Breaking the trade-off between mobility and on-off ratio in oxide thin-film transistors

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Abstract

Indium oxide stands out as a highly promising material for Back-end-of-line processes due to its combination of high mobility, low contact resistance, and compatibility with ALD at low temperatures. However, the challenge lies in managing the degenerate high carrier concentration, which results in a trade-off between mobility and on-off ratio, restricted its applicability in future electronic devices. While scaling the channel thickness can result in a reduction of the carrier concentration, this approach also leads to a degradation in mobility. In this study, fluorine-based plasma was utilized to overcome this trade-off. CF_4 plasma treatment was applied to nanometer-thick In_2O_3 transistors, resulting in a positive shift of the threshold voltage as treatment time increased, achieving a substantial positive V_T tuning window of up to 70 V. It is worth noting that the mobility of In_2O_3 increases as its thickness increases from 2 nm to 10 nm. However, if the thickness exceeds 3 nm, the transistor loses its on/off properties. After CF_4 plasma treatment, In_2O_3 of all thicknesses exhibits an excellent on/off ratio. Notably, the 10 nm In_2O_3 transistor maintains its higher mobility, indicating that the trade-off between mobility and the on/off ratio is successfully overcome. The XPS analysis indicates that the positive shift of V_T is due to the passivation of oxygen vacancies by fluorine atom and the capture of electrons by absorbed fluorine atoms, which possess a higher electronegativity than oxygen. Owing to the precise tunability of threshold voltage (V_T), we successfully realized the depletion-load NMOS inverter. This result indicates that fluorine-based plasma treatment and ALD-based ultrathin In_2O_3 have significant potential for the future BEOL electronic applications.

Keywords - In_2O_3, atomically-thin semiconductors, threshold voltage tuning, CF_4 plasma treatment, mobility on/off ratio trade-off