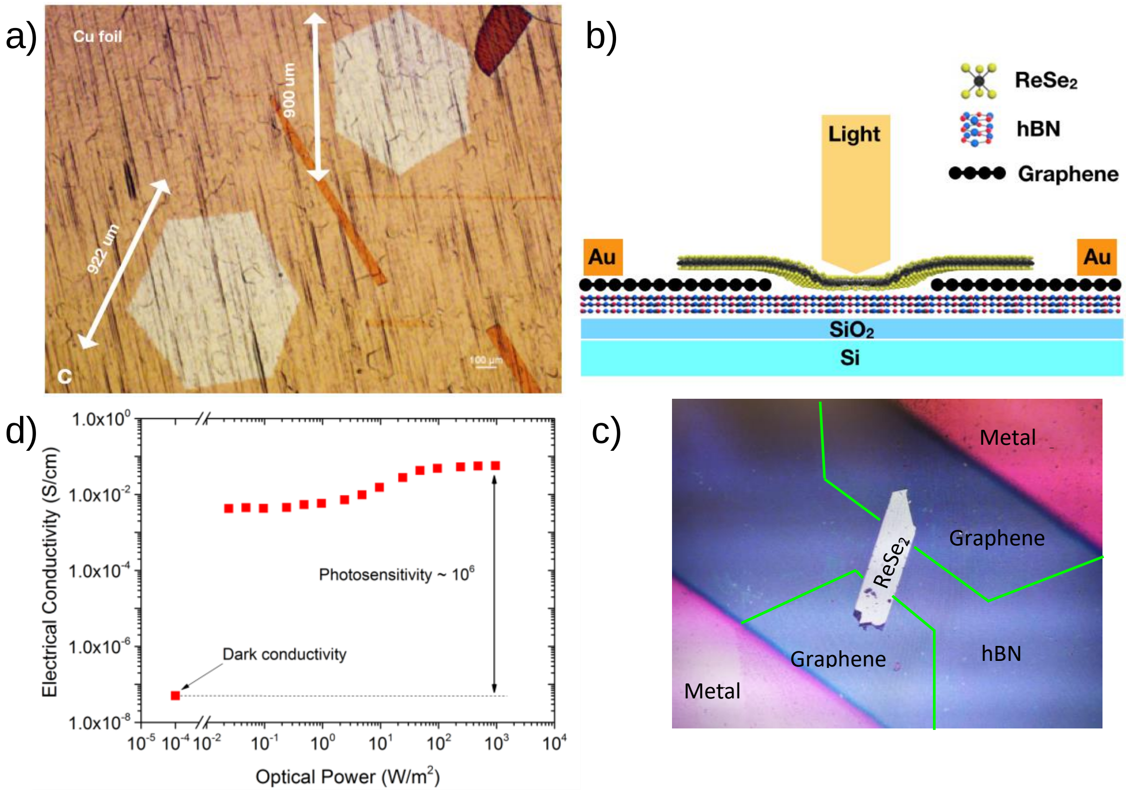

Figure 1: a) Micrograph of millimeter-sized single-crystal graphene on Cu used as electrodes for the device; b) Schematic of the photodetector device;.c) Top view of van der Waal stack device; d) Electrical conductivity as a function of irradiance under white light illumination.