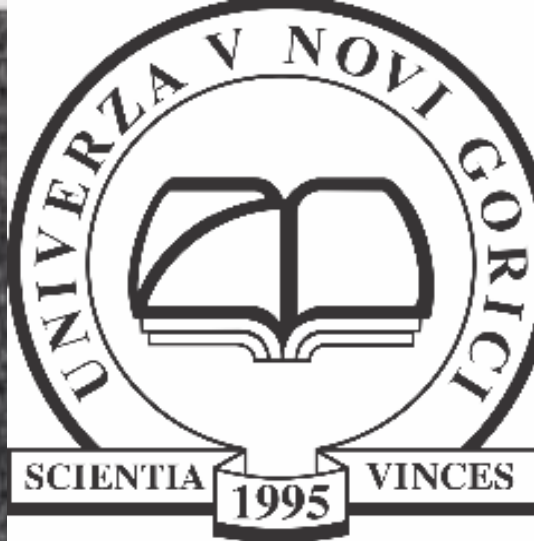
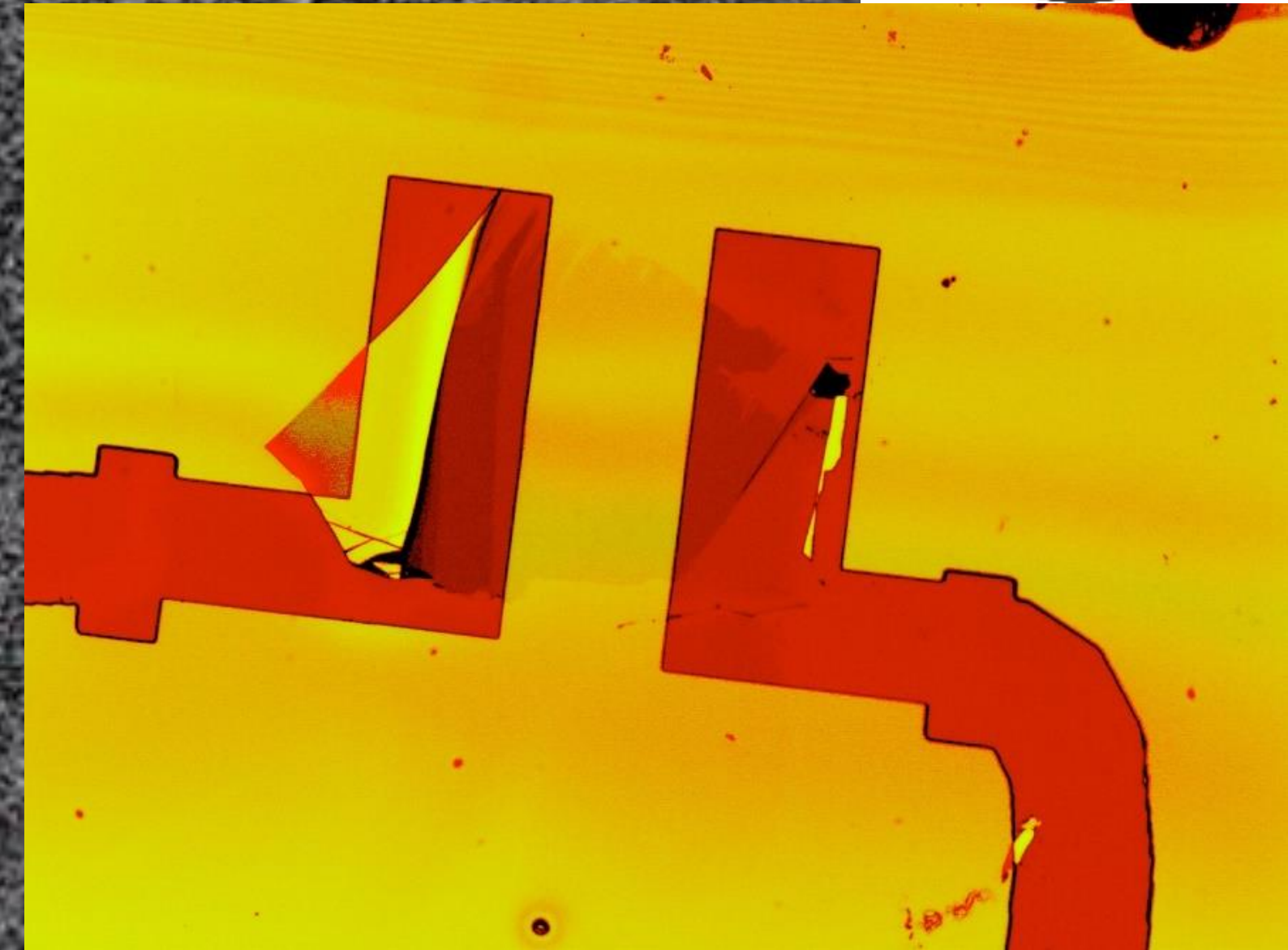


100
ZNO



Znanost na cesti in
univerza v Novi Gorici

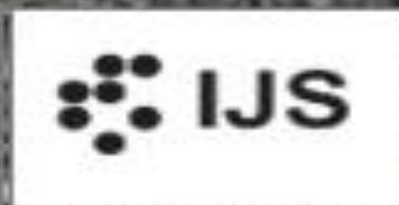


Dvodimenzionalni materiali in organski polprevodniki: nov pogled na stare znance

prof. dr. Gvido Bratina

(Laboratorij za fiziko organskih snovi, Univerza v Novi Gorici) in

Maja Ratej



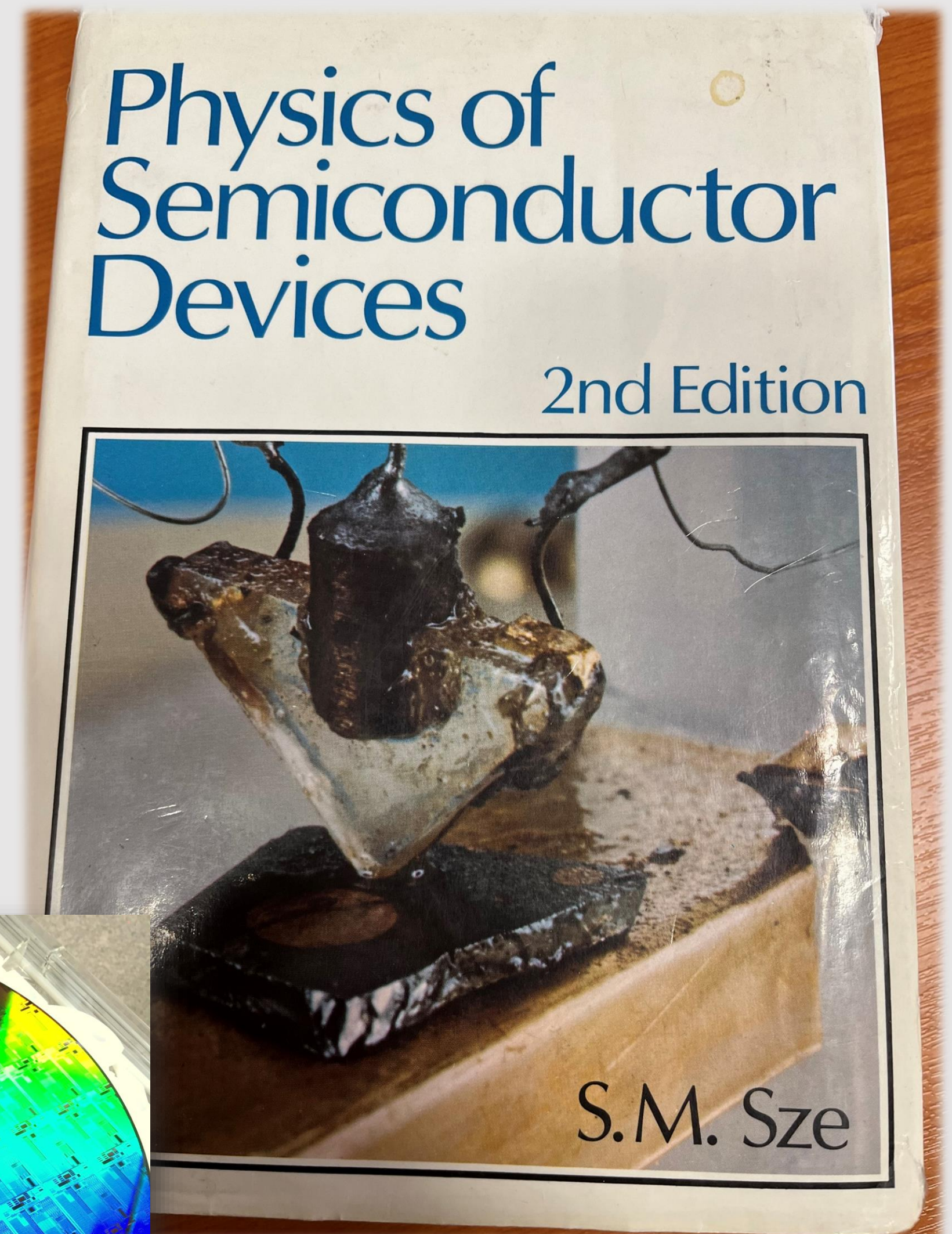
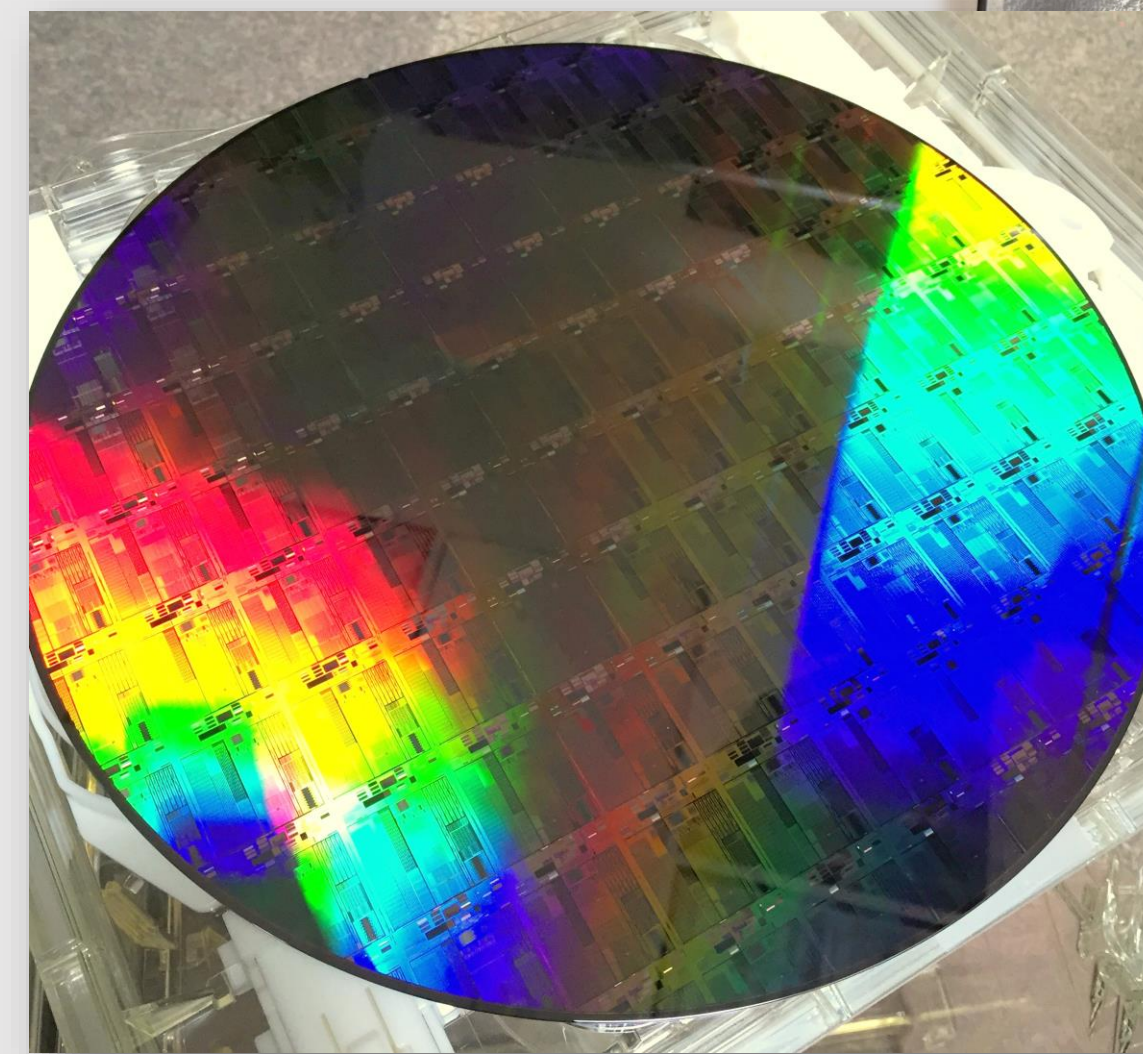
Tranzistorjevih 76 let

