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Flexible and Stretchable Thin-film Transistors of Transition Metal Dichalcogenides

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The atomically thin 2D transition metal dichalcogenides (TMDCs) with a large bandgap offer a high degree of electrostatic control than those of bulk forms, which provide potential electronic device applications, such as transistors, diodes, and sensors [1]. In addition to these electronic features, the mechanical properties, including flexibility and stretchability, are highly desired in 2D TMDCs. Within its 2D forms, the strong bonding between chalcogen and transition metal atoms results in in-plane stiffness comparable to those of steel, providing significant possibilities for flexible and stretchable electronics. However, limited sample sizes and the lack of efficient carrier doping methods still hamper the practical utility of TMDCs for application to large-area flexible and stretchable complementary devices.

In this paper, we fabricated ion-gel-gated thin-film transistors (TFTs) using large-area TMDC monolayers, MoS_2, $MoSe_2$ and WSe_2, grown by chemical vapor deposition [2,3]. Owing to the huge specific capacitance of ion gels, the Fermi level of TMDCs can be continuously shifted by applying gate voltage, making us realize both hole and electron transport in these devices. The hole mobility of WSe_2 can be enhanced up to 90 cm^2/Vs at high carrier density of 10^{14} cm^{-2}, whereas MoS_2 exhibits electron mobility of 60 cm^2/Vs. By combining MoS_2 and WSe_2, we demonstrate complementary logic inverters, which yield extremely high voltage gain of 110 that is the highest value in 2D materials. Furthermore, the flexible nature of ion gels enables integration of TFTs onto bendable or elastic substrates, as shown in Fig1 [4,5]. The accordion structured films can be created during film transfer process, resulting superb flexibility and stretchability of fabricated TFTs through relaxation of these ripples (Fig1). Finally, we demonstrate flexible and stretchable complementary logic circuits of TMDCs.

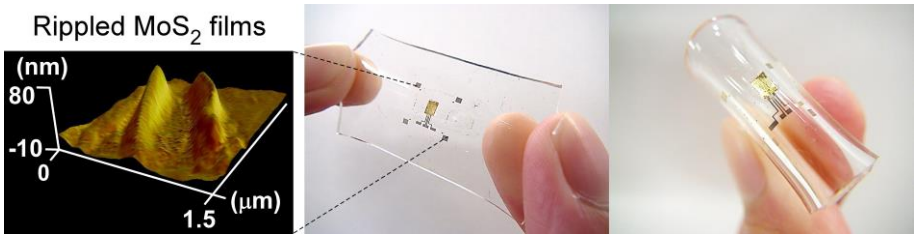

Fig1. Flexible and stretchable TMDC TFTs

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