80 % Exfoliation Efficiency and Green Approach Production for Few-layer Black Phosphorus via Superhydrophobic Silicon-nanowire-embedded Microfluidic Process

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The exfoliation of bulk black phosphorus (BP) into few-layer BP flakes is a critical process for wide applications of atomically thin layered BP. Although liquid exfoliation provides the scalable and facile production of the few-layer BP flakes, the low exfoliation efficiency remains a major hurdle, pursuing an advanced exfoliation technique. Here we introduce a novel exfoliation technique using a superhydrophobic silicon nanowire (SiNW) microfluidic system under the ultrasonic treatment, which is design to significantly promote the cavitation effect. The promoted cavitation effect enables to rapidly fragment bulk BP, and the delamination of the fragmented BP subsequently occurs at much lower cavitation effect. The strategic separation between the fragmentation and delamination under the controlled cavitation effect achieves the rapid production of few-layer BP flakes as high as 80 % total exfoliation efficiency in aqueous medium. These results substantiate the promise of the superhydrophobic SiNW microfluidic system for clean and highly efficient production of thin layered 2D materials.