Supporting Information

Engineering a 3D MoS_2 Foam Using Keratin Exfoliated Nanosheets

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Calculation of exfoliation yield: Post lyophilization the exfoliated sheets were redispersed in known amount of DI water and subjected to bicinchoninic acid assay (BCA) analysis to calculate the amount of bound protein on the sheets (Table S1; refer to Protein Quantification section for detailed methodology) and subtracted from the total dry weight to obtain the amount of exfoliated MoS_2. The exfoliation yield was calculated to be 56% for K_MoS_2 and 32% for B_MoS_2. The yield of B_MoS_2 is similar to previously published report (~27%).[1] However, keratin resulted in significant improvement over BSA and commercial polymers. The maximum reported yield of 40% has been reported for NMP mediated liquid exfoliation method,[2] making the present method most efficient reported thus far.

Table S1: Quantification of total protein concentration and sulfhydryl group in the exfoliated products as determined using BCA and Ellman's assay, respectively

Sample	**Total Protein (µg/mL)**	**Sulfhydryl Group (µM)***
K_MoS_2	171 ± 0.9	78.9 ± 0.3
B_MoS_2	296 ± 1.7	67.8 ± 1.9

*Ellman's assay utilizes 5,5'-dithiobis-(2-nitrobenzoic acid) (DTNB) which cleaves the disulfide bonds to give 2-nitro-5-thiobenzoate (TNB^-). TNB^- further gets reduced in the presence of alkaline pH to give a yellow color TNB^{-2} ion which was quantified using the spectrophotometer.

Table S2: Electrical conductivity values of previously reported 2D MoS_2 substrate and compared against the observed value in this work

Sample	**Conductivity**	**Reference**
MoS_2 film	~2.5 x 10^{-6} S/cm	[3]
MoS_2 film	6 x 10^{-9} S/cm	[4]
MoS_2 film	5 x 10^{-8} S/cm	[5]
MoS_2 pellet	9.4 x 10^{-7} S/cm	[6]
MoS_2 film	**5 x 10^{-4} S/cm**	**This study**

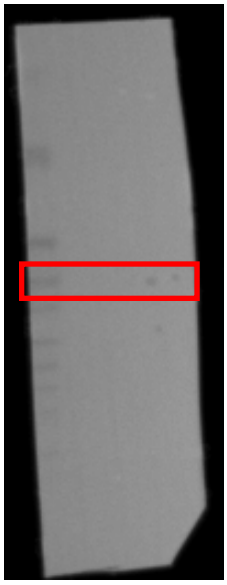

Figure S1: Protein expression of extracted keratin measured using western blot. Red box showing the keratin band at ~ 55 kDa

