NANOTECHNOLOGIES

UTAustin Portugal

Nanomaterials for New Markets Growth of 2D chalcogenide heterostructures (InSe, In_2Se_3 and GaSe) and applications

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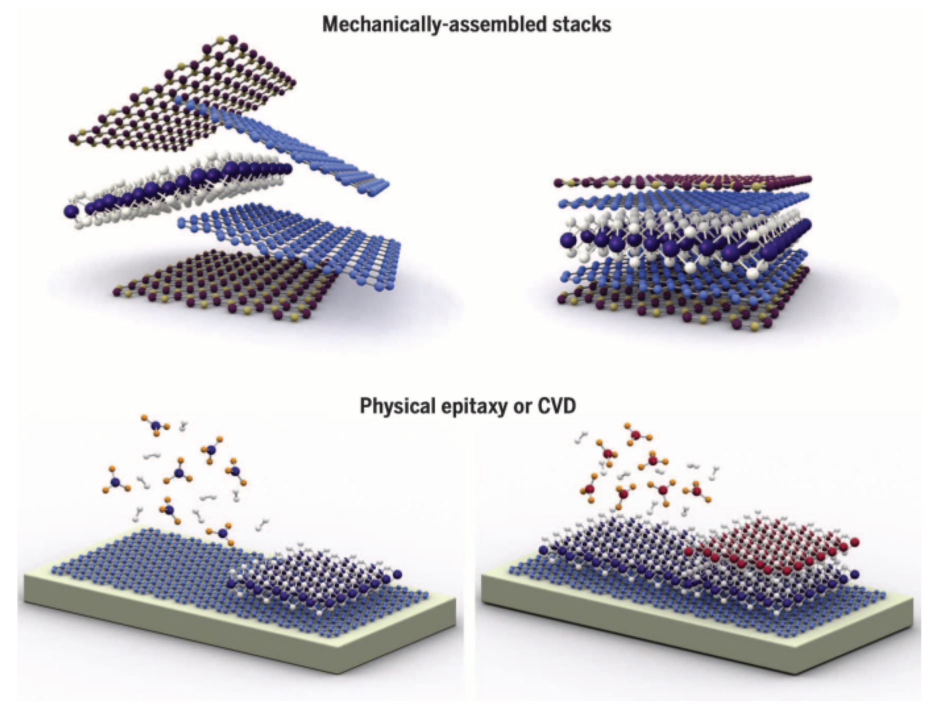
Background

The family of two-dimensional (2D) materials has been investigated extensively in the past years due to their novel properties compared to their 3D counterparts. Furthermore, electronic and optical properties can be tuned by changing the number of layers in a given material. Recently, devices made of these materials have shown impressive performance as photodetectors, non-volatile random-access memory or photovoltaics. Such improvements could be even better if 2D materials of different qualities are sandwiched together or with 3D materials to form heterostructures.



K. S. Novoselov et al., Science 353, aac9439 (2016). DOI: 10.1126/science.aac9439

Methodology

Molecular beam epitaxy (MBE) is known to be the method of growth with highest purity and controllability. Using an MBE with In, Ga and Se solid sources, we grew In_xSe_y and Ga_xSe_y thin films at different conditions. The growth was monitored in situ by Reflection High-Energy Electron Diffraction (RHEED) and then analysed by Atomic Force Microscopy (AFM), X-Ray Diffraction (XRD), Raman Spectroscopy, and High Angular Annular Dark Field (HAADF) Scanning Transmission Electron Microscopy (STEM).

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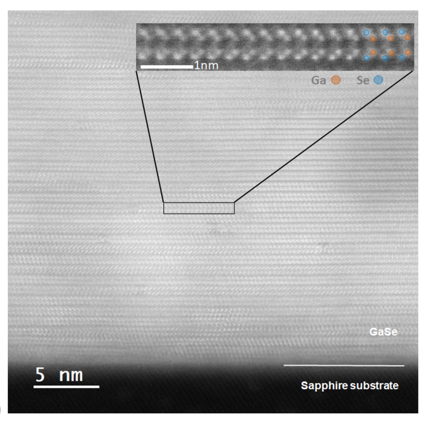

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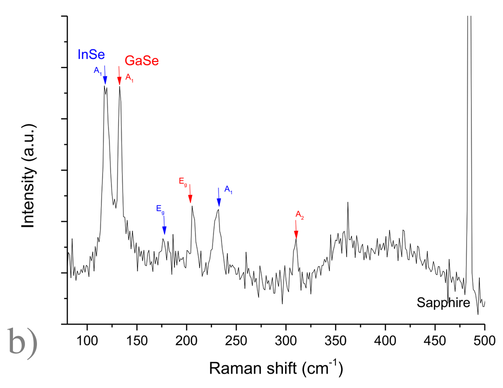