When the points were very close together got voltage amp about 2 but not power amp. This voltage amplification was independent of frequency 10 to 10,000 cycles.

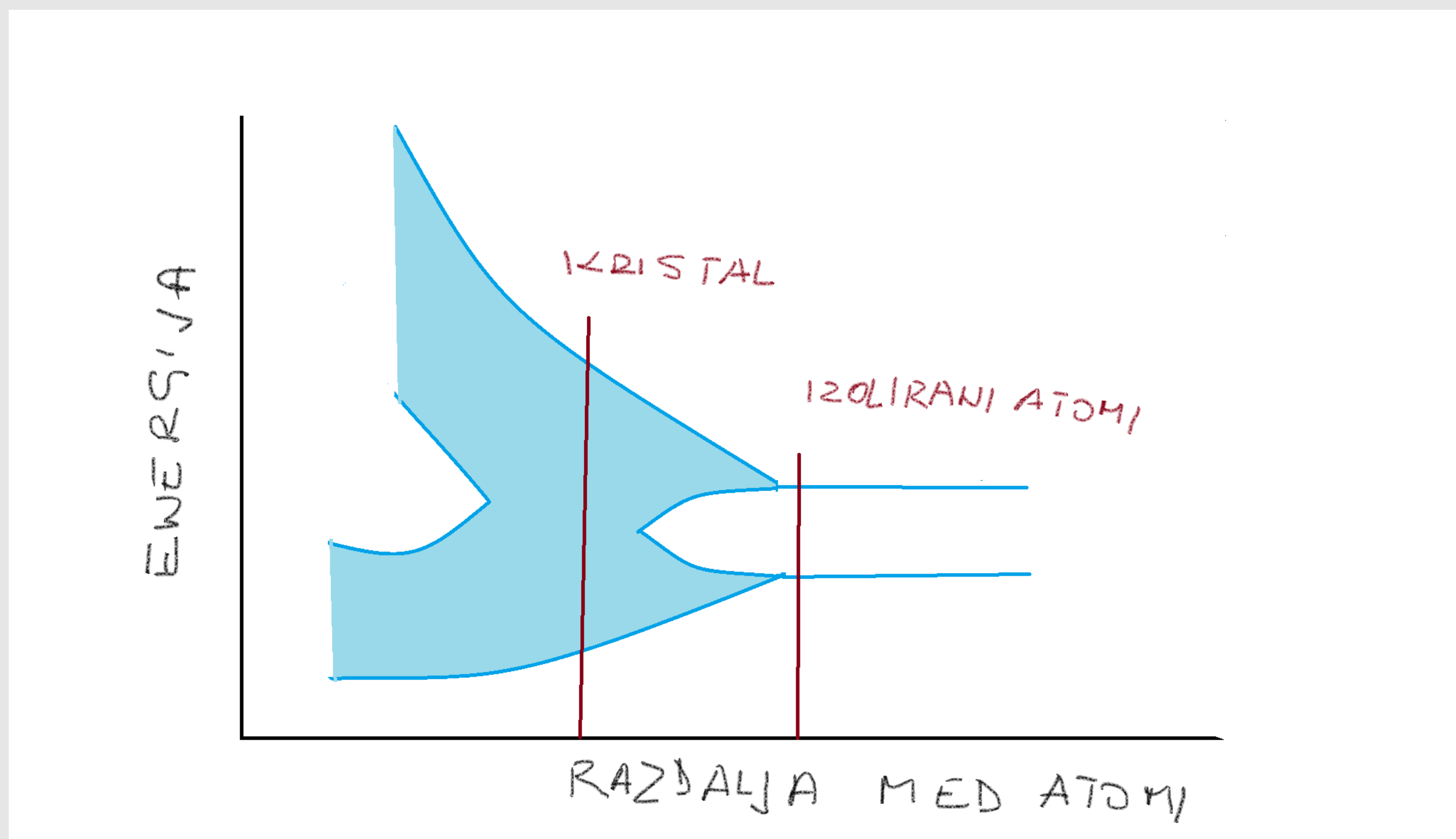
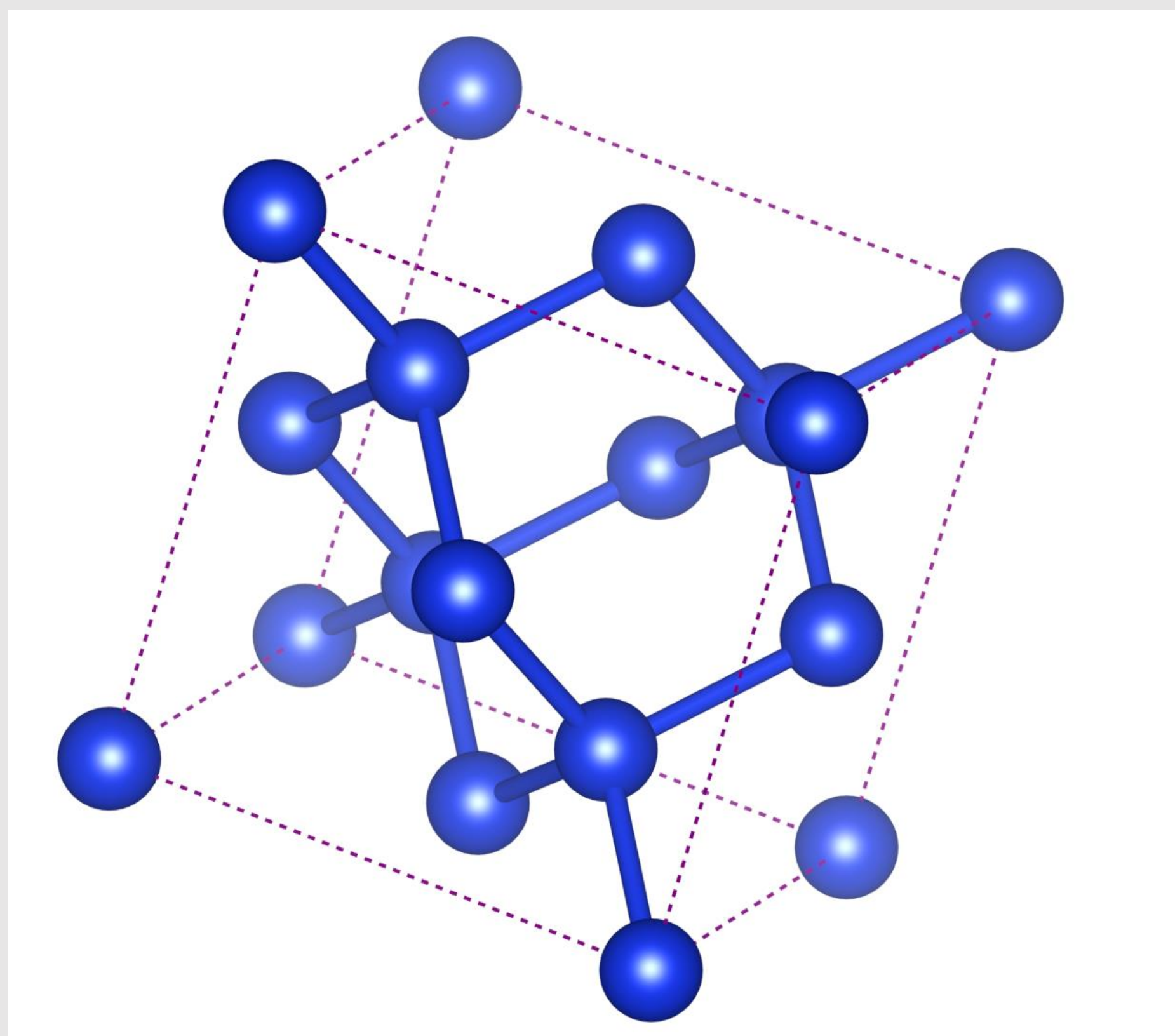
(W.H. Brattain, laboratorijski dnevnik, december 1947)



