Supporting Information

Outstanding Stretchability and Thickness-Dependent Mechanical Properties of 2D HfS_2, $HfSe_2$, and Hafnium Oxide

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Force-deflection measurements of thin nano-drumheads

We characterized a large number of HfS_2 and $HfSe_2$ nano-drumheads, which all demonstrated similar qualitative behavior to those shown in the main text (see Fig. 2e,f and Fig. 7g). Additional force-deflection curves of thin HfS_2, $HfSe_2$, and hafnium oxide nano-drumheads are shown in Fig. S1, S2, and S3, respectively **(each force-deflection curve is related to a different nano-drumhead)**.

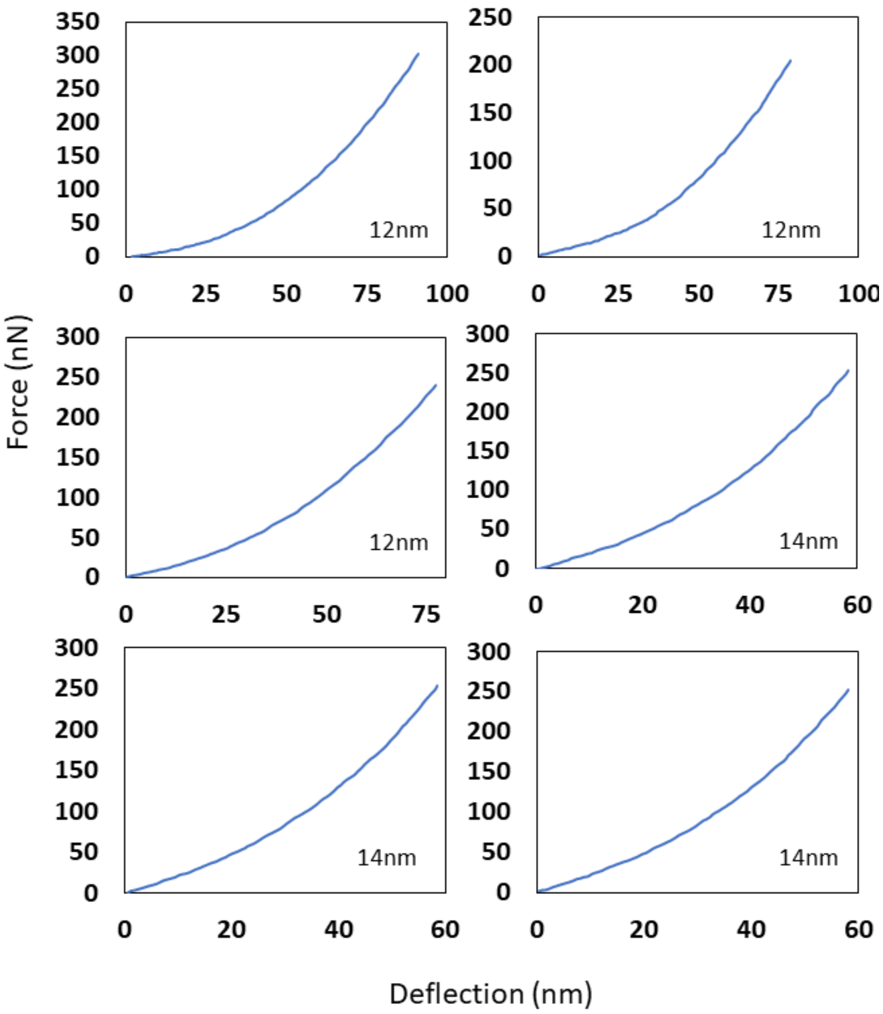

Fig. S1. Force–deflection curves of thin HfS_2 nano-drumheads.

