Mechanical Stress Induced Tuning of Resistance in MoS_2 Junctions

P. Chaudhary[1], H. Lu[1], M. Loes[2], A. Lipatov[2], A. Sisnitskii[2], and A. Gruverman[1]

NEBRASKA CENTER FOR ENERGY SCIENCES RESEARCH

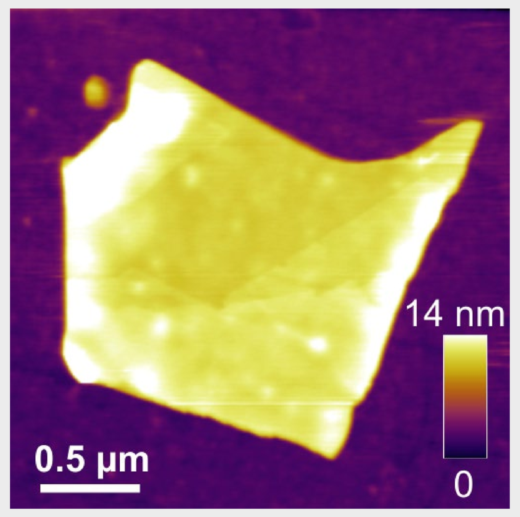
[1]*Dept. of Physics and Astronomy, University of Nebraska, Lincoln, NE 68588*
[2]*Dept. of Chemistry, University of Nebraska, Lincoln, NE 68588*

Tuning of Resistance by AFM tip Load

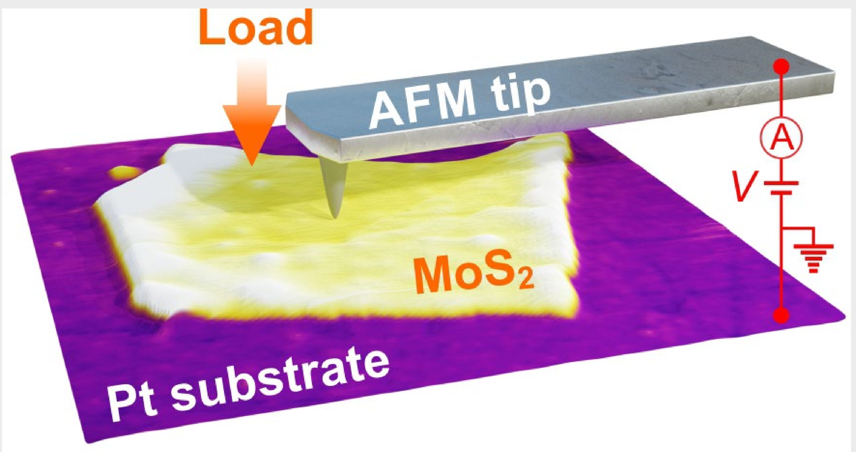
➢Continuous reduction of MoS_2 junction resistance by ~4-orders of magnitude due to tip-applied force

➢Gradual transition of I-V curves from asymmetric to symmetric with increase in tip loading force

