# Deterministic assembly of arrays of lithographically defined $WS_2$ and $MoS_2$ monolayer features directly from multilayer sources into van der Waals heterostructures

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One of the major challenges of van der Waals (vdW) integration of 2D materials, the process of assembling dissimilar 2D materials together using the universal vdW force, is achieving high-yield and high-throughput assembly of pre-defined sequences of monolayers into heterostructure arrays. Mechanical exfoliation has recently been studied as a promising technique to transfer monolayers from a multilayer source synthesized by other techniques [1], allowing the deposition of a wide variety of 2D materials without the constraints imposed by the harsh synthesis conditions. Although a variety of techniques have been developed to exfoliate the 2D materials mechanically from the source and place them deterministically onto a target substrate, they typically can transfer only either a wafer-scale blanket [2, 3] or one small flake at a time with uncontrolled size and shape [4]. Here we present a method to exfoliate arrays of lithographically defined monolayer $WS_2$ and $MoS_2$ features from multilayer sources and directly transfer them in a deterministic manner onto target substrates. This exfoliate–align–release process, without the need of an intermediate carrier substrate, was enabled by a new transfer medium fabricated by spin-coating a partially-crosslinked and transparent adhesive onto a transparent, electrostatically active backing material with low surface energy. $WS_2/MoS_2$ vdW heterostructure arrays produced by this method were characterized, showing the expected coupled exciton between the monolayers. Light-emitting devices using $WS_2$ monolayers were also demonstrated, proving the functionality of the fabricated materials. Our work demonstrates a significant step towards developing mechanical exfoliation as a scalable transfer technique for the manufacturing of functional, atomically thin materials.

References:


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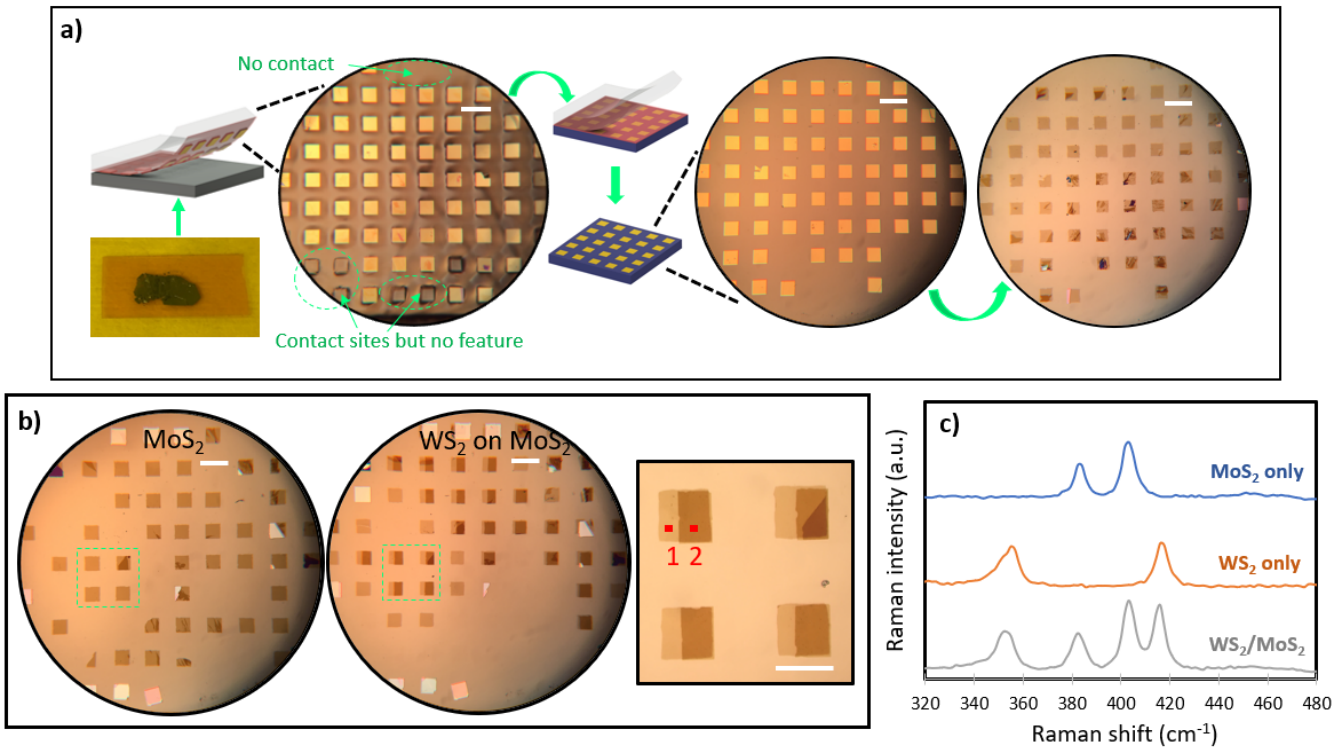


**Figure 1: Fabrication of monolayer and heterostructure arrays by the Covalent-Bond Exfoliate-Align-Release (CoBEARs) process** . (a) Optical microscopy images of the array of $WS_2$ micro-features after critical steps. The target substrate is 50 nm $SiO_2$/Si. The monolayer array is obtained after one single exfoliation. Scale bars are 200 µm. (b) $WS_2/MoS_2$ heterostructure array obtained by repeating the steps in (a), with the first cycle depositing $MoS_2$ and the second cycle depositing $WS_2$. From left to right, scale bars are 200 µm, 200 µm and 100 µm. (c) Raman spectra of the samples in (b). The $MoS_2$-only spectrum was obtained before $WS_2$ deposition. The $WS_2$-only and $WS_2/MoS_2$ spectra correspond to the two red spots numbered 1 and 2 respectively in the high-magnification image of (b).