Atom-Thick Materials for the Next Revolution in Electronics

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Abstract

Electronics is at a crossroads. The materials and technologies that have enabled the information revolution of the last 60 years are quickly reaching their ultimate physical limit. Fortunately, a new generation of atom-thick materials has recently been discovered. This talk will review these new materials, all of them less than one nanometer thick, and the novel devices and applications enabled by their amazing properties.

Graphene was the first one of these materials to be discovered. A two-dimensional structure of carbon atoms with sp^2 bonding, graphene has demonstrated the highest electron and hole mobility at room temperature in any semiconductor material. Its transport properties make it ideal for all kind of non-linear analog electronics, it shows extremely high frequency performance, and its one-atom-thickness enables transparent and highly flexible electronics.

MoS_2 and other transition metal dichalcogenides (TMD) materials are another example of two-dimensional materials with unique properties. Made of only three-atoms thick, they can complement graphene to build flexible digital and mixed-signal circuits, overcoming its lack of bandgap while still sharing many of graphene's excellent mechanical and thermal properties. We will describe some of our recent results on the development of 2D nanoelectronics on MoS_2 and TMD materials. First, large-area single-layer MoS_2 material is grown by chemical vapor deposition (CVD) that makes the wafer-scale fabrication of MoS_2 devices and circuits possible for the first time. Second, the top-gated transistors, fabricated for the first time on single-layer MoS_2 grown by CVD, show multiple state-of-the-art characteristics, such as high mobility, ultra-high on/off current ratio, record current density and current saturation. Finally, the first fully integrated digital and analog circuits based on MoS_2 are constructed to demonstrate its capability for both logic and mixed-signal applications. Key circuit building blocks for digital and analog electronics such as inverter, NAND gate, memory and ring oscillator circuits are demonstrated.

References

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Figures

a) b)

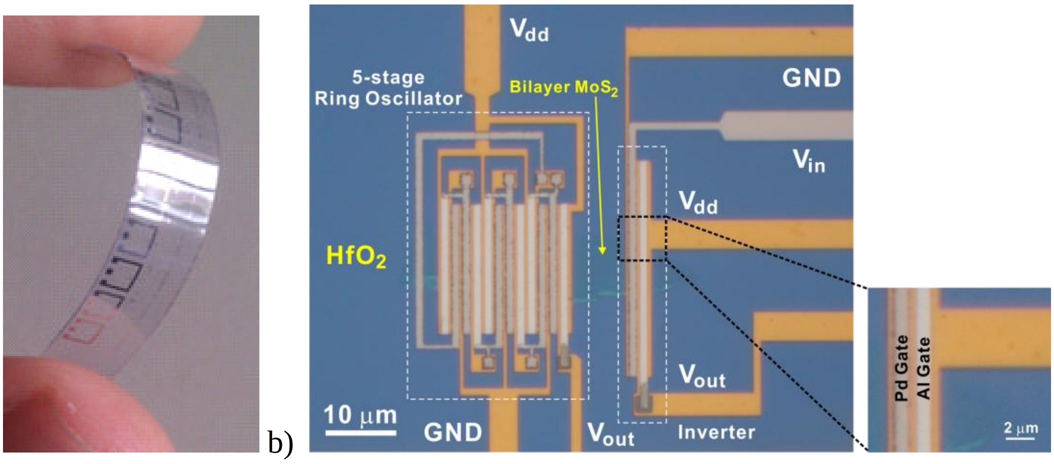

Figure 1. a) Graphene transistors and chemical sensors transferered to a transparent, flexible substrate. b) Optical micrograph of a MoS_2 integrated circuit, a 5-stage ring oscillator.