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Soft exfoliation of 2D SnO with size-dependent optical properties

Two-dimensional (2D) materials have recently gained exceptional attention as potential candidates for next generation optoelectronic devices due to their unique electrical, optical and mechanical properties [1-3]. Following the pioneering work on graphene, many 2D materials have been obtained, including transition metal dichalcogenides (TMDC, such as MoS_2, $MoSe_2$, WS_2, WSe_2, NbS_2); metal oxides and hydroxides (such as MoO_3, MnO, WO_3, $Ni(OH)_2$ and many ternary compounds), metal nitrides and carbides (such as hexagonal BN and the family of compounds known as MXenes). Tin monoxide, SnO, is an important *p*-type semiconductor with interesting properties, including a small indirect band gap of ~0.7 eV, a much larger direct band gap of ~2.7 eV, and high hole mobility. Due to such unique properties, SnO has been used to fabricate high mobility *p*-type and ambipolar thin film transistors, efficient photocatalysts for water splitting, and even improved anodes for lithium ion batteries. However, despite its potential in several important technological applications, SnO remains underexplored in its 2D form. Here we present the "*soft*" liquid-phase exfoliation of layered SnO microspheres to produce 2D SnO nanosheets with lateral size ranging between hundreds of nanometers to few micrometers and thickness as low as 2 nanometers [2]. Our strategy relies on the synthesis of highly layered SnO microspheres that can be easily exfoliated through a simple and fast sonication treatment at low powers typically in common solvents such as ethanol. We adopted a controlled centrifugation process to separate different populations of nanosheets according to their size. Further, we demonstrate that the optical properties of 2D SnO are strongly dependent on its dimensions. At low centrifugation speeds, the SnO exhibits a yellow color solution, where the optical properties show the presence of large and/or thick flakes. These 2D flakes possess a direct band gap close to that of bulk SnO. With increased centrifugation speed, the solution progressively becomes colourless. Remarkably, a large (>1 eV) band gap widening is observed for the first time in atomically thin SnO. This is verified through optical absorption and photoluminescence studies, and highlights the strong quantum confinement properties of 2D SnO. Moreover, through photoconductivity measurements, we establish a strong correlation between the quantum-confined properties of 2D SnO and its selective photoresponse in high energy UV light. This indicates the potential of few monolayer thick SnO for optoelectronic applications under specific UV light conditions. We envisage that the ability to tune the properties of 2D SnO nanosheets according to their thickness will have important technological implications for the fabrication of highly efficient optoelectronic devices. These results also highlight the importance of carefully designing the starting materials that can be easily exfoliated to produce their 2D counterparts. This work provides a facile strategy that constitutes a step forward to developing reliable and scalable methods to manufacture 2D materials and establish their unique properties.

References

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Figures

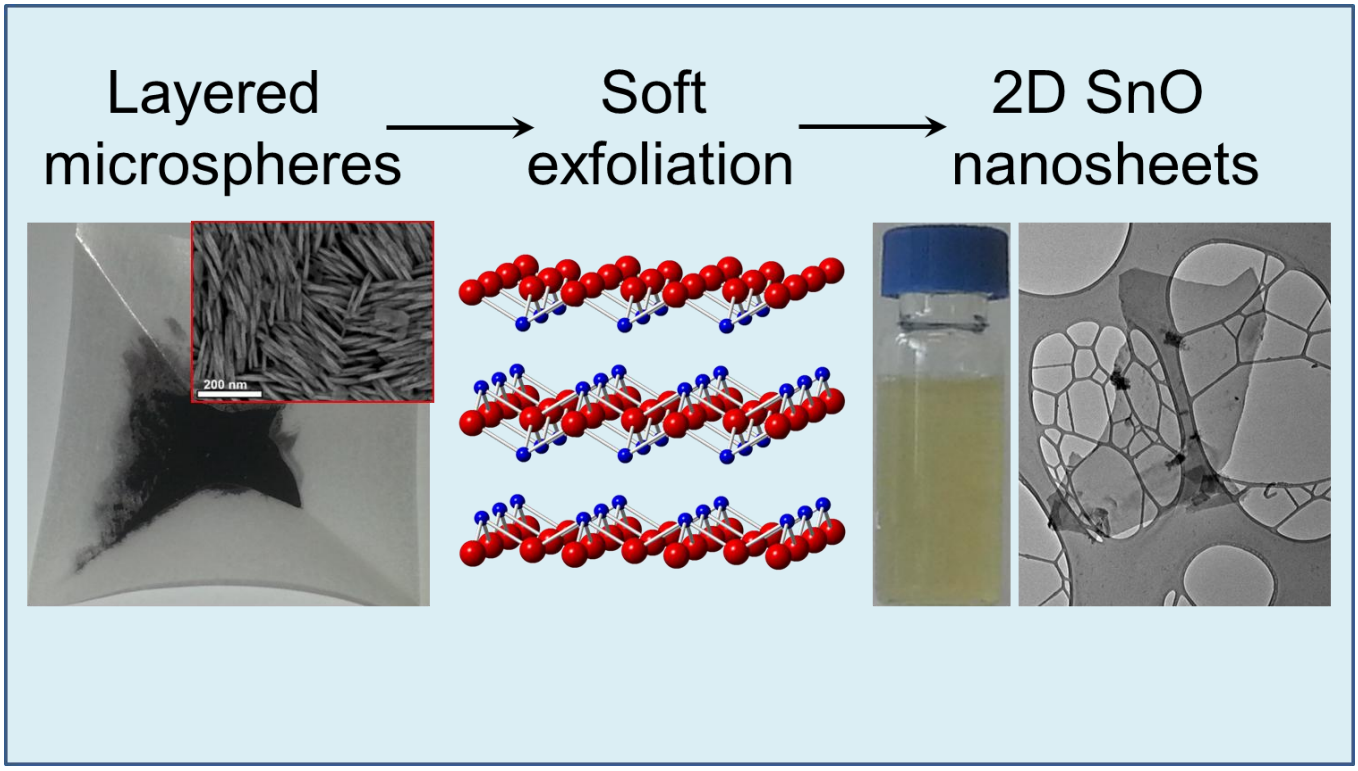

Figure 1: Schematic representation of the process involving the exfoliation of the synthesized layered microspheres to produce 2D SnO nanosheets.