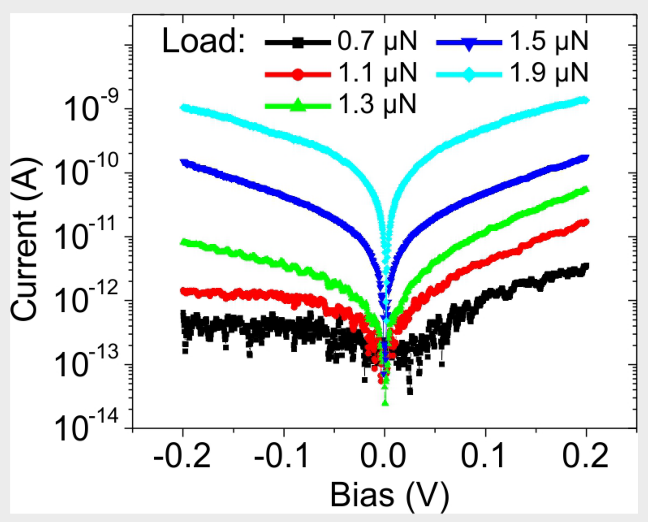
Topography



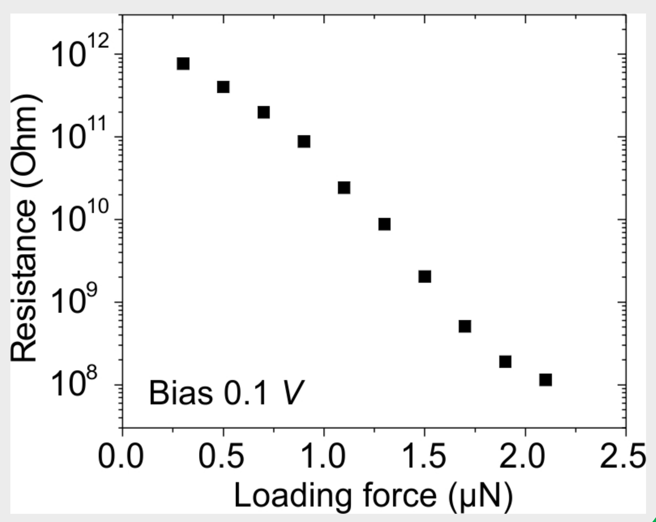
Schematic



I-V curves on MoS_2



Junction resistance vs force

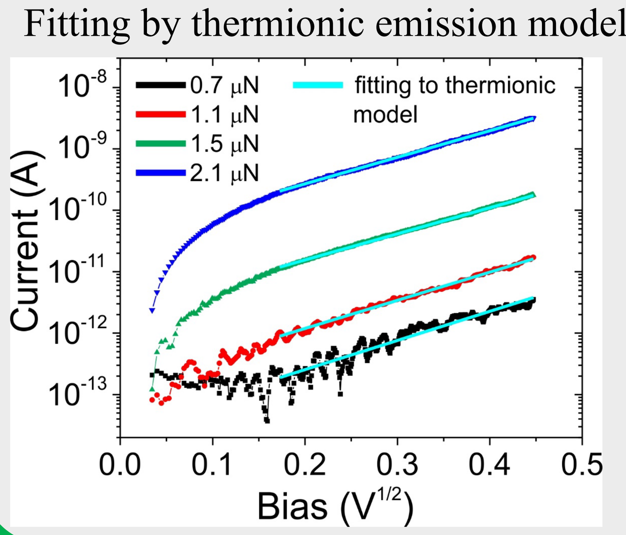


Barrier Height Lowering due to Tip-induced Pressure

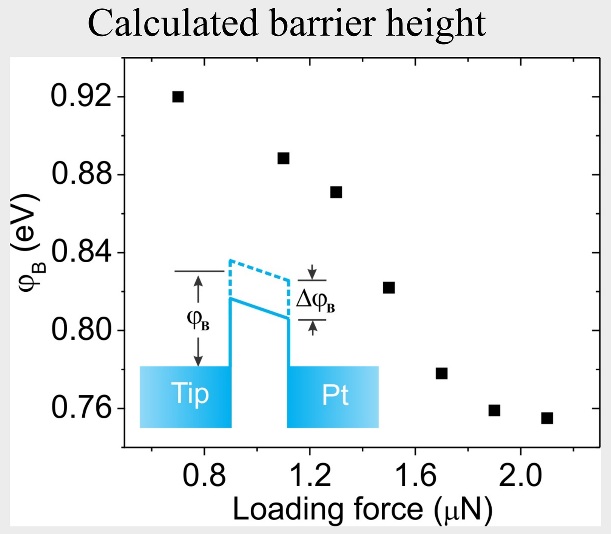
➢Reasonable fitting of I-V characteristic curves suggests thermionic emission as conduction mechanism

➢Gradual reduction of Schottky barrier height by 0.16 eV at 2.1 μN load caused by reduction of band gap