John Bardeen, William Shockley in Walter Brattain v Bellovih Laboratorijh.



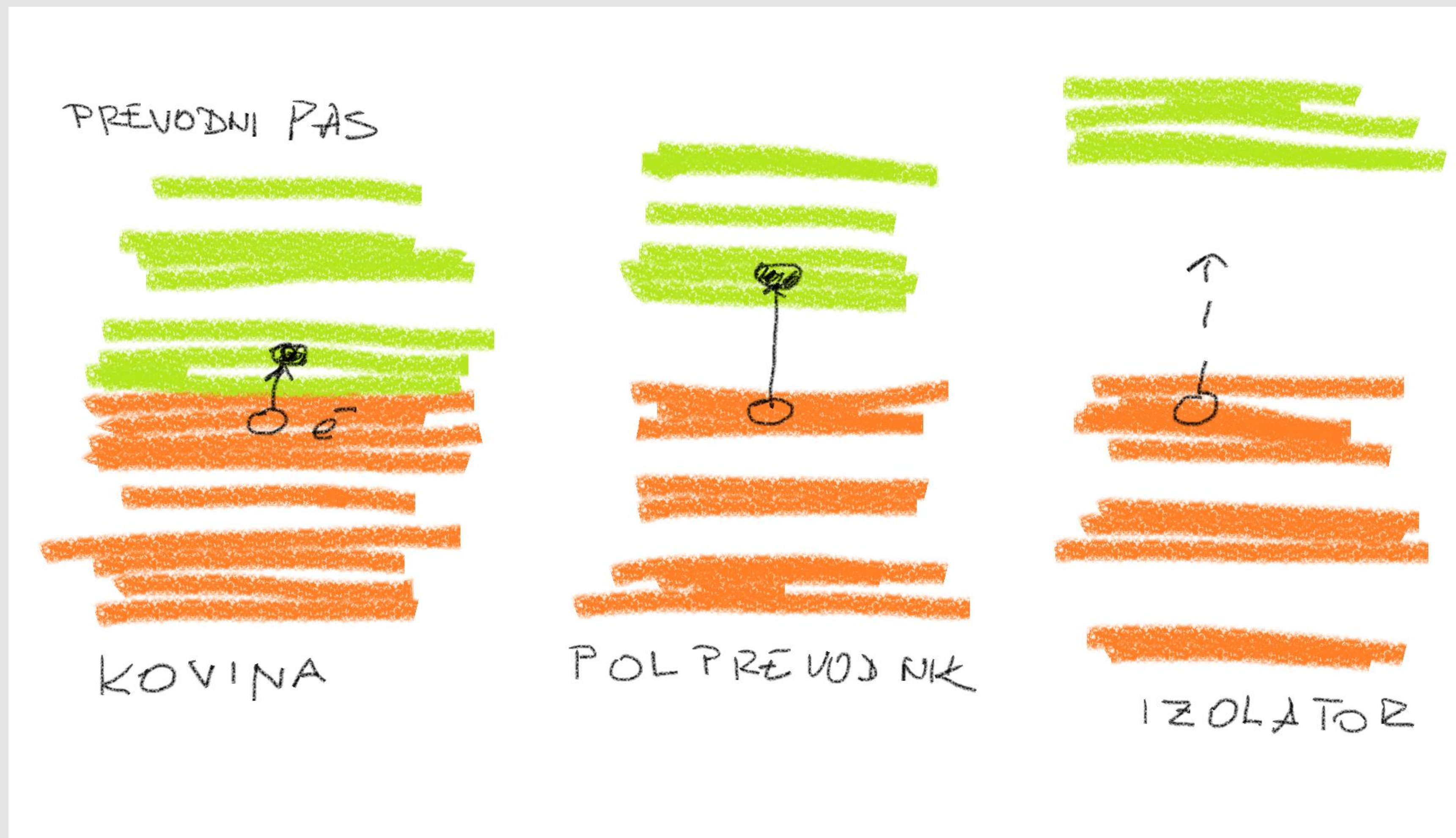
Elektroni v kristalu



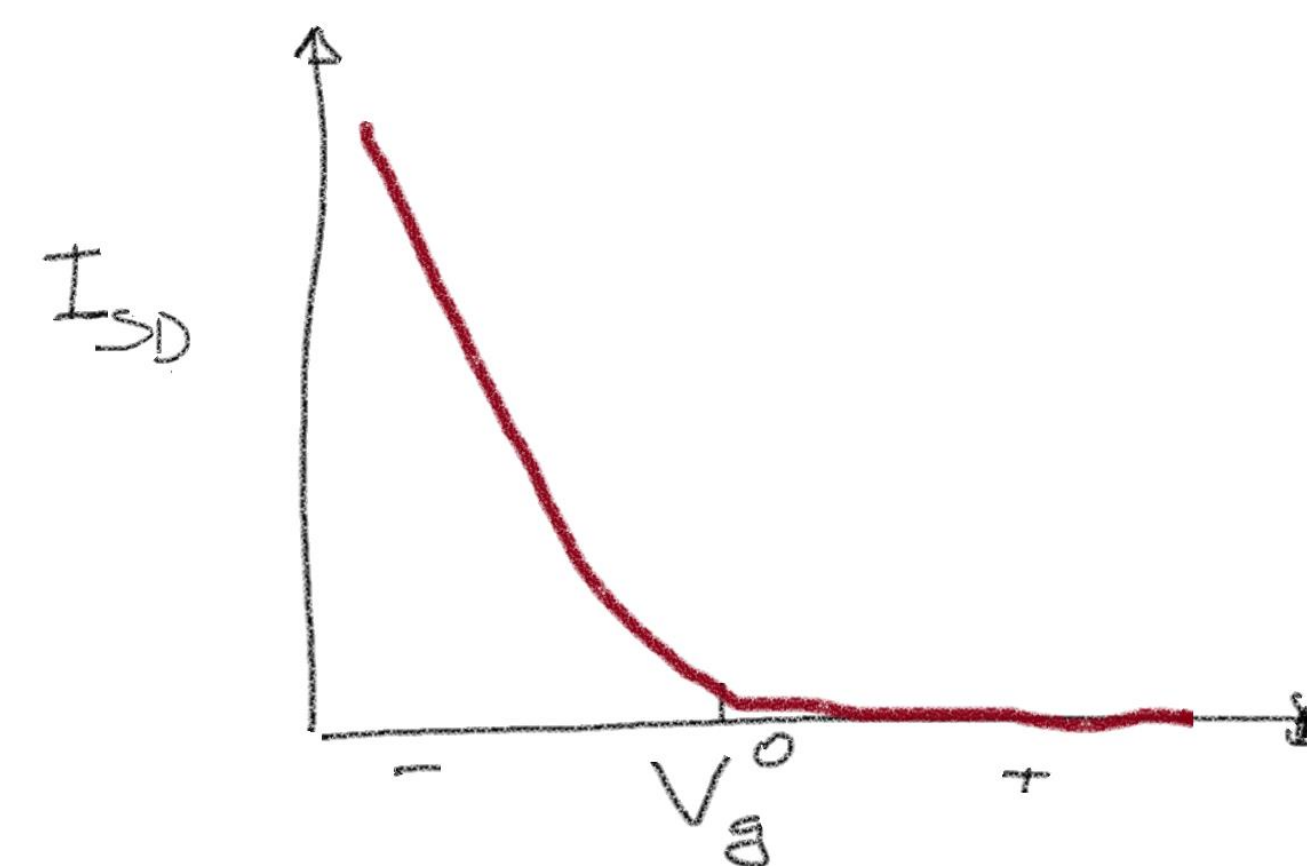
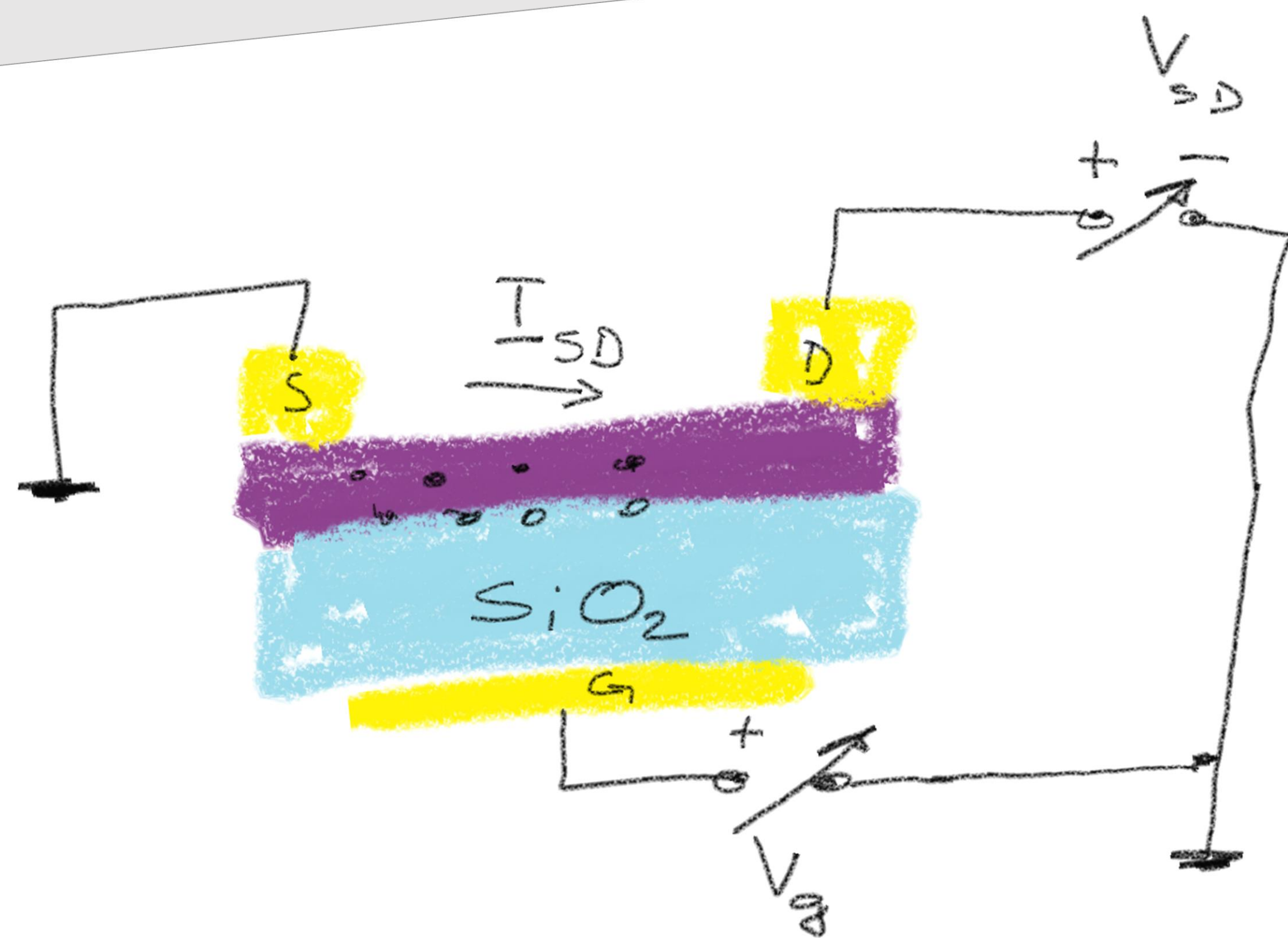
Elektroni v kristalni strukturi:

- Valovanje
- Namesto energijskih nivojev, **energijski pasovi**

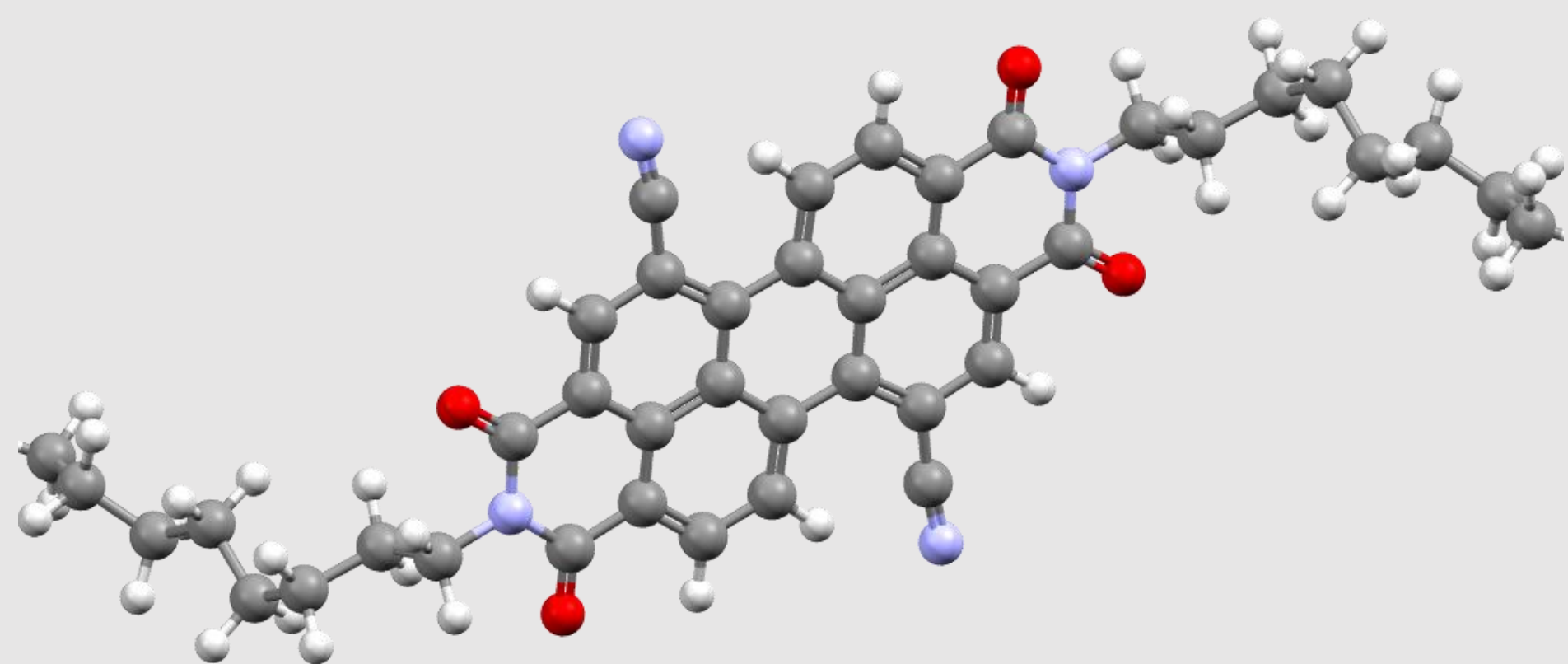
Električna prevodnost v materialih



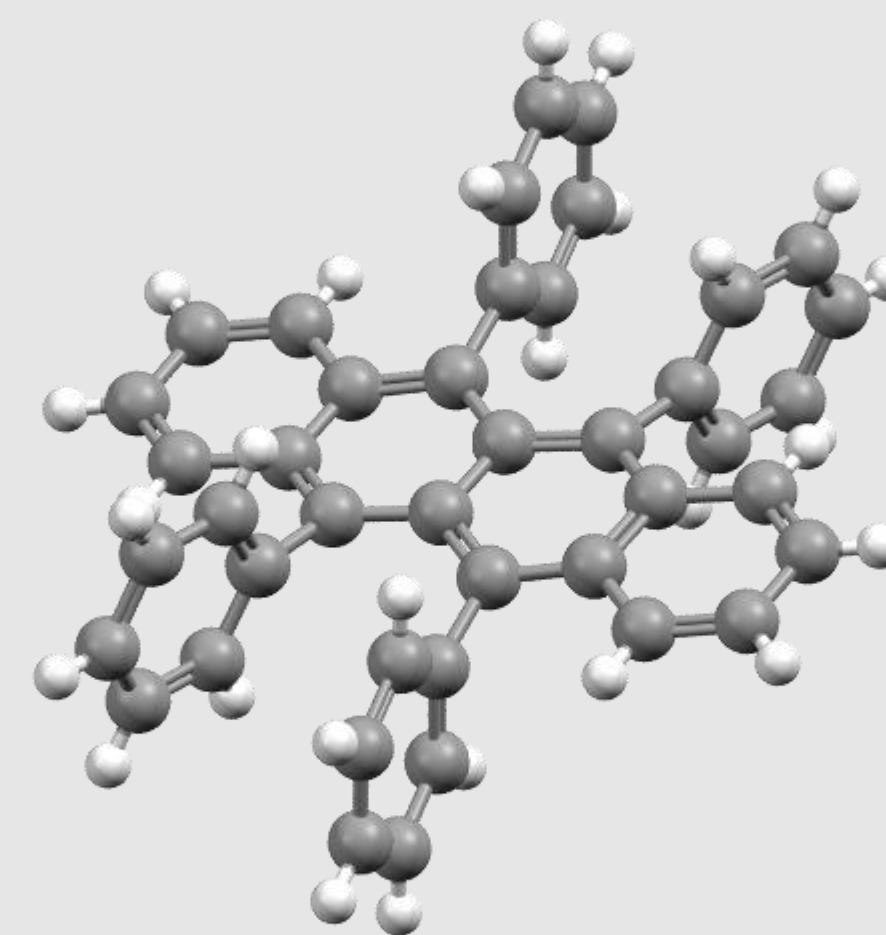
Tranzistor: stikalo



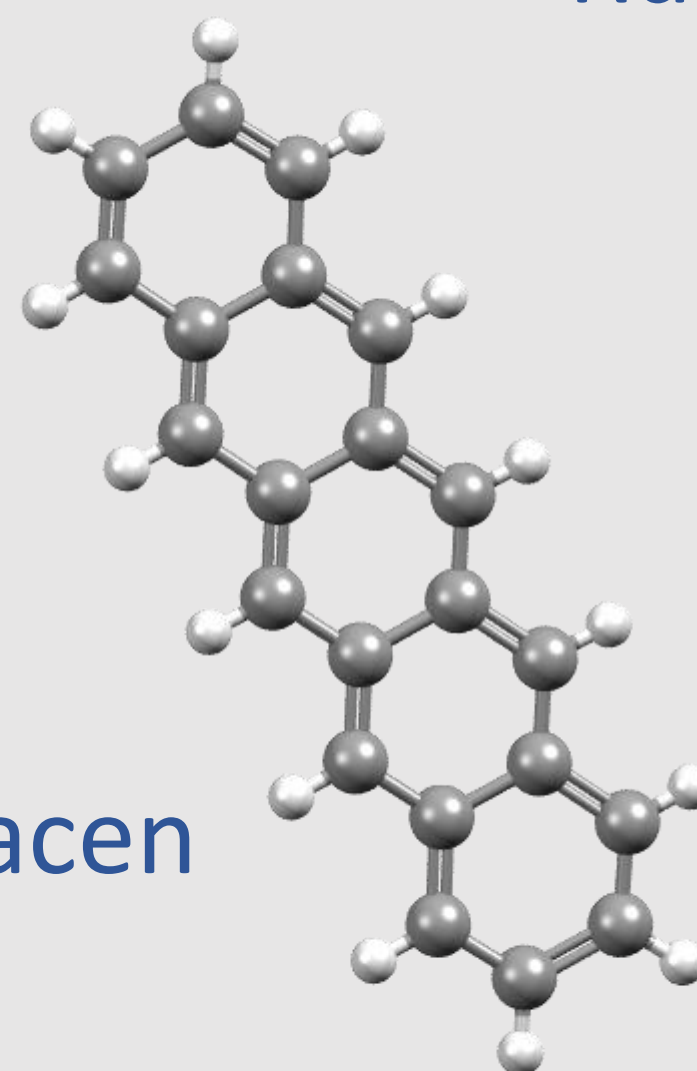
Organski polprevodniki



PDI8-CN2



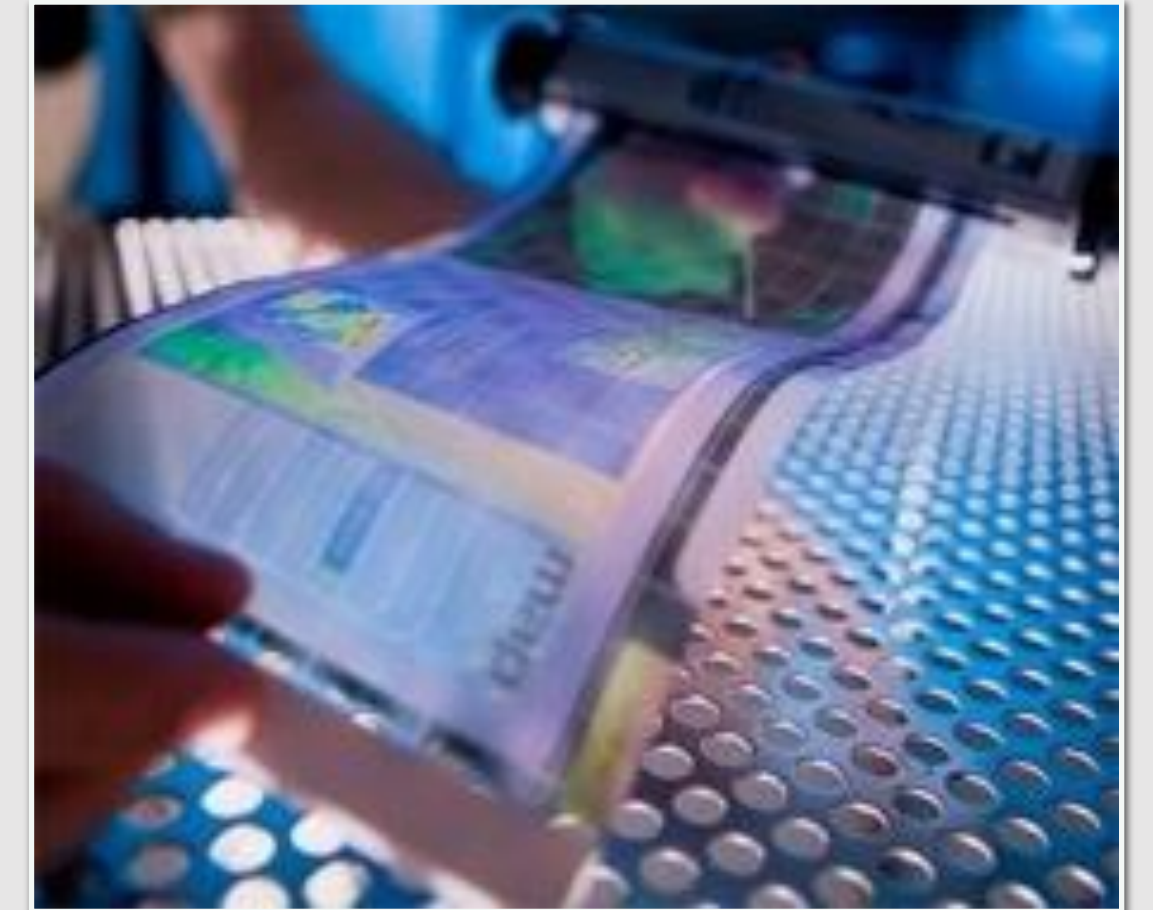
Rubren



Pentacen

Zakaj organski polprevodniki?

- Osnovni gradniki so molekule
- Šibke vezi med njimi
- Nanašanje na gibke podloge (polietilenske folije)
- Izdelava elektronskih komponent na velikih površinah (raztopine, brizganje, tiskanje)
- Za okolje manj škodljiva tehnologija (manj kislin in baz)





RESEARCH & DEVELOPMENT

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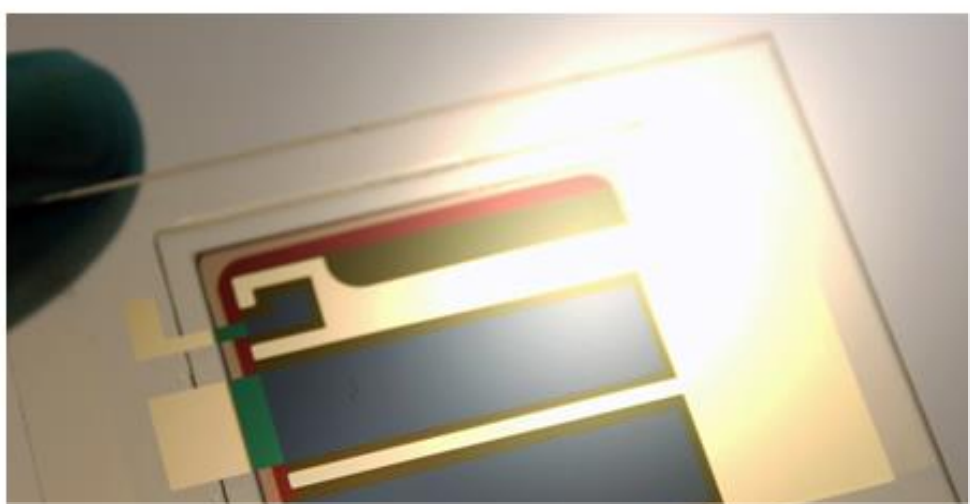
Heliatek achieves 12% organic solar cell efficiency

23 Jan 2013

Organic approach challenges silicon, thin film - as German company seeks further investment for process optimisation.

Organic solar films developer **Heliatek**, Dresden, Germany, reports that it has pushed the conversion efficiency of its organic photovoltaic (OPV) cells to 12%, which the company says is equivalent to at least 15% in conventional semiconductor-based cells.