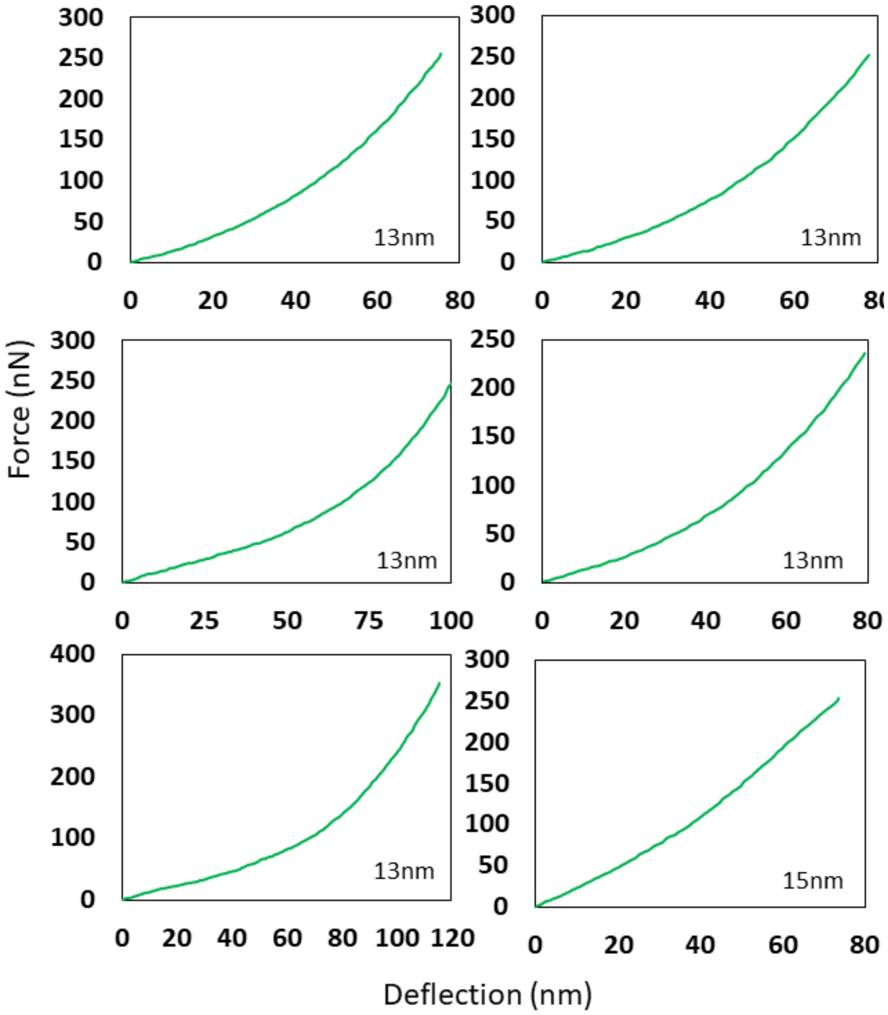

Fig. S2. Force–deflection curves of thin $HfSe_2$ nano-drumheads.

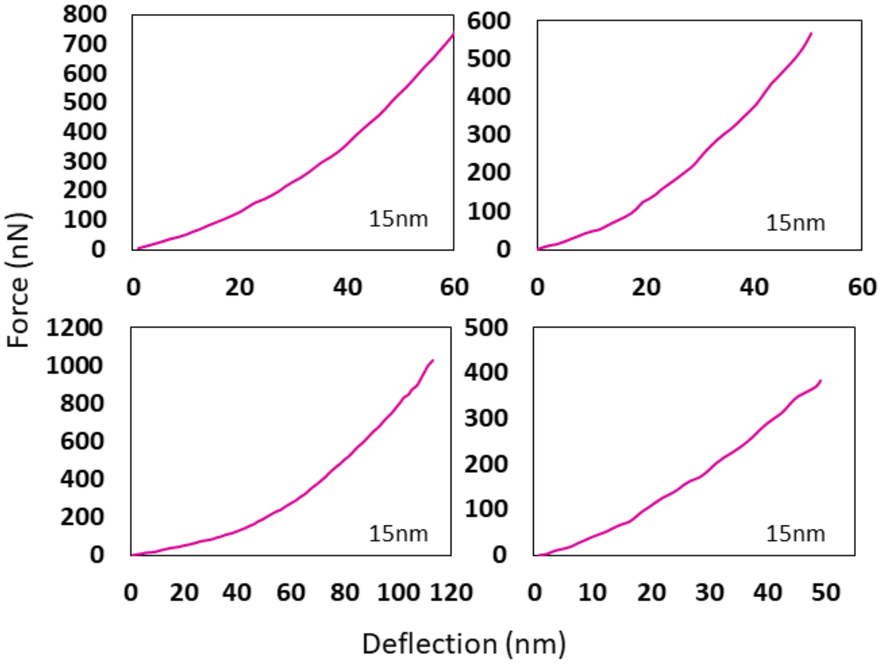

Fig. S3. Force–deflection curves of thin hafnium oxide nano-drumheads.

