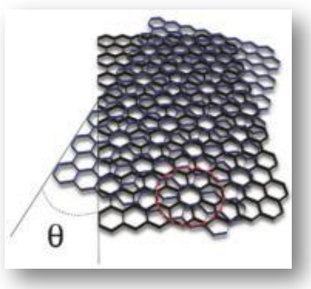
# Shear-Enhanced Near-Surface Superconductivity

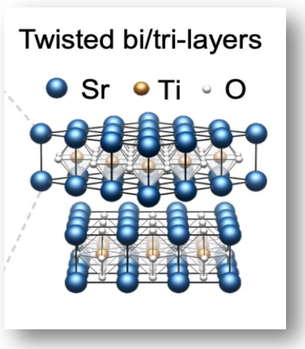

## Abstract

We have studied the effect of high-pressure torsion (HPT) on the near-surface superconductivity of W–Re and Mo–Re alloy films using Ag-tip point-contact spectroscopy. By comparing the sheared and stationary faces of the same specimens, we identify a pronounced surface-selective response: the strongly sheared face exhibits enhanced superconducting gaps and increased critical temperatures, whereas the compression-dominated face remains close to the unprocessed state. The findings demonstrate that the HPT technology can serve as a **surface-selective tool** for engineering superconducting states in three-dimensional materials and may be relevant to interface-dominated devices such as point contacts, Josephson junctions, and proximity structures.


## Motivation




✓ Twistronics in van der Waals heterostructures explores how rotating two-dimensional atomic layers relative to each other dramatically transforms electronic and magnetic properties.




✓ Twisting layered (in particular, superconducting) oxides, which are held together by strong chemical bonds, distorts the atomic structure, causing a gradual rotation of the atomic lattice at the layers interface.

## Experimental Method & Processing

✓ We have developed a new, third direction in twistronics by extending its principles to bulk metallic superconductors. We show that surface-localized severe plastic deformation, realized via HPT, serves as a powerful method to dramatically enhance local superconducting coupling.




✓ In this technique, a sample is pressed between two anvils while one rotates. The magnetron-sputtered films on sapphire were treated at 5.3–5.8 GPa with five rotations.

✓ The sheared surface became nearly mirror-smooth. Despite five rotations, the dimensions changed little, suggesting much of the deformation occurred through surface sliding, leaving most of the material relatively unchanged.

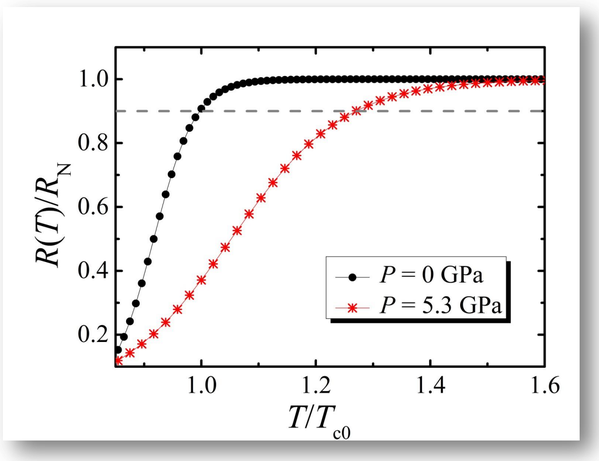
## Results and Discussion

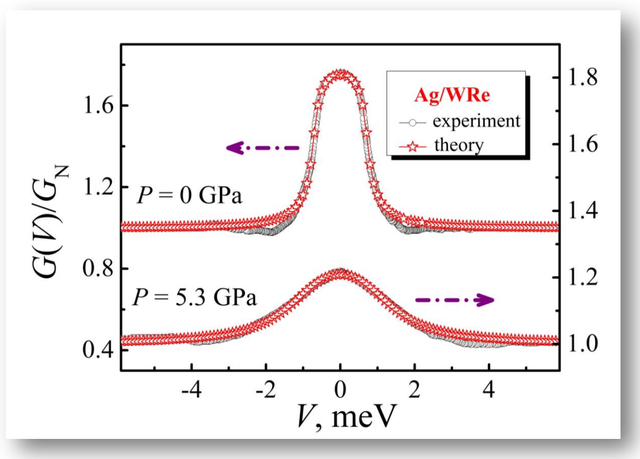
***Ag/Superconductor point contacts.***

***Left:*** Temperature-dependent resistances normalized to their normal-state values as functions of $T/T_{c0}$, where $T_{c0} = T_c(P = 0)$.