The company says this performance, which was achieved in cooperation with the University of Ulm and TU



Organske sončne celice

$\eta = 12 \%(2013)$ ➔ $\eta = 22 \%(2022)$

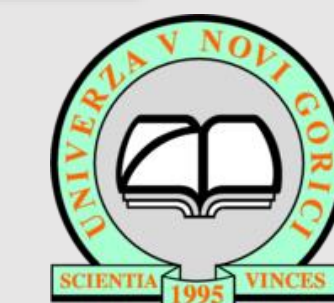
ADVANCED MATERIALS

Research Article

Constructing Monolithic Perovskite/Organic Tandem Solar Cell with Efficiency of 22.0% via Reduced Open-Circuit Voltage Loss and Broadened Absorption Spectra

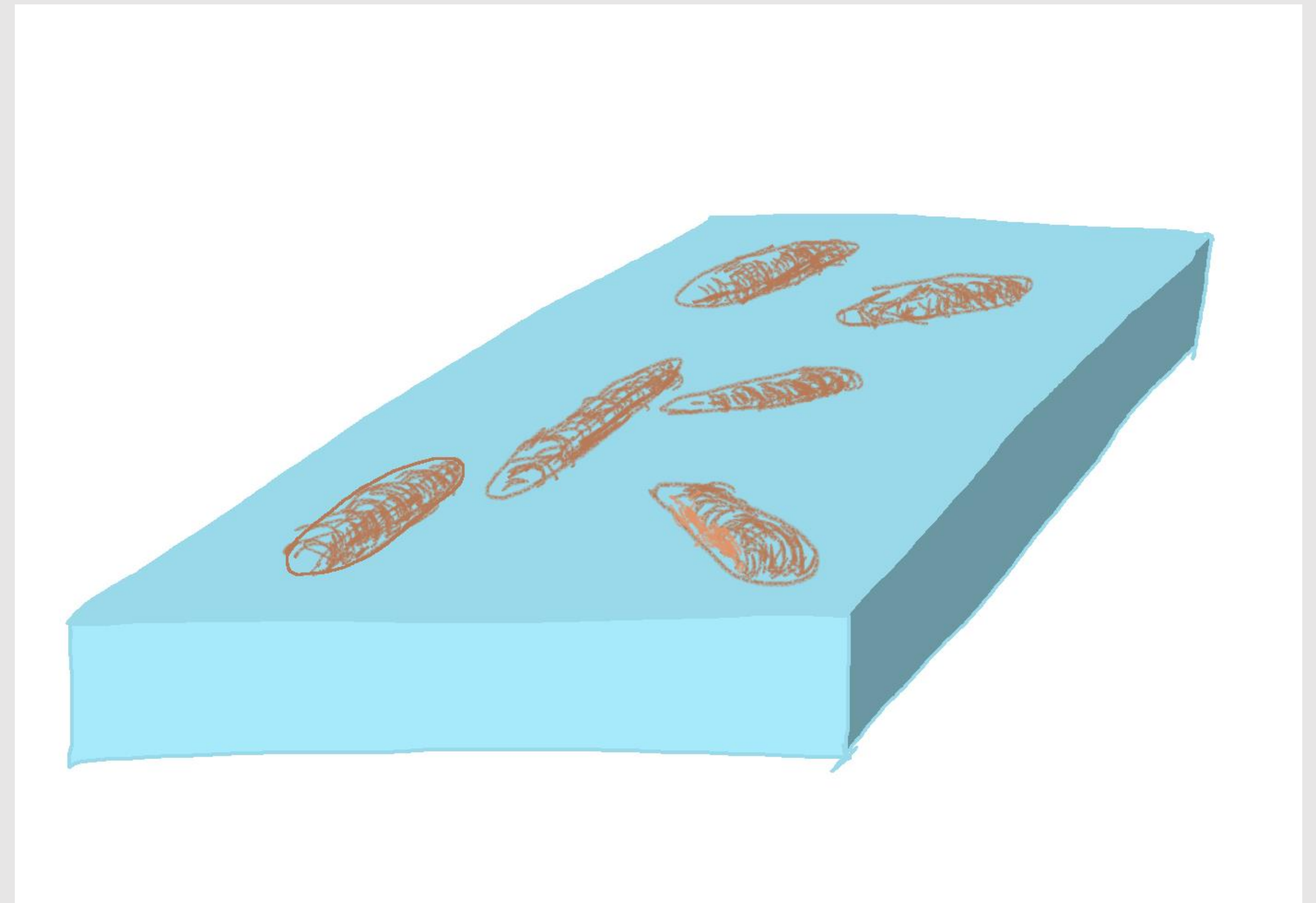
Shucheng Qin, Chenxing Lu, Zhenrong Jia, Yiyang Wang, Siguang Li, Wenbin Lai, Pengju Shi, Rui Wang, Can Zhu, Jiaqi Du, Jinyuan Zhang, Lei Meng ✉, Yongfang Li ✉

First published: 19 January 2022 | <https://doi.org/10.1002/adma.202108829> | Citations: 12