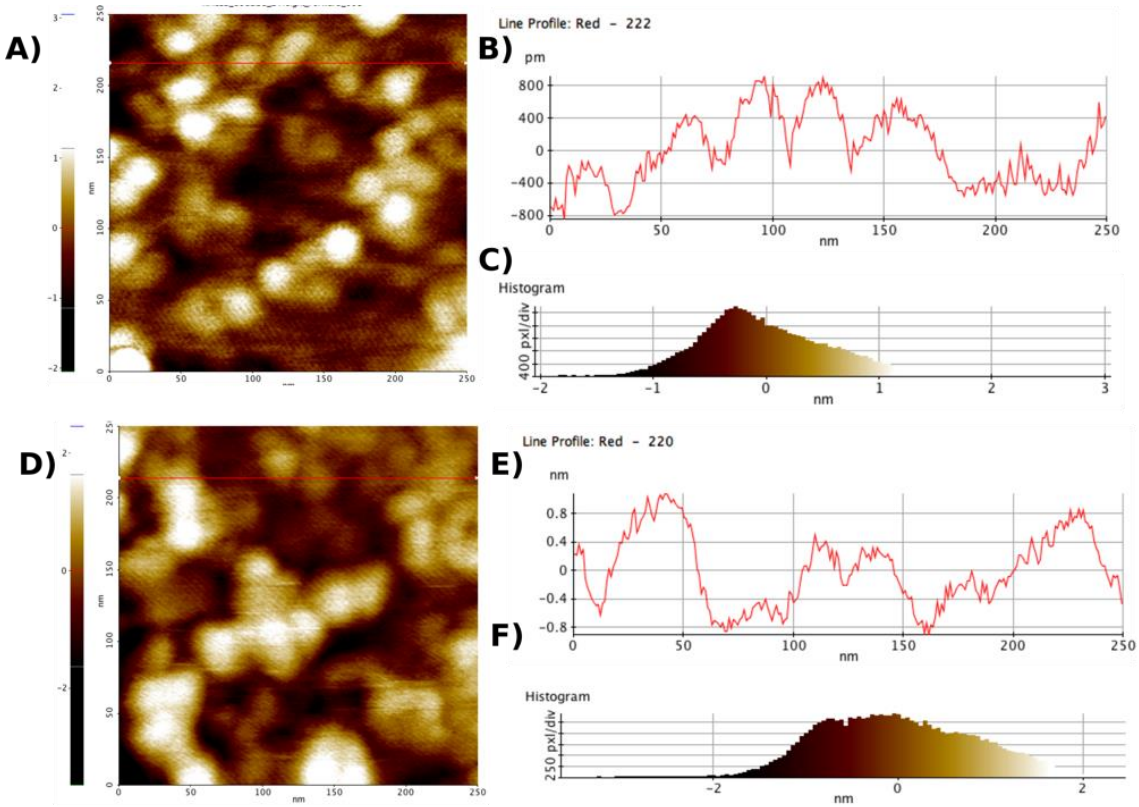

Figure S2: Non-contact mode AFM topographic image of A and D) as-exfoliated K_MoS_2 and B_MoS_2 nanosheets; B and E) corresponding height profiles across the red line shown in (A and D); C and F) histogram analysis showing the polydispersity in nanosheet height size profiles from (A and D). The histogram analysis of the height distribution confirmed that most of the sheets in the case of K_MoS_2 are concentrated around -0.8 nm with very narrow size distribution while B_MoS_2 had a broader distribution confirming a mixture of single and few (two/three)-layered sheets. The B_MoS_2 values corresponds well with the previously reported values.[1]

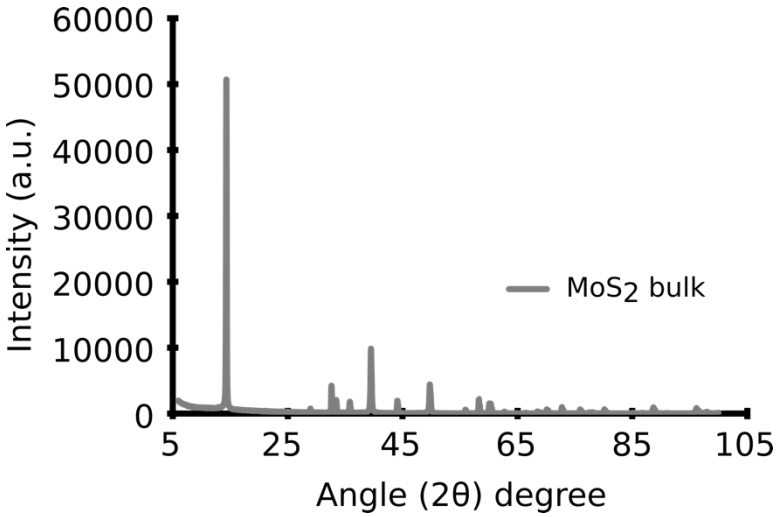

Figure S3: XRD of bulk as-received MoS_2. The observed sharp peaks confirmed the crystalline nature of the as-received bulk MoS_2 which was confirmed from the JCPDS card No. 37-1492

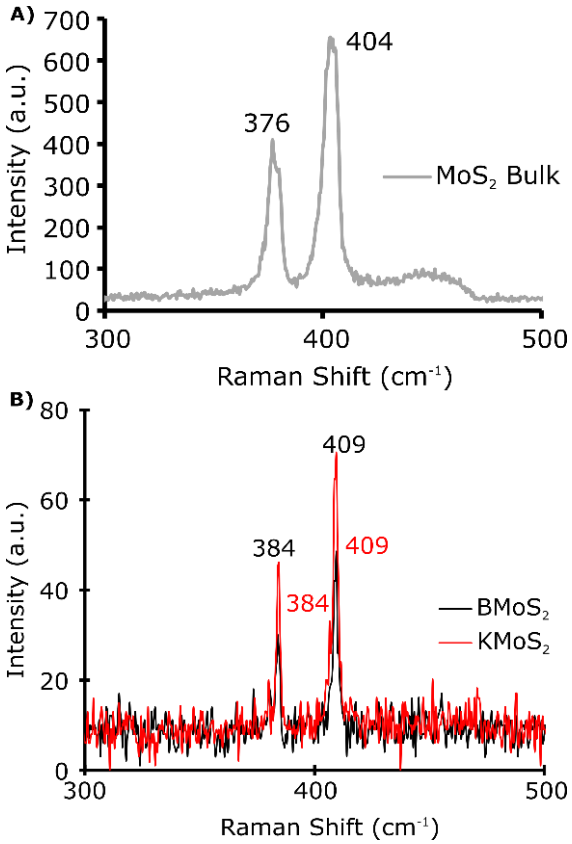

Figure S4: Raman spectra of A) bulk MoS_2 powder, B) aqueous dispersion of exfoliated nanosheets. Raman spectra of the exfoliated samples were measured in liquid state to avoid restacking of sheet upon drying.

