Colloidal synthesis of alloyed monolayers of transition metal dichalcogenides.

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The bandgap tunability of two-dimensional (2D) transition metal dichalcogenides (TMDCs) makes them one of the best candidates in the domain of optics and electronics. This ability to tailor bandgap is accessible by alloying [1]. In this regard, most of the work has been conducted by using high-temperature chemical vapour deposition or molecular beam epitaxy techniques. We adopted a different low-temperature colloidal synthesis strategy as an efficient alternative to these previous methods. Two classes of alloys of TMDC using group VI transition metals and chalcogens are generally studied: one with varying the composition of transition metals ($W_{(1-x)}Mo_{(x)}S_2$ or $W_{(1-x)}Mo_{(x)}Se_2$) and the other with varied composition of chalcogens ($MoS_{2(1-x)}Se_{2x}$ or $WS_{2(1-x)}Se_{2x}$). Due to their band structure and band gap position, each alloy exhibits special properties. Because these 2D materials can have 2 different phases, phase engineering is also important, and can significantly change their properties between the 1T (metallic) to the 2H (semiconducting) phases [2].
Here, we report a direct-solution based synthesis of colloidal well-dispersed monolayers 1T-$WS_{2(1-x)}Se_{2x}$ and its transformation to the 2H phase via annealing. By varying the composition we can tailor the first excitonic peak of these TMDC alloy nanosheets from 1.6 eV to 2.1 eV. This phase conversion has been further verified using ultraviolet-visible spectroscopy. The dispersion and size of these nanosheets are characterized using transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM). The size of monolayers can be tuned from 10 nm to 60 nm. Furthermore, using energy dispersive X-Ray (EDX) analysis, the exact composition of each alloy could be identified from x=0 to 0.7. We are now investigating these alloys in photoluminescence and photocatalytic applications.

References

[1] Sun, Yifan, et al., *Journal of the American Chemical Society*, "Low-temperature solution synthesis of transition metal dichalcogenide alloys with tunable optical properties."(2017):11096-11105
[2] Lin, Zhong, et al., *2D Materials*, "2D materials advances: from large scale synthesis and controlled heterostructures to improved characterization techniques, defects and applications." (2016): 042001

Figures

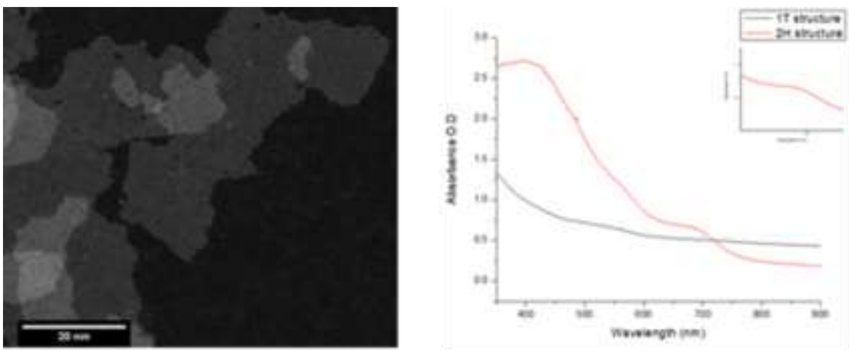

Figure 1: scanning transmission electron microscopy of well-dispersed monolayers and Photoabsorption spectrum of alloy with 59% Selenium in the structure. The black line is the spectrum of as synthesized nanosheets and the red line is the spectrum of annealed one.