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From 2D to 1D: Atomically Precise Bottom-Up Fabrication of 1D Transition Metal Chalcogenides

Materials with reduced dimensionality can exhibit exotic properties absent in their bulk counterparts. In recent years, this has been significantly demonstrated in van der Waals (vdW)-bonded materials such as graphene and transition metal chalcogenides (TMCs). For instance, two-dimensional (2D) monolayer MoS_2 exhibits a direct bandgap that changes from indirect in the bulk, allowing various applications in optoelectronics. In theory, further dimensional reduction to 1D structures could drastically alter their electronic and magnetic properties [1, 2]. However, experimental exploration of their potentials has been hampered by their limited availability: Although they have been fabricated using chemical and lithographic methods, the reliable production of 1D TMCs with chemical precision still remains a significant challenge.

Here we report bottom-up synthesis of atomically precise MX nanowires and MX_2 nanoribbons (M=metal; X=chalcogen) inside carbon/boron-nitride nanotubes (CNTs/BNNTs). Chemically and thermally robust CNTs and BNNTs serve as “nanotest-tubes” for 1D materials formation and effectively preserve the properties of the products [3]. Transmission electron microscopy reveals unique torsional dynamics of MoTe/WTe nanowires absent in their bulk counterparts (Figure 1) [4]. On the other hands, atomic-resolution electron energy spectroscopy demonstrates that the electronic structures of MoS_2 nanoribbons are significantly different from those of monolayer MoS_2 (Figure 2). Our results may open opportunities to exploit the novel physics and chemistry of unexplored 1D TMCs.

References

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[4] M. Nagata et al., Nano Lett., in press.

Figures

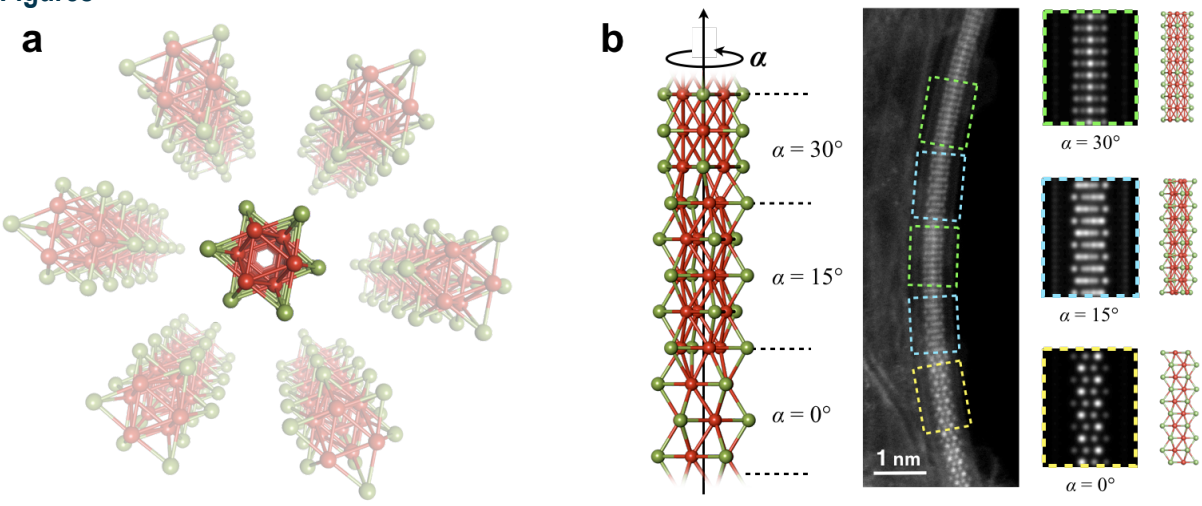

Figure 1: (a) A schematic image of transition metal monochalcogenide nanowire. (b) Torsional dynamics of a single MoTe nanowire confined within a CNT.

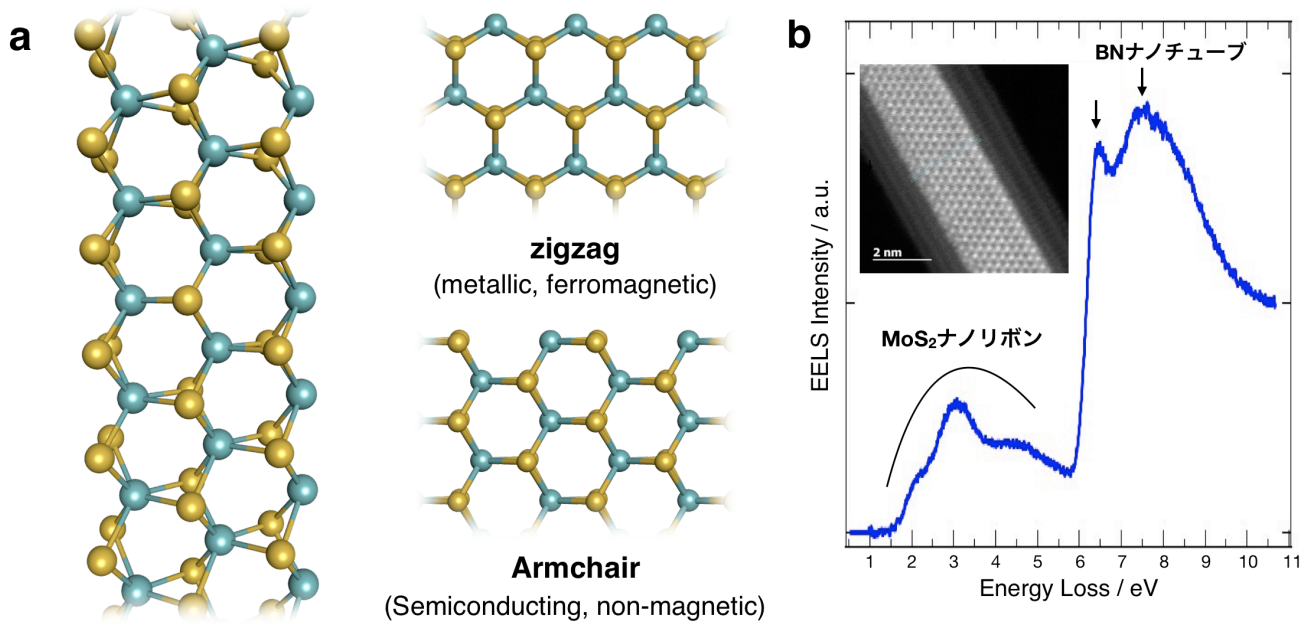

Figure 2: (a) A schematic image of transition metal dichalcogenide nanoribbon. (b) Atomic-resolution electron energy spectrum of an individual MoS_2 nanoribbons encapsulated inside a BNNT.