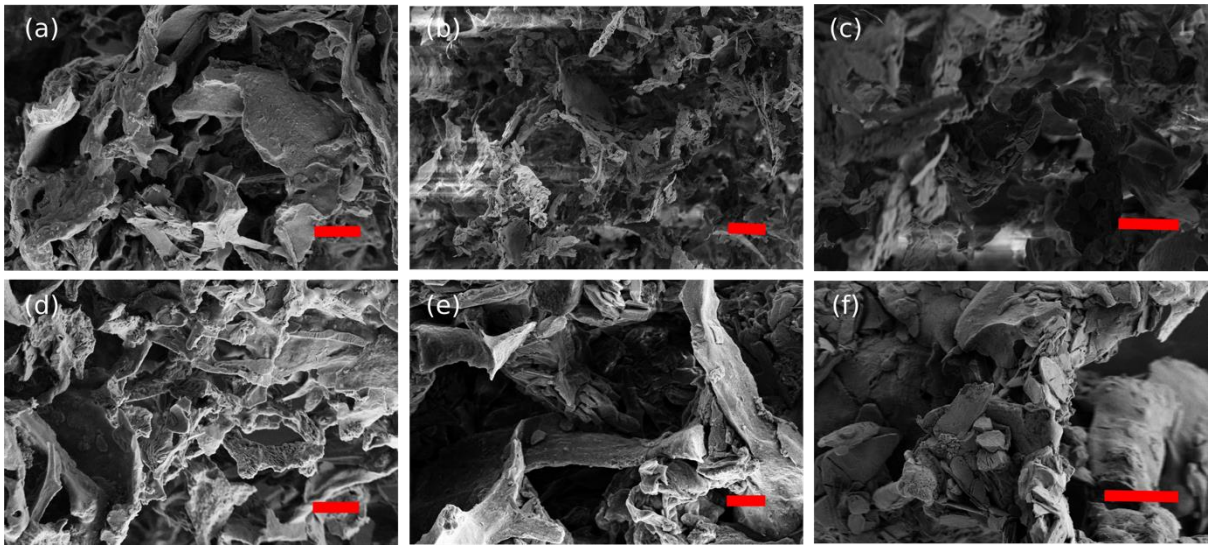

Figure S5: Scanning electron micrograph (SEM) image of the 3D K_MoS_2 foam at different magnifications. scale bar: (a-b) 20 μm and (c-f) 10 μm

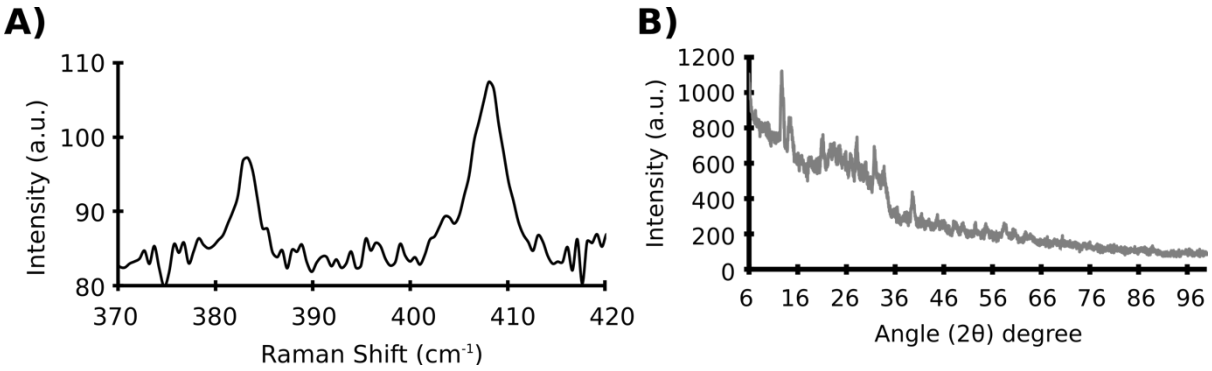

Figure S6: Characterization of the K_MoS_2 foam. A) Raman analysis showing the characteristic E^1_{2g} and A_{1g} peaks; B) X-ray diffraction analysis showing the disordered restacking of the sheets post lyophilization. The observed signal-to-noise has been attributed to the 3D porous nature of the foam which was not compressed while acquiring the XRD spectrum. The sample was not compressed because of the notion that the compression of the sample would exhibit bulk behavior and would not necessarily demonstrate the true characteristic of the 3D foam.

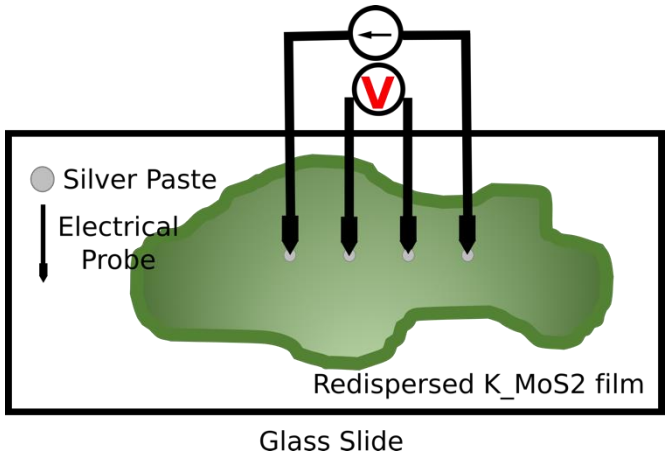

Figure S7: Schematic of the electrical measurement set-up of the film.

References

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