Improved strain engineering of atomically thin MoS_2 by polymer encapsulation

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Controlling the band structure through strain engineering is an exciting avenue for tailoring optoelectronic properties of materials at the nanoscale [1]. However, in the case of 2D materials, weak van der Waals interactions can cause severe slippage between the material and substrate, dominating the bending or stretching processes and leading to inefficient strain transfer. Encapsulation of 2D materials is a promising technique to reduce this slippage, as well as to improve the transferable strain [2]. This approach shows increased strain transfer in many cases, although it can be difficult to accomplish for some encapsulating layers or materials [3]. In this work we report a comparative statistical study of the strain transfer modulation of MoS_2 flakes on polypropylene substrates, which have been encapsulated with three different solution–based polymers: polycarbonate (PC), poly(methyl methacrylate) (PMMA) and poly(vinyl formal) (Formvar). The flakes have been covered following a simple and cost–effective technique, in which the polymers in solution are spin-coated on the 2D material. Through micro-reflectance spectroscopy, we have observed a remarkable increase in strain gauge factors, which have been obtained by direct bending of the substrate, as well as by changing its temperature. In the first case, uniaxial strain is achieved, while in the second case biaxial strain is achieved due to the much higher thermal expansion coefficient of the polypropylene substrate compared to the MoS_2 flakes. The gauge factors seen for non-encapsulated monolayer and bilayer MoS_2 through uniaxial mechanical strain are ~30 $meV/\%$, while the ones achieved under the same conditions with PMMA or Formvar encapsulation lie around ~50 $meV/\%$. Maximum transferable strain before slippage also increased with encapsulation, achieving best results for Formvar and PMMA. An improve in the lifetime of MoS_2–based devices has also been observed. Finally, devices with Formvar encapsulation showed better photoresponse than their unencapsulated counterparts, as well as reduced dark current.

References

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