Modification of the electrical properties of FET fabricated from ultra-thin structures of TMD alloys

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In the field of 2D materials, significant progress has been made in semiconductor research. A prominent example is transition metal dichalcogenides (TMDs), which exhibit high electron mobility and stability, a thickness-dependent bandgap, high on/off current ratios (I_{ON}/I_{OFF}), and reasonable hole mobility. They demonstrate excellent electrostatic control and improved resistance to short-channel effects beyond the capabilities of silicon-based technologies [1]. Furthermore, the fabrication of TMD alloys enables tuning their optical, electrical, and mechanical properties, for example, to enhance field-effect transistors (FET) performance [2]. To fabricate FET, we used specially prepared SiO_2/Si substrates with gold planar electrical contacts. The results of our research show that modifying the S/Se ratio in the $Mo(S_xSe_{1-x})_2$ alloy improves FET efficiency. For instance, the I_{ON}/I_{OFF} ratio, for $MoS_{0.82}Se_{1.18}$ increases by one order of magnitude compared to the parent TMDs (i.e., MoS_2 and $MoSe_2$). For digital logic applications, the I_{ON}/I_{OFF} ratio should exceed 10^5 [3]. Our study demonstrates that the use of alloys makes it possible to meet this requirement at temperatures (T) in the range of 350-400 K. In addition to performance, parameter stability under varying environmental conditions is also crucial. The $MoS_{0.82}Se_{1.18}$ alloy exhibits improved stability, particularly with respect to changes in operating temperature. This improvement is evident in both the I_{ON}/I_{OFF} ratio and the threshold voltage (V_T). For MoS_2 and $MoSe_2$, the threshold voltage is highly unstable between T = 250 K and T = 350 K, changing by approximately 20 V. Adjusting the S/Se ratio reduces V_T variations to about 10 V. It should also be noted that the electrical properties of the FET vary nonlinearly with increasing temperature, as shown in the figure below. Based on these preliminary results, it can be concluded that the electrical properties of FET is strongly temperature-dependent and that modifying the S/Se ratio in the $Mo(S_xSe_{1-x})_2$ alloy enhances both device performance and thermal stability.

References

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[2] K. Król, M. Tamulewicz-Szwajkowska, A. Piejko, J. Kopaczek, Ł. Gelczuk, J. Serafińczuk, ACS Applied Electronic Materials, 8 (2025) 63-72
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Figures

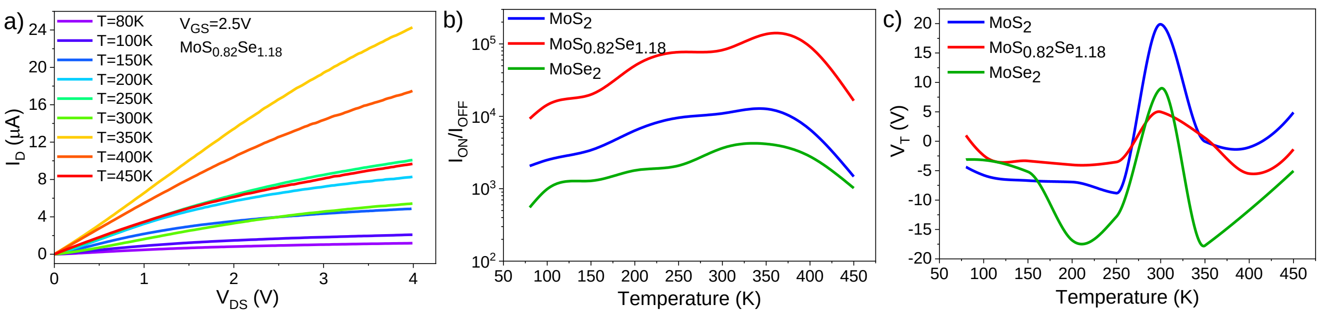

Figure 1: Temperature dependence of the FET properties (a) output characteristics of $MoS_{0.82}Se_{1.18}$ FET measured at a constant gate-source voltage (V_{GS}=2.5V), (b) the ratio of on-state to off-state current (I_{ON}/I_{OFF}), and (c) the threshold voltage (V_T).