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Author(s)	陳, 麗米
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Abstract

In-situ TEM observation of electron irradiation gate effect in MoS_2 nanoribbon channels

Limi Chen (Oshima Laboratory)
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In-situ transmission electron microscopy (TEM) provides a powerful platform for probing the electrical behavior of two-dimensional (2D) devices under simultaneous structural observation. However, conventional gating methods are incompatible with electron-transparent TEM holders. Here, we demonstrate a non-contact gating strategy by focusing a scanning transmission electron microscope (STEM) beam onto the SiN_x substrate adjacent to a few-layer MoS_2 channel.

We successfully fabricated a MoS_2 nanoribbon device on a 50 nm SiN_x film designed for TEM observation. During characterization, we observed that the drain-source current I_{ds} increased upon irradiation by a sharp electron probe positioned 15 μm away from the MoS_2 nanoribbon. This increase in I_{ds} was found to correlate positively with the electron beam current I_{beam}, eventually reaching a saturation value.

This behavior mirrors the I_{beam} dependence of positive charge accumulation in the SiN_x film, attributed to the emission of secondary electrons induced by electron beam irradiation. The results indicate that the accumulated positive charges in the SiN_x film electrostatically induce negative carriers in the MoS_2 channel, thereby modulating its conductance. Notably, we observed an immediate increase in I_{ds} concurrent with the initiation of electron beam irradiation and a gradual exponential decay in I_{ds} with a time constant $\tau \approx 90$ s after turning the beam off. Such a long time constant could be confirmed by impedance spectroscopy measurements.

These findings provide compelling evidence that the SiN_x film becomes positively charged due to electron beam irradiation. This charging effect acts analogously to a gate in a field-effect transistor, enabling remote and damage-free modulation of the MoS_2 channel. Thus, sharp electron beam irradiation of the SiN_x film can function effectively as an indirect gate. This approach presents a valuable technique for evaluating the electrical properties of 2D materials without subjecting them to direct irradiation damage.

Keywords: *in-situ* TEM, indirect electron beam gating, MoS_2 based-device, dielectric charging, Schottky contact