Engineering wafer-scale epitaxial two-dimensional materials for advanced high-performance nanoelectronics

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Abstract: Atomically thin two-dimensional (2D) metal dichalcogenides (MX_2) have attracted great interest in extending Moore's law beyond silicon due to their unique structural and electronic properties.[1-5] As one of the most promising substrates for wafer-scale single crystalline 2D MX_2 deposition, the single crystalline c-plane sapphire (0001, α-Al_2O_3) has been considered as a suitable substrate to achieve this, due to its specific lattice orientation, atomically smooth surface and high quality single crystal nature. MX_2 deposition on this kind of substrates can show a specific orientation preference, which is determined by the crystal symmetry and the surface terraces of the sapphire substrates.[6-7] However, the single crystalline c-plane sapphire has a complex surface structure, typically composed of a terrace and step structure as a result of the sapphire ingot grinding and polishing processes, which can influence the surface termination of sapphire wafers.[8] It has been demonstrated that the atomic steps on sapphire have significant effects on the growth behaviour of the MX_2.[9] It is poorly understood how inhomogeneous sapphire surface structure influences the epitaxial growth of the 2D materials and device performance. In this work, we observe the inhomogeneous surface terrace structure of sapphire wafers can result in different nucleation rate and then growth of monolayer 2D MX_2 among the terraces. This influences further the electrical properties of the coalesced monolayer and the performance of monolayer MoS_2 transistors. This finding is applicable to other MX_2 materials and brings breakthrough knowledge to understand better how the sapphire surface structure influence the MX_2 epitaxial growth and the performance of related electronic devices.

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