Force-deflection measurements of thick nano-drumheads

We also characterized a few tens of nanometer thick HfS_2 and $HfSe_2$ nano-drumheads, see representative AFM thickness measurements in Fig S4. The force-deflection curves of these thick HfS_2 and $HfSe_2$ nano-drumheads are shown in Fig. S5 and S6 (each force-deflection curve is related to a different nano-drumhead).

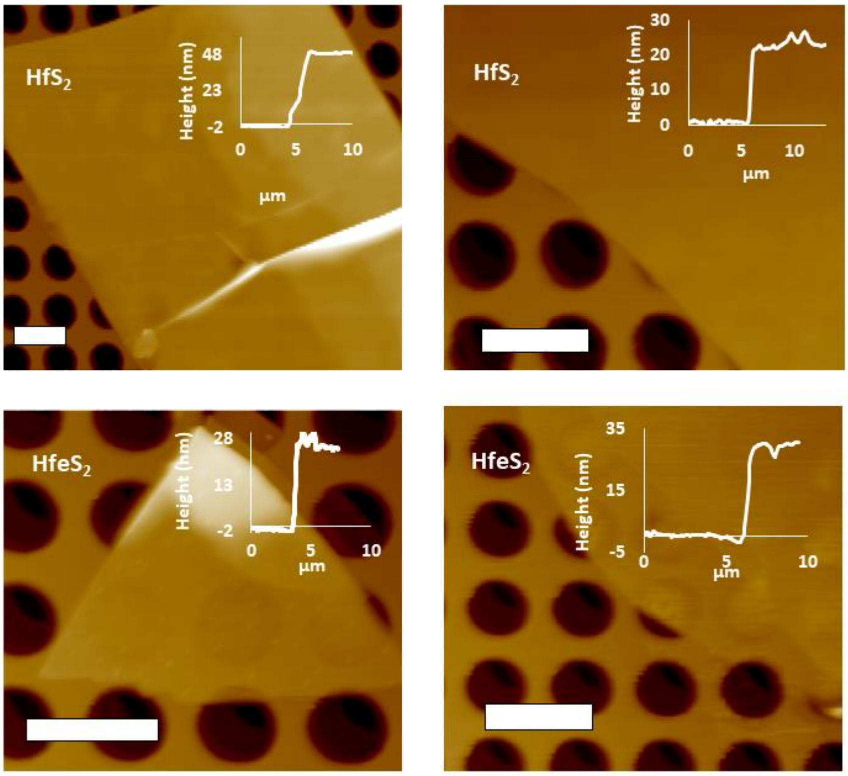

Fig. S4. Height profiles of (a) 50 nm thick HfS_2, (a) 21 nm thick HfS_2, (a) 26 nm thick $HfSe_2$, and (a) 28 nm thick $HfSe_2$.