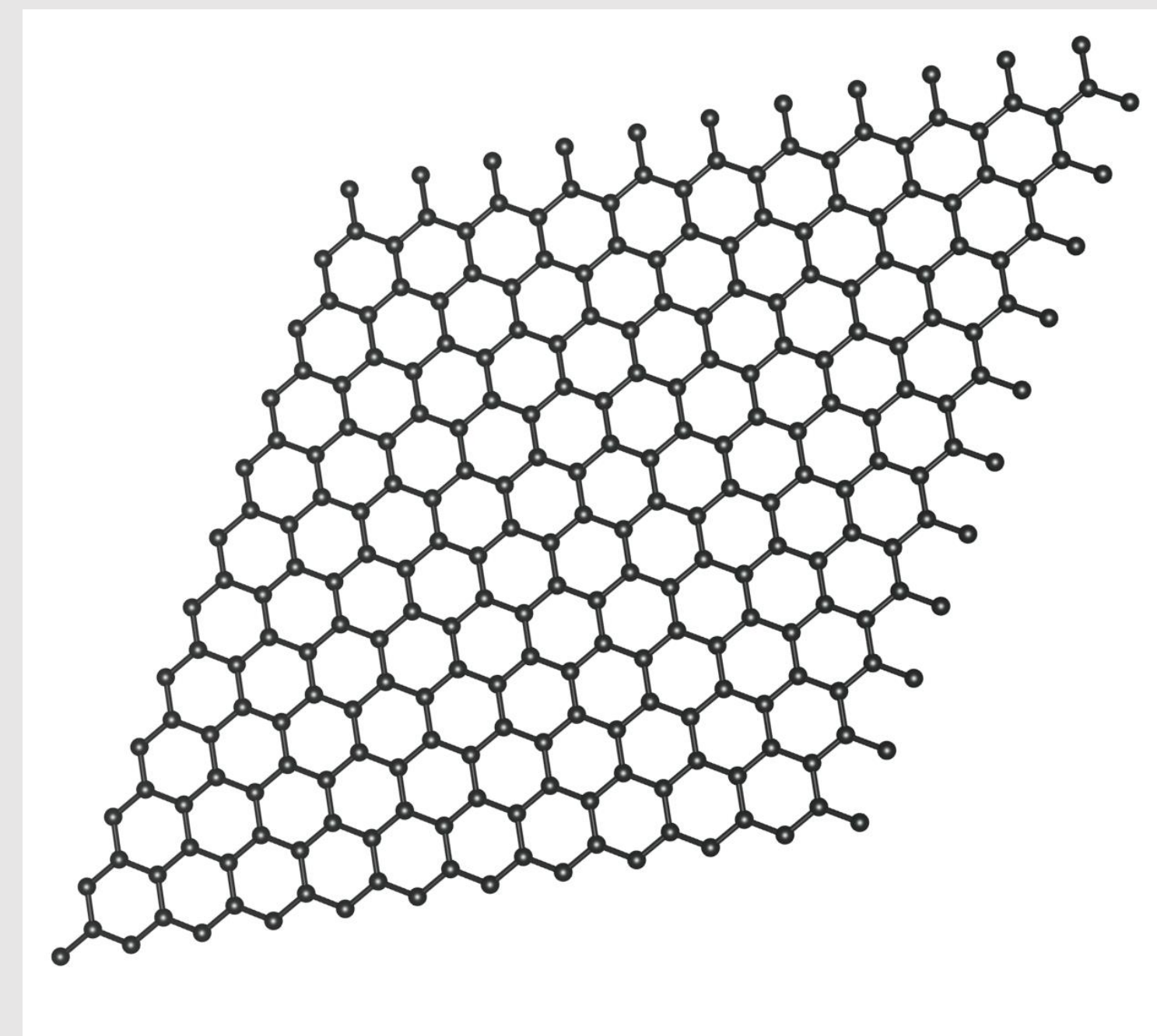
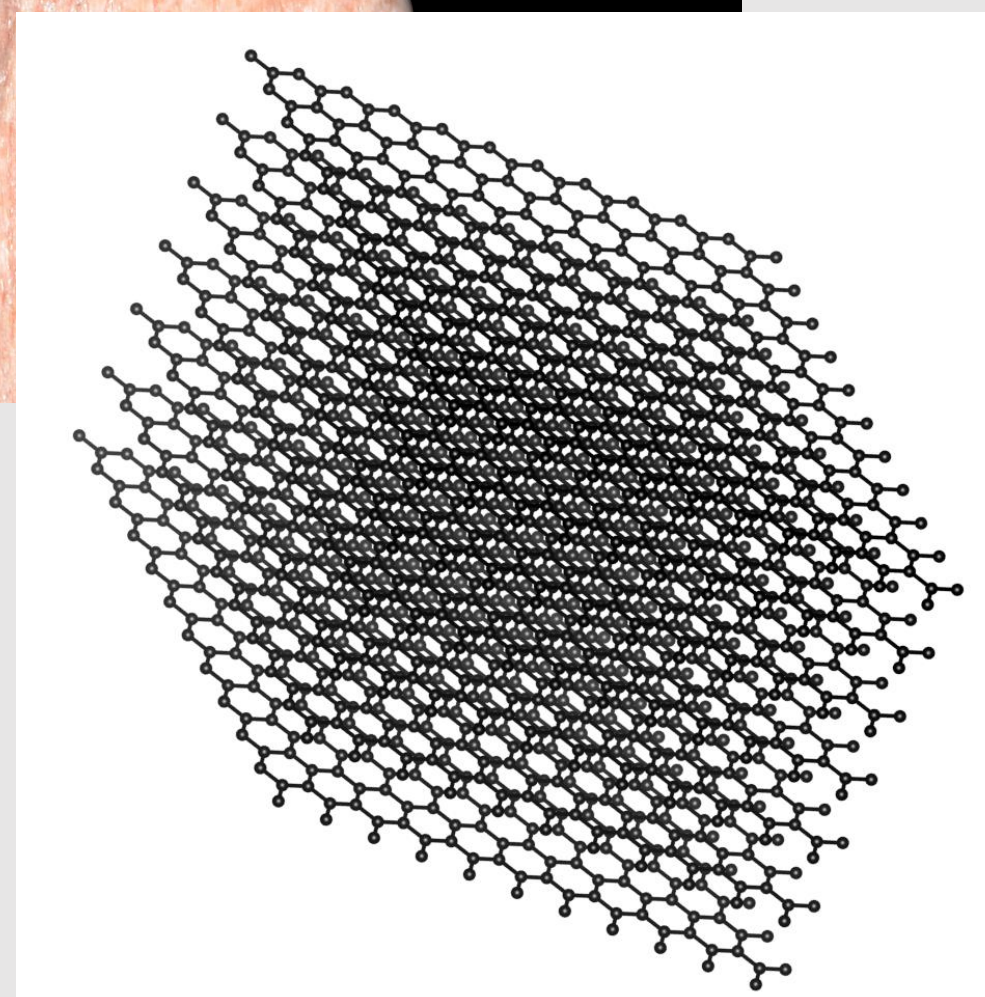
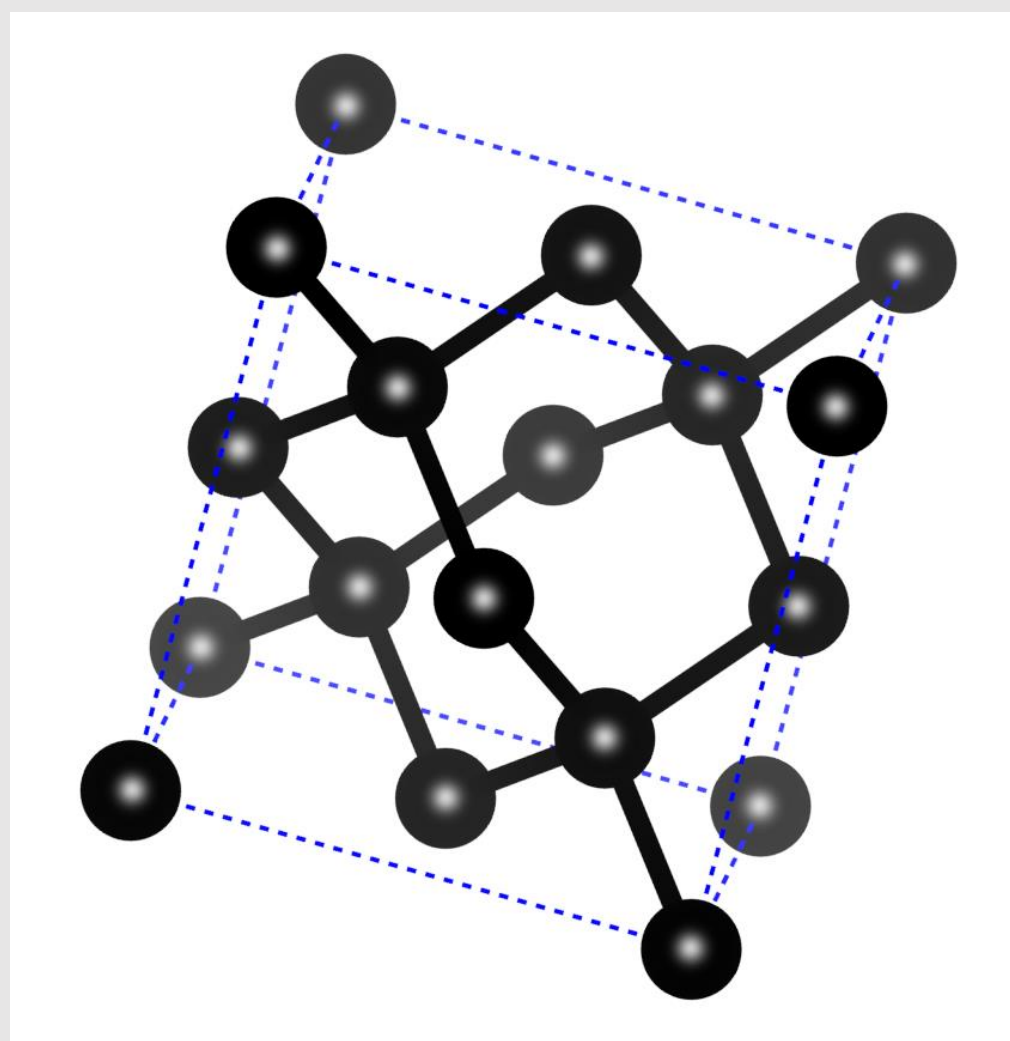
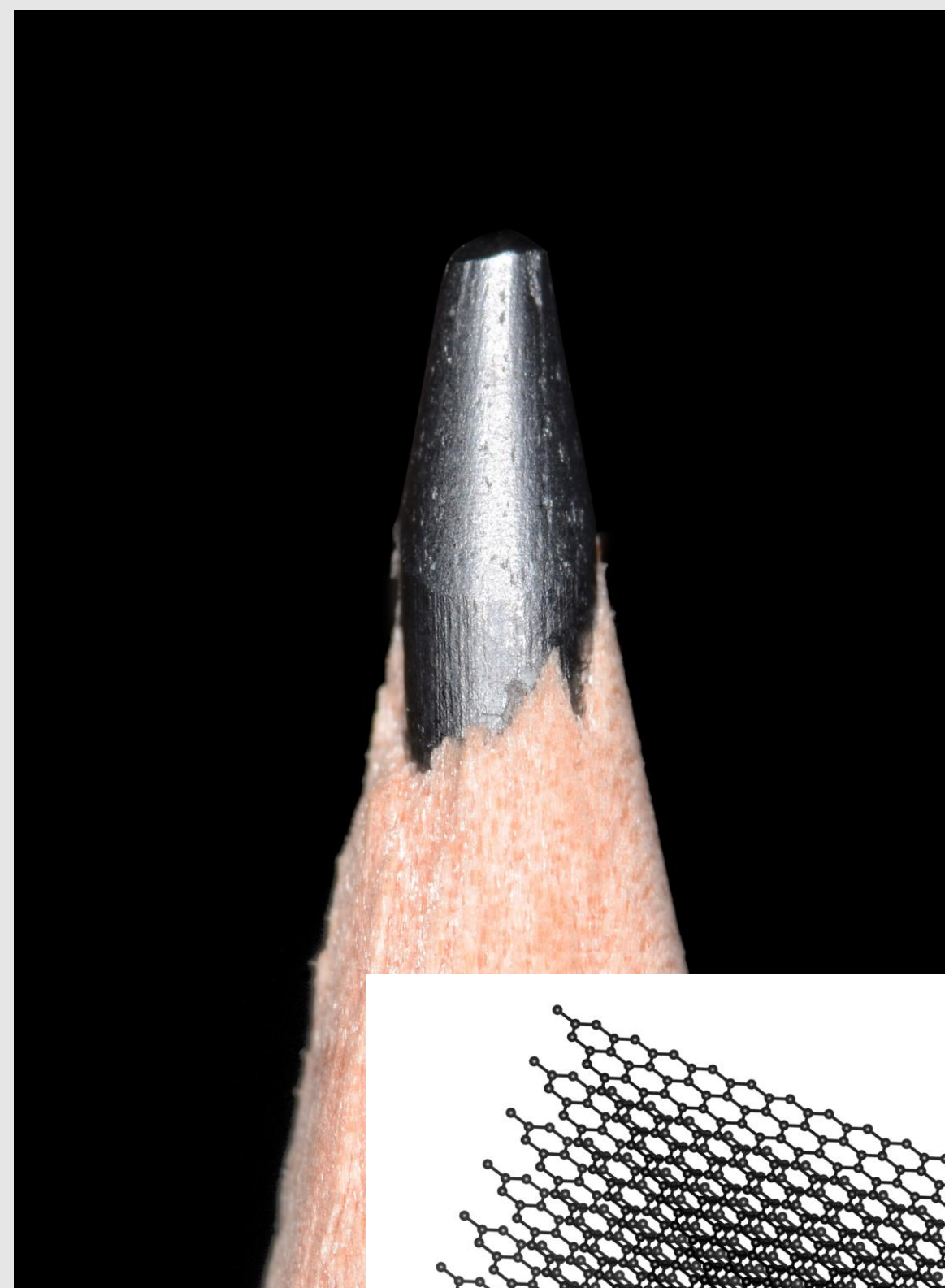


Organski polprevodniki: ovire

- Neurejena struktura
- Množica kristalografskih napak
- Nizka gibljivost elektronov ($1 \text{ cm}^2/\text{Vs}$)
- Občutljivost na topila