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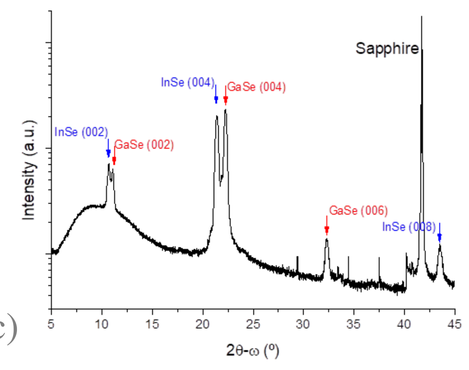
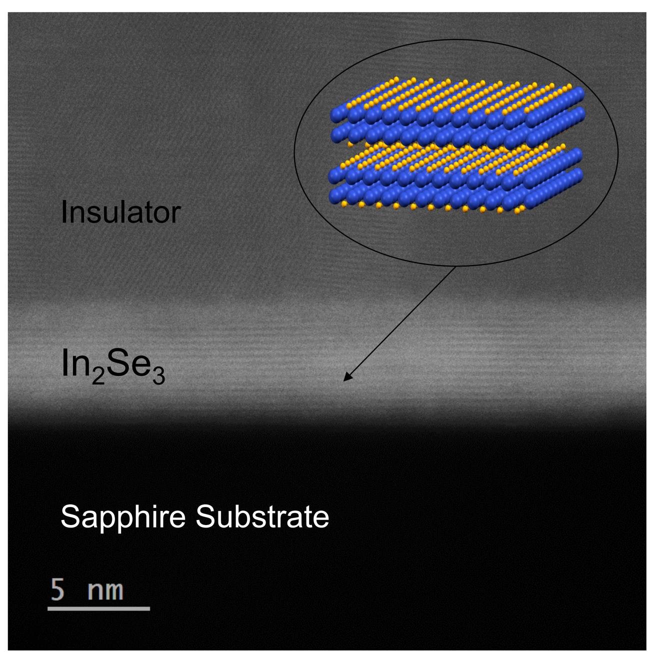


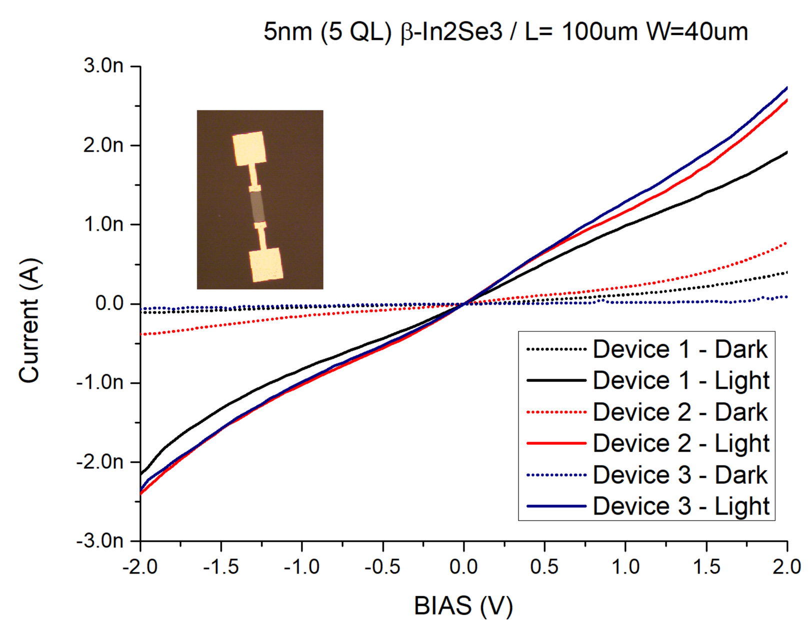
a) HAADF STEM image of layered structure of GaSe on 2" Sapphire wafer
b) b) Raman spectrum of InSe/GaSe heterostructure
c) c) XRD of InSe/GaSe heterostructure

Results

We obtained high quality, pure phase InSe, GaSe and In_2Se_3 epitaxial layers, as well as some heterostructures. The very few layers, down to 4 layers, were continuously grown over 2-inch Sapphire and Si wafers. Phase transformations, atomic diffusion and segregation are observed in the heterostructures. The developed photonic devices show good performance and are homogenous all over the wafer



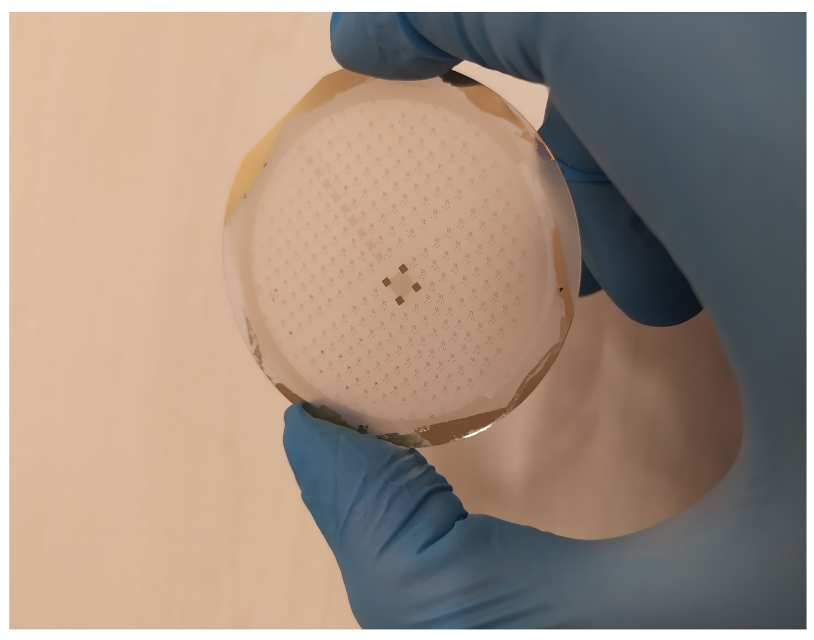
a) Cross-section STEM image of the developed 2D material photodetector device



b) Response to light of the developed 2D photodetector

Impact/Conclusions

Until now, only a few 2D heterostructures and even fewer devices based on them have been realized since the actual methods of production, i.e. synthesis of single crystal or thin films followed by mechanical exfoliation of small flakes are slow, cumbersome and most of the time non-reproducible. Also, these methods cannot be transferred to the industrial scale. Our method produces full wafers that can be processed in devices using standard CMOS processing techniques, thus enabling the rapid integration and deployment of the 2D materials technology.



Wafer full of devices produced by standard CMOS processes

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