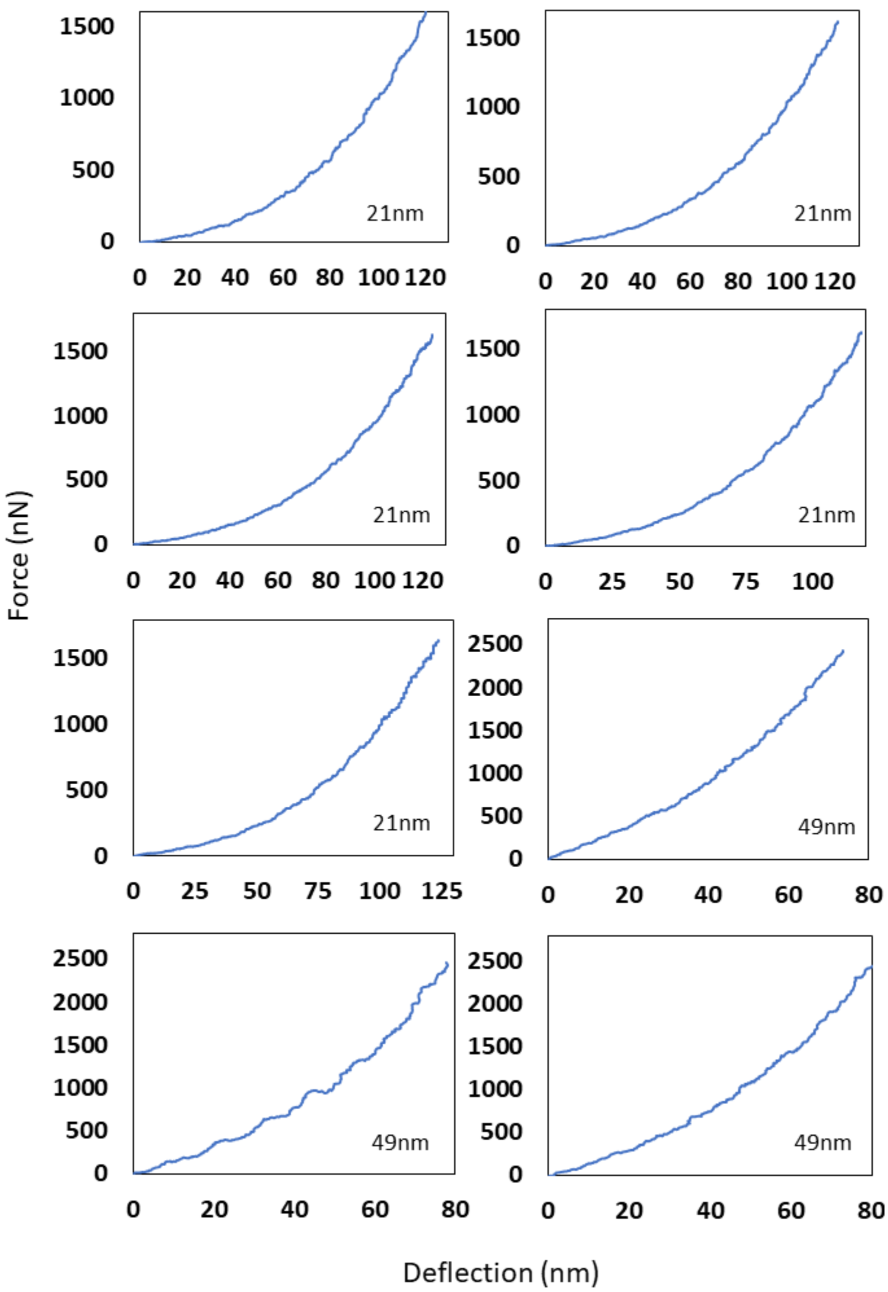

Fig. S5. Force–deflection curves of thick HfS_2 nano-drumheads.