***Right:*** Differential conductance spectra $G(V) = dI(V)/dV$ normalized to normal-state values $G_N$ as functions of the voltage bias measured at 4.2 K at the upper sample surface before (P = 0) and after HPT treatment.

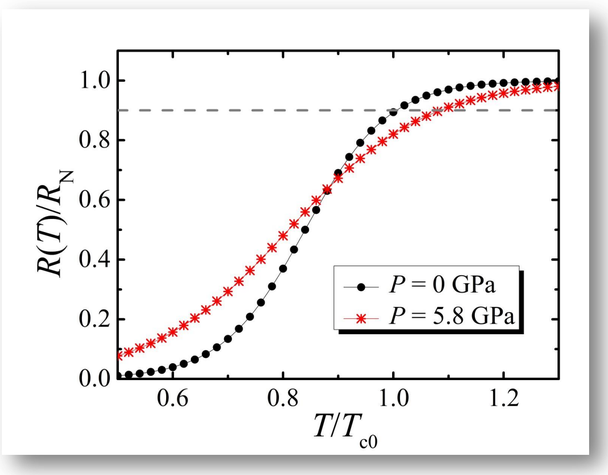
### WRe

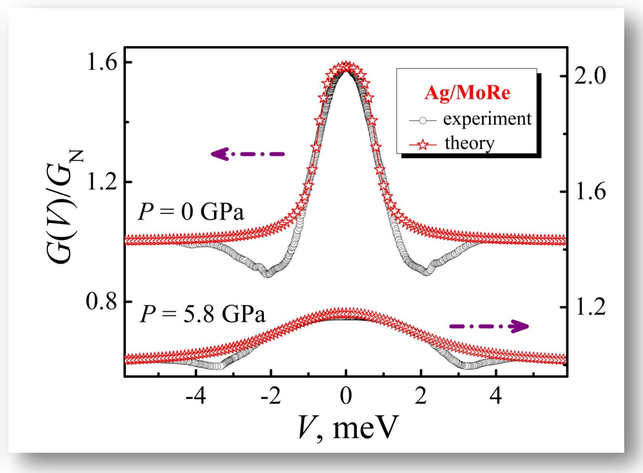



| $T_{c0}$ | $T_{cP}/T_{c0}$ | $\Delta_0$ | $\Delta_P$ | $\Gamma_0$ | $\Gamma_P$ | $Z_0$ | $Z_P$ | $2\Delta_0/k_BT_{c0}$ | $2\Delta_P/k_BT_{cP}$ |
|---|---|---|---|---|---|---|---|---|---|
| 4.8 K | 1.27 | 0.68 meV | 1.09 meV | 0.1 meV | 0.95 meV | 0 | 0 | 3.29 | 4.14 |

### MoRe




| $T_{c0}$ | $T_{cP}/T_{c0}$ | $\Delta_0$ | $\Delta_P$ | $\Gamma_0$ | $\Gamma_P$ | $Z_0$ | $Z_P$ | $2\Delta_0/k_BT_{c0}$ | $2\Delta_P/k_BT_{cP}$ |
|---|---|---|---|---|---|---|---|---|---|
| 9.5 K | 1.06 | 0.81 meV | 1.6 meV | 0.18 meV | 1.51 meV | 0.14 | 0.11 | 2.08 | 3.77 |

## Conclusions

Our results demonstrate that, through intense torsional shear, HPT offers a promising new approach to engineering the near-surface superconducting properties of metallic materials. We revealed a significant enhancement of the electron-phonon coupling following HPT treatment. These changes occur predominantly on strongly shear-deformed surfaces, demonstrating the decisive role of torsional deformation rather than compression alone.

FAKULTA MATEMATIKY, FYZIKY A INFORMATIKY
Univerzita Komenského v Bratislave

CENAM
Centre for Nanotechnology and Advanced Materials

MATFYZ CONNECTIONS


This research received partial support from the Slovak Research and Development Agency under contracts No. APVV-23-0238 and APVV-25-0276.



E. Zhitlukhina, M. Belogolovskii
Centre for Nanotechnology and Advanced Materials, Comenius University Bratislava, Slovakia

V. Tarenkov, V. Dmitrenko
Donetsk Institute for Physics and Engineering named after O.O. Galkin, Kyiv, Ukraine