Fitting by thermionic emission model



Calculated barrier height



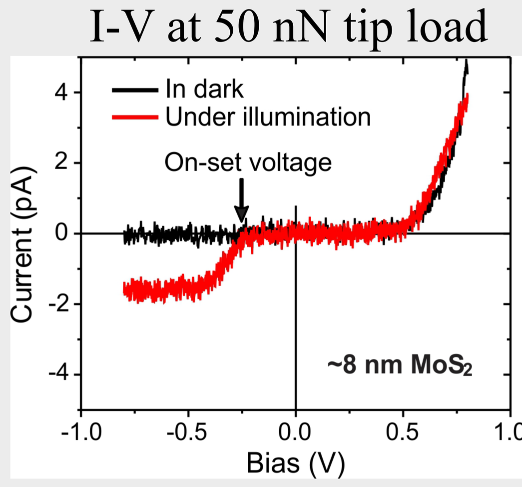
Photovoltaic Studies on tip/MoS_2/Pt Junctions

➢Tip load generates downward flexoelectric field that compensates the upward built-in field resulting to a symmetric barrier profile at junction

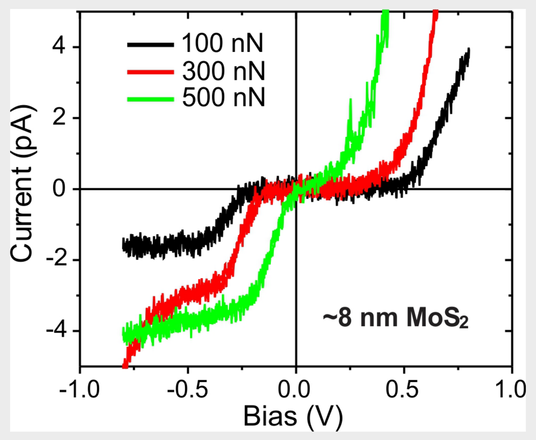
➢Shift of the photocurrent on-set voltage for 8 nm thick flake and open circuit voltage (V_{oc}) for 35 nm thick flake evident from flexoelectric effect

Shift of Photocurrent On-Set Voltage by Flexoelectric effect

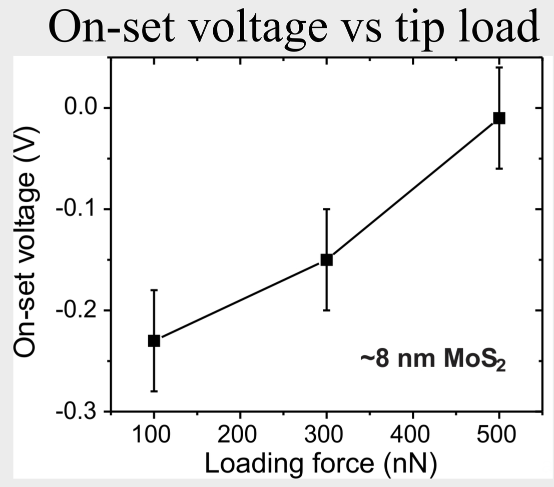
I-V at 50 nN tip load



I-V under illumination



On-set voltage vs tip load

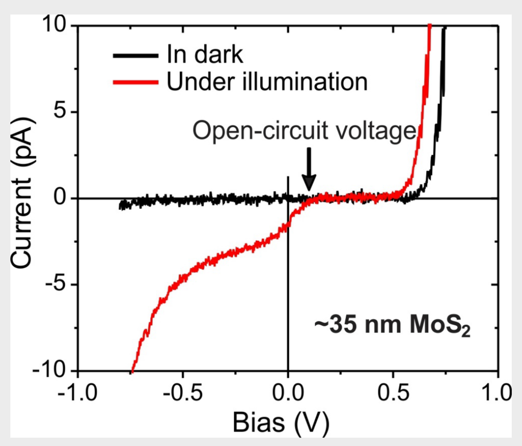


➢ Occurrence of on-set voltage at negative bias in thinner flake

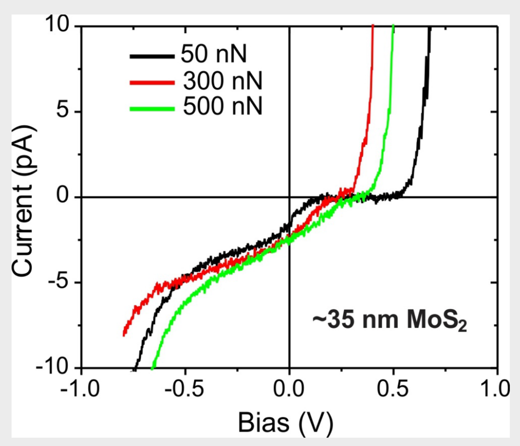
➢ Right shift of on-set voltage due to flexoelectric field as tip load increases