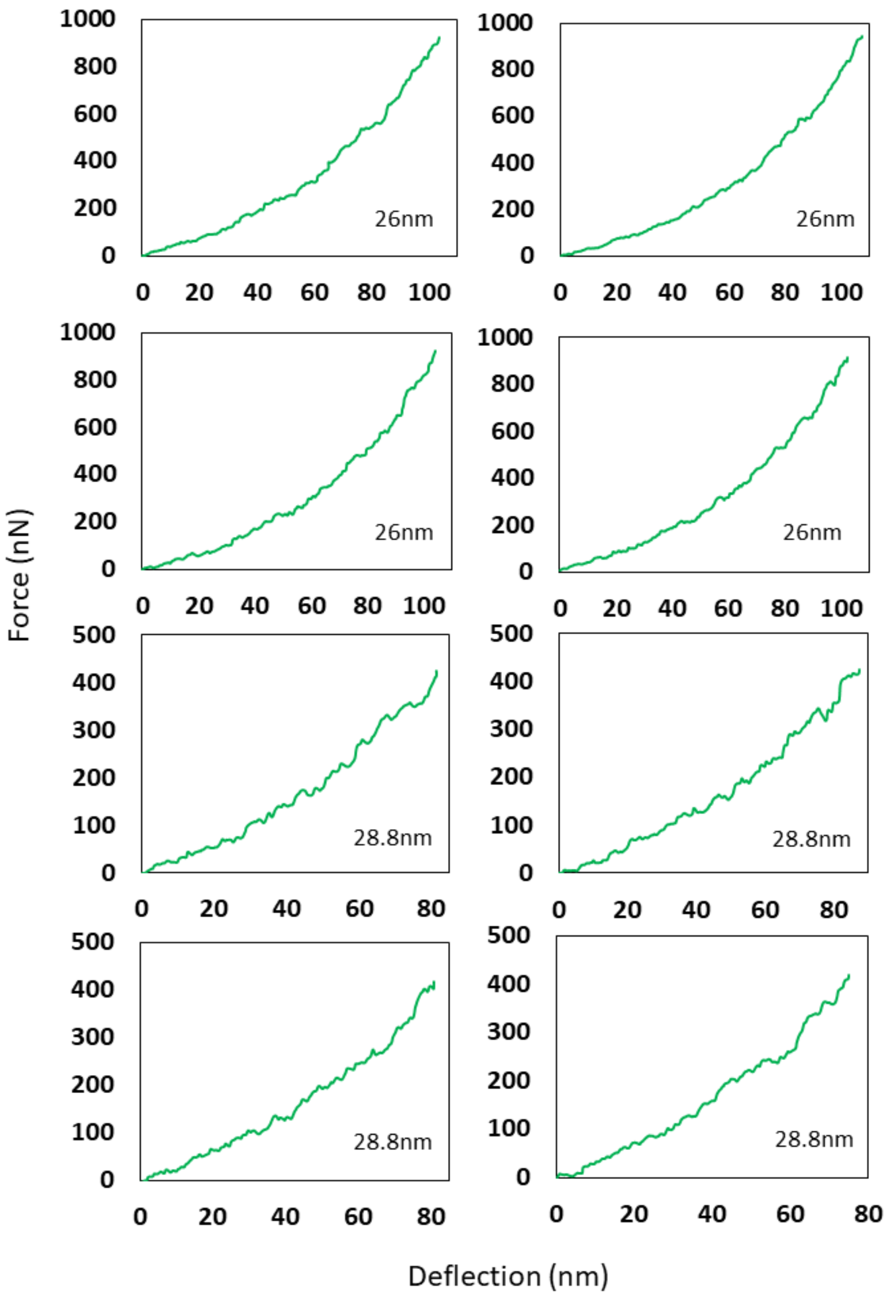

Fig. S6. Force–deflection curves of thick $HfSe_2$ nano-drumheads.

Sources for inaccuracies in the analysis of the indentation method

The term in Eq. (1) shown in the main text was widely used to describe the force-deflection relationship of thin films (for example, see Ref. 1, 16, 17-19, 21-24, 29-32 in the main text). However, this term does not take into consideration the inherent nonlinearity that appears even under small deflections due to the logarithmic nature of the force-deflection

relationship, as was indicated by Vella and Davidovitch (see Eq. (15) and (16) in Ref. 33). Nevertheless, when extracting the properties of the material from indentation measurements, the inaccuracies come not only from theoretical simplifications, such as the ones used to develop Eq. (1). More importantly, inaccuracies stem from experimental noise related to the many factors that deviate the experiment from the ideal case that is simulated theoretically. These factors include, for example, imperfect nano-drumhead and AFM tip geometries, uncertainties in the mechanical properties of the AFM cantilever, etc. In addition, most estimations do not take into consideration atomic-scale defects, such as vacancies, imperfect lattice order, layer mismatch, etc. Those imperfections surely exist in real devices and have a significant impact on the measured mechanical properties that far exceed that simplification related to Eq. (1). Despite all sources of inaccuracies, many publications demonstrated that Eq. (1) reliably describes the force-deflection relationship of thin nano-drumheads.