Focused helium-ion induced direct write engineering of 2D materials

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Two-dimensional (2D) materials have attracted much attention because of their exceptional electronic and distinctive opto-electronic properties. For implementation into next-generation devices, developing methods to engineer highly tunable structural, optical, and electrical properties as well as electrical junctions and direct write geometries of 2D materials are paramount.

Recent work has realized the potential of focused ion beams as a tool for processing of 2D materials [1–3]. Here, we utilize a focused helium-ion (He^+) beam for direct-write patterning and electrical tuning of 2D materials. Specifically, a laser-assisted He^+ irradiation technique was developed to enable high-resolution (< 50 nm) graphene patterning with a significant reduction in undesired peripheral backscattered ion-induced damage in the graphene. This enables nanopatterning whilst retaining 2D material quality and reduces undesired damage that is intrinsic with focused ion beam processing.

Electrical, structural, and optical tuning of transition metal dichalcogenides (TMDs) were also achieved via He^+ irradiation. By controlling the ion irradiation dose, we selectively introduce precise defects in few-layer WSe_2 thereby locally tuning the resistivity and transport properties of the material. Hole transport in the few layer WSe_2 is degraded more severely relative to electron transport after He^+ irradiation. Furthermore, by selectively exposing material with the ion beam, we demonstrate a simple yet highly tunable method to create lateral homo-junctions in few layer WSe_2 flakes, which constitutes an important advance towards two dimensional opto-electronic devices. These studies provide insight for the use of focused He^+ induced processing of 2D materials.

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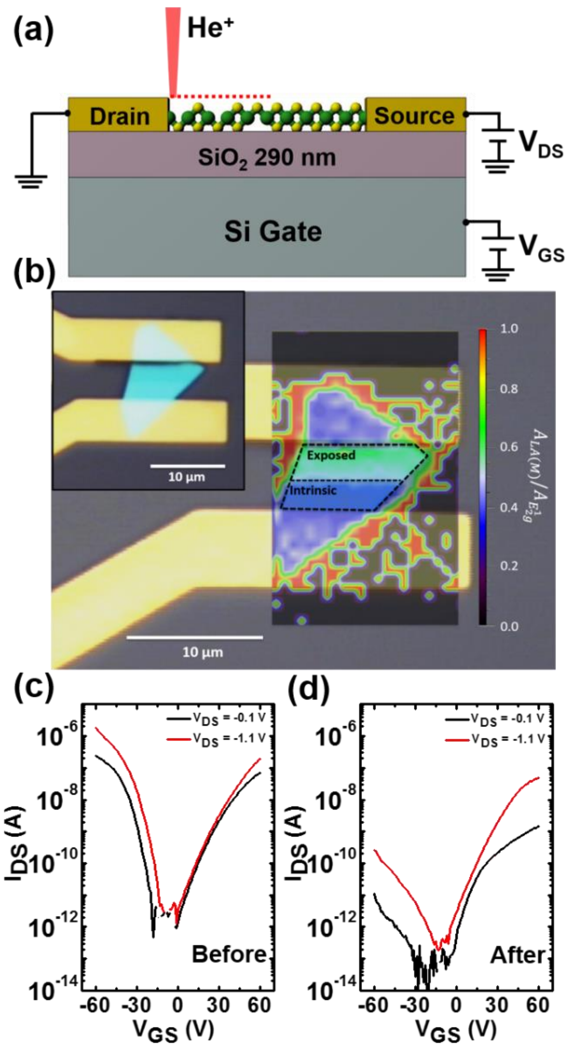

Figure 1. (a) Schematic of the WSe_2 field effect transistor (FET) device irradiated with He^+ over half of the channel length to induce a homo-junction. (b) Spatially resolved Raman map of He^+ irradiated junction ($1x10^{15}$ ions/cm^2) on a WSe_2 flake. Map shows ratio of integrated peak area of LA(M) (associated with defects) to the main Raman peak E^1_{2g}**.** The inset in the upper left corner shows an optical micrograph of WSe_2 device. The measured transfer characteristics of a WSe_2 FET device (c) before and (d) after, He^+ irradiation was used to create a homo-junction at a dose of $1x10^{15}$ ions/cm^2.