Shift of Open-Circuit Voltage by Flexoelectric effect

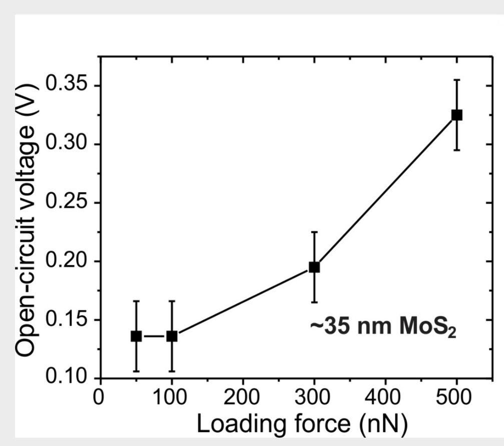
I-V at 50 nN tip load



I-V under illumination



V_{oc} vs tip load



➢ Occurrence of open-circuit voltage (V_{oc}) at positive bias in 35 nm thick MoS_2 flake

➢ Right shift in V_{oc} due to downward flexoelectric field as tip load increases

Acknowledgement

This research was supported by Nebraska Public Power District through the Nebraska Center for Energy Sciences.

Evolution of Barrier due to Tip-induced Strain and Strain Gradient

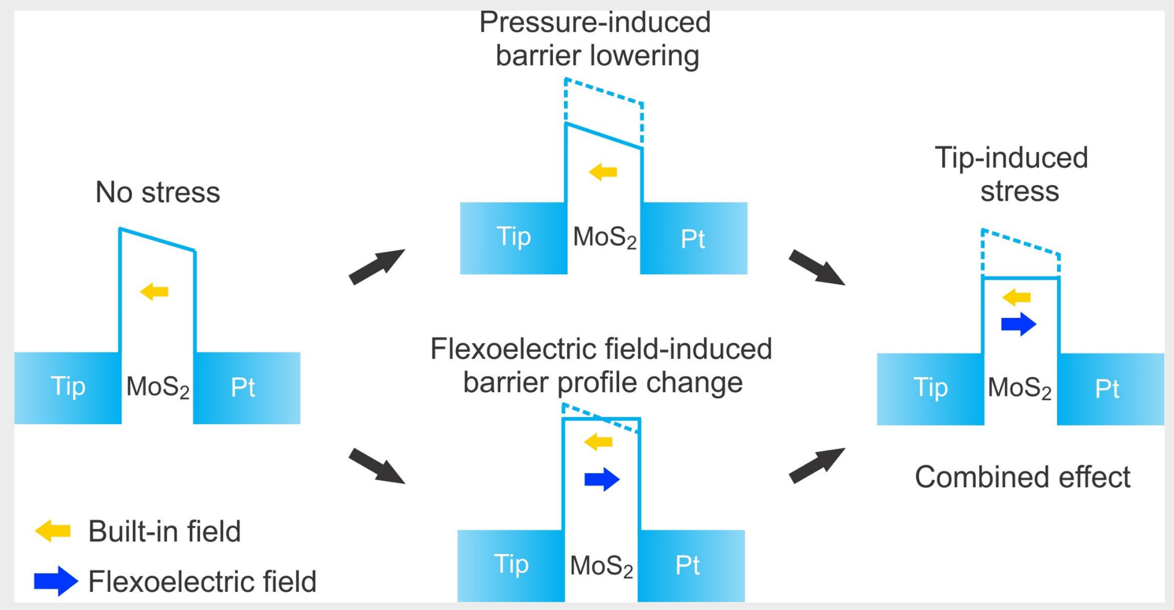
➢Presence of upward built-in field accounting to asymmetric I-V curves at low load

➢Lowering of barrier height due to the tip-induced homogeneous strain generated at high load

