Tunable Nanostructuring for van der Waals Materials

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Two-dimensional (2D) van der Waals (vdW) materials have captured significant attention in scientific research due to their distinctive properties, which hold promise for next-generation electronic and optoelectronic devices [1]. However, the practical application of 2D materials in photonics faces limitations related to their form-factor – whether they are exfoliated flakes or grown through chemical vapor deposition (CVD) and epitaxial processes. At the same time, most effective way to manipulate light at the nanoscale involves interaction with nanostructured materials. Therefore, nanostructuring vdW materials offers a compelling avenue to advance nanophotonics by expanding its material database [2]. In recent years, diverse approaches have been explored to nanostructure anisotropic vdW crystals, resulting in the creation of nanophotonic devices such as waveguides, nanoantennas, and metasurfaces [3-7]. This study addresses this challenge by showcasing, for the first time, the remarkable versatility of the femtosecond laser synthesis method for producing colloidal nanoparticles (NPs) from vdW materials and perovskites. Our approach enables precise control over the morphology, size, composition, and optical properties of NPs, achieving high colloidal stability and maintaining the original crystalline structure of over 50 vdW materials. We have demonstrated that laser synthesis can produce a diverse array of nanostructures, including fullerene-like, polygonal, and pyramidal shapes from transition metal dichalcogenides (TMDCs), single-crystalline NPs from M(A)Xenes, and crystalline nanocubes from perovskites. Molecular dynamics simulations further elucidate the crystallization processes involved, revealing that both heterogeneous and homogeneous nucleation mechanisms contribute to the formation of these nanostructures, with the size and core-shell ratio being dependent on the cooling rate.

References

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Figures

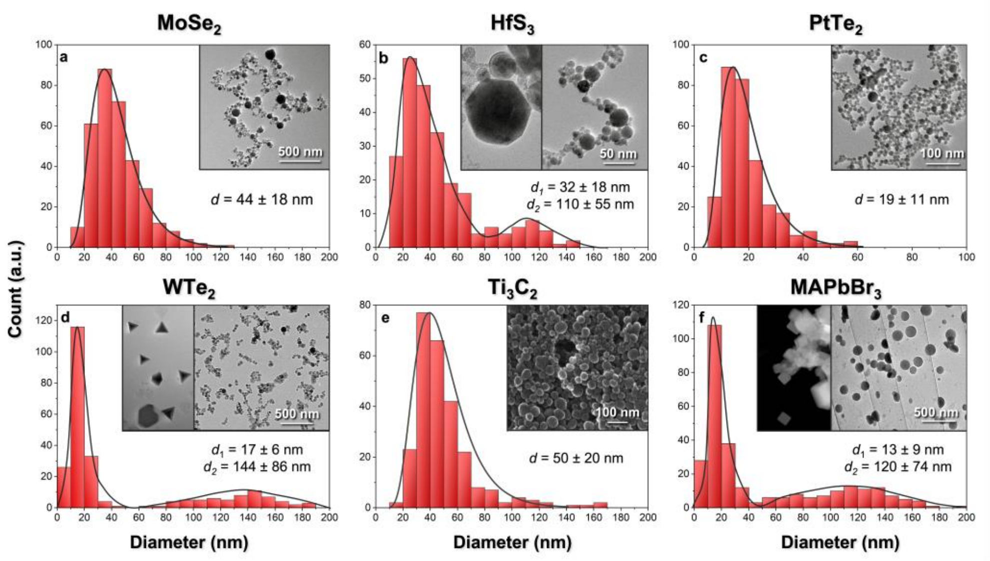

Figure 1: Size distribution and representative TEM/SEM image of laser-synthesized vdW NPs.