2D-NEMS: 2D-Material Heterostructure NEMS Sensors

Main area: Sensors from GRMs and their heterostructures
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Abstract

Micro and nanoelectromechanical system (NEMS) sensors such as pressure sensors, accelerometers and gyroscopes are important for a variety of applications, including wearable electronics for activity level monitoring, patient recovery monitoring, implantable systems for heart failure monitoring, and the Internet of Things (IoT). For most of these applications, it is of critical importance that the NEMS sensors are further miniaturized. This is due to application requirements and goes beyond the obvious advantage of reduced cost per device.

Recently our teams have demonstrated suspended graphene membranes as excellent electromechanical transducer elements for ultra-miniaturized piezoresistive NEMS sensors. However, graphene NEMS sensors suffer from the comparably low piezoresistivity of graphene, which leads to typical gauge factors of only 2-4. 2D materials with higher gauge factors, such as molybdenum disulfide (MoS_2) suffer from less stability compared to graphene and hexagonal boron nitride (h-BN).

To address these limitations, we will explore novel heterostructures made of stacked two-dimensional (2D) materials, with the aim to explore the underlying physics of novel NEMS transducers with gauge factors that are at least a factor of ten higher than those of existing NEMS transducers. To achieve this goal, we will explore suspended heterostructures of 2D materials, including graphene, h-BN, MoS_2, and other 2D transition metal dichalcogenides (e.g. WS_2, $MoSe_2$, WSe_2). We will also leverage a new method for 2D material stacking based on an adhesive wafer bonding technique, recently developed by our teams. To evaluate the utility of the novel heterostructures as piezoresistive transducers, we will develop three NEMS demonstrators: (1) Strain gauges based on 2D material heterostructures to perform strain-dependent transport measurements; (2) piezoresistive NEMS pressure sensors based on suspended 2D material heterostructure membranes; (3) piezoresistive NEMS accelerometers based on suspended 2D material heterostructure ribbons with attached proof masses. If successful, this work will contribute to an improved understanding of the material properties and the transduction mechanisms in 2D material heterostructures. This will pave the way for novel NEMS sensors with dramatically reduced size and improved performance. Such sensors will have wide-ranging potential applications, spanning several important scientific and technological areas, including biomedical implants, nanoscale robotics, wearable electronics and material characterization.

Consortium

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