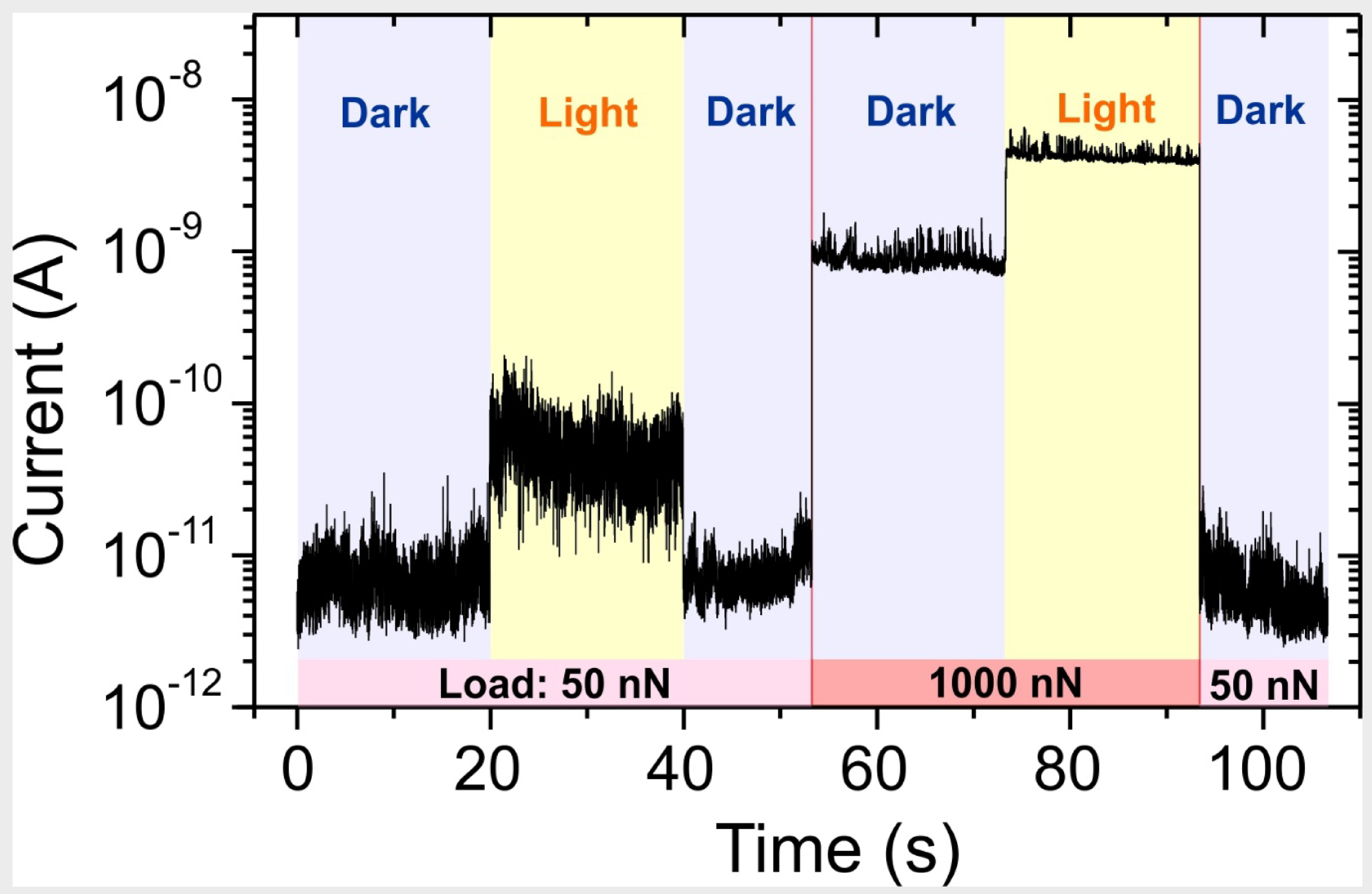
➢Modification of energy barrier profile due to the compensation of built-in field by flexoelectric field

➢Overall modified barrier profile due to tip-induced strain and gradient leading to symmetric I-V curves

Change of MoS_2 Barrier due to Applied Tip Load



Demonstration of Resistance Tuning due to Light, Load and their Combination



➢ Enhanced MoS_2 conductivity due to tip load or light

➢ Combined excitation approach adds to further enhancement (~ 1 order of magnitude) of conductivity