Diamant, grafit, grafen

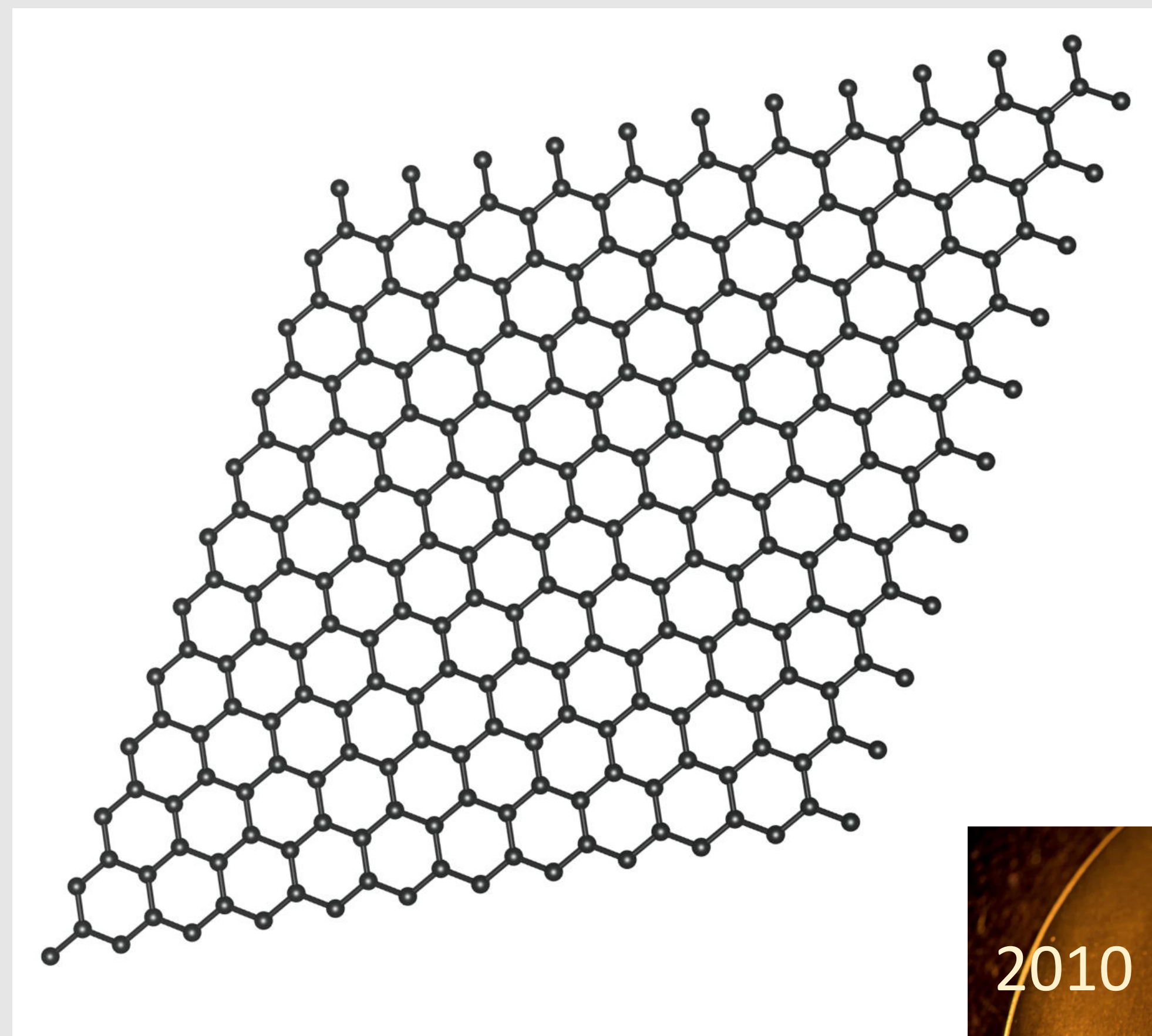


Grafen: dvodimenzionalen material

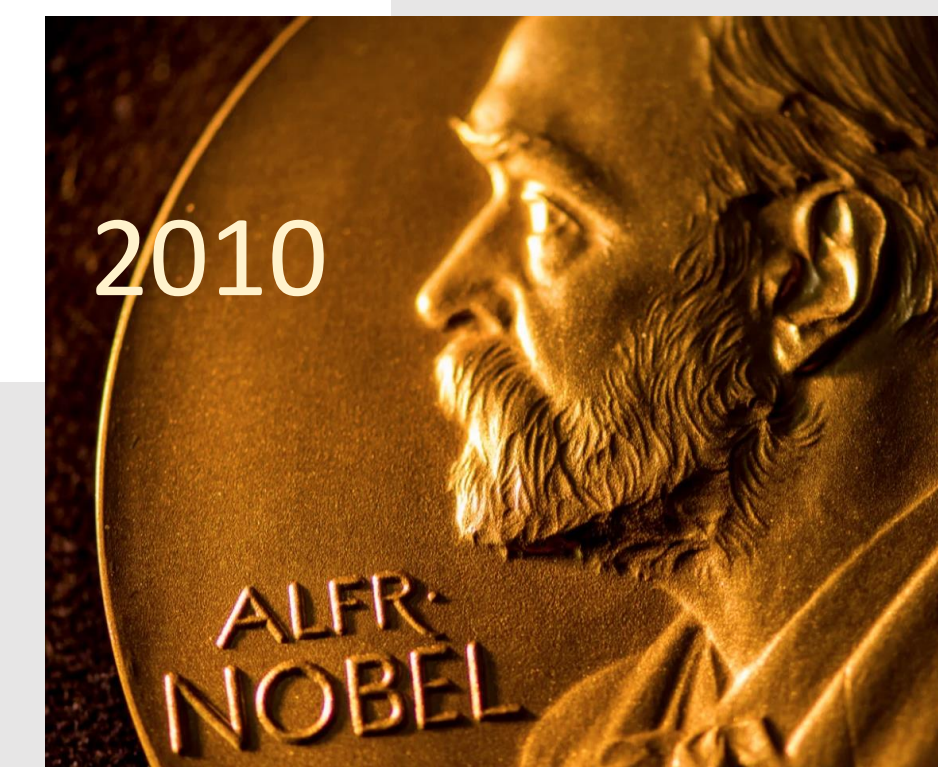
Debelina grafena: 1 atom ogljika

Material	Natezna trdnost
Jeklo (A36)	400 MPa
Kevlar	375 MPa
Grafen	130 GPa

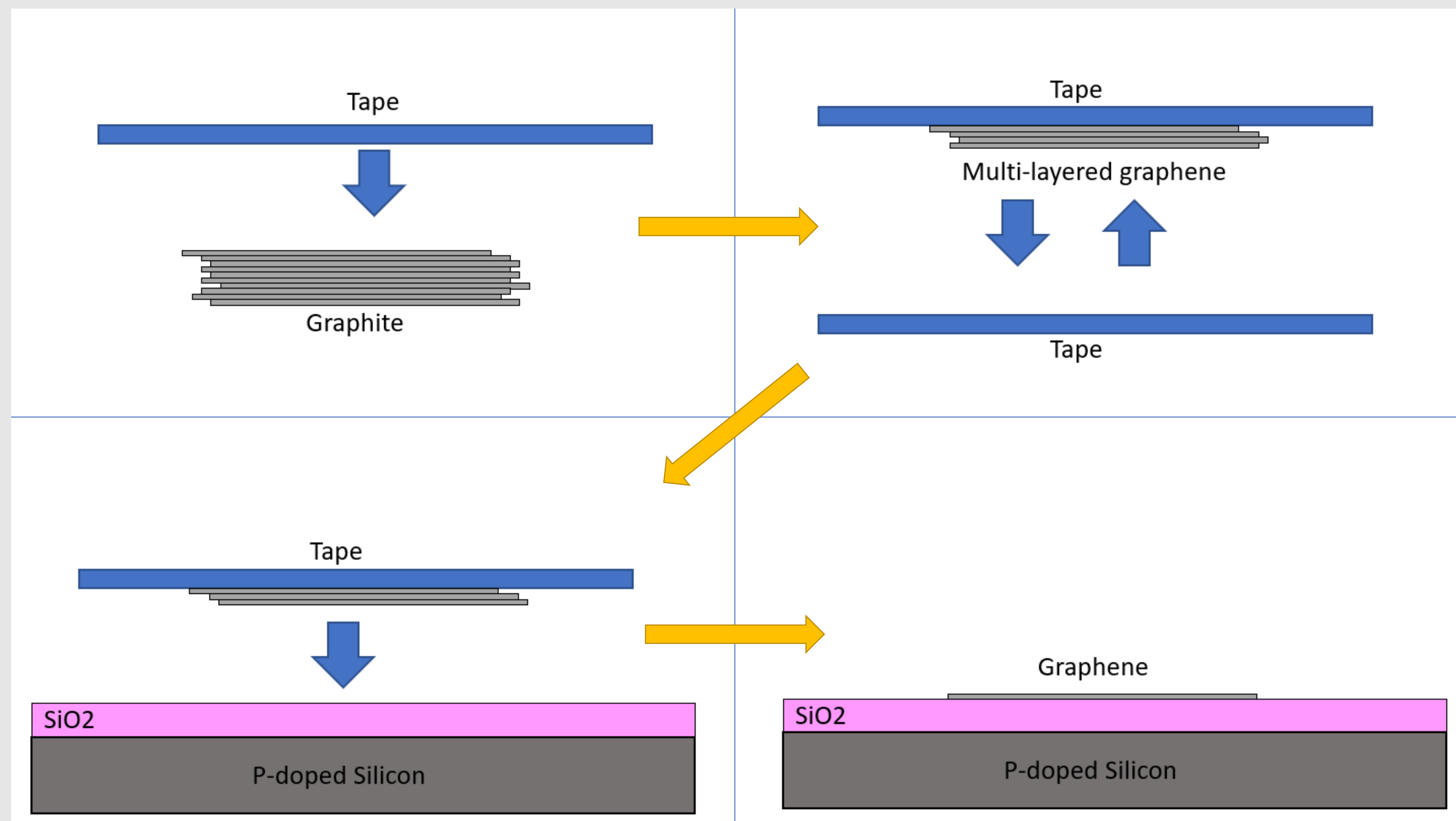
Giblivosť elektronov: $200.000 \text{ cm}^2/\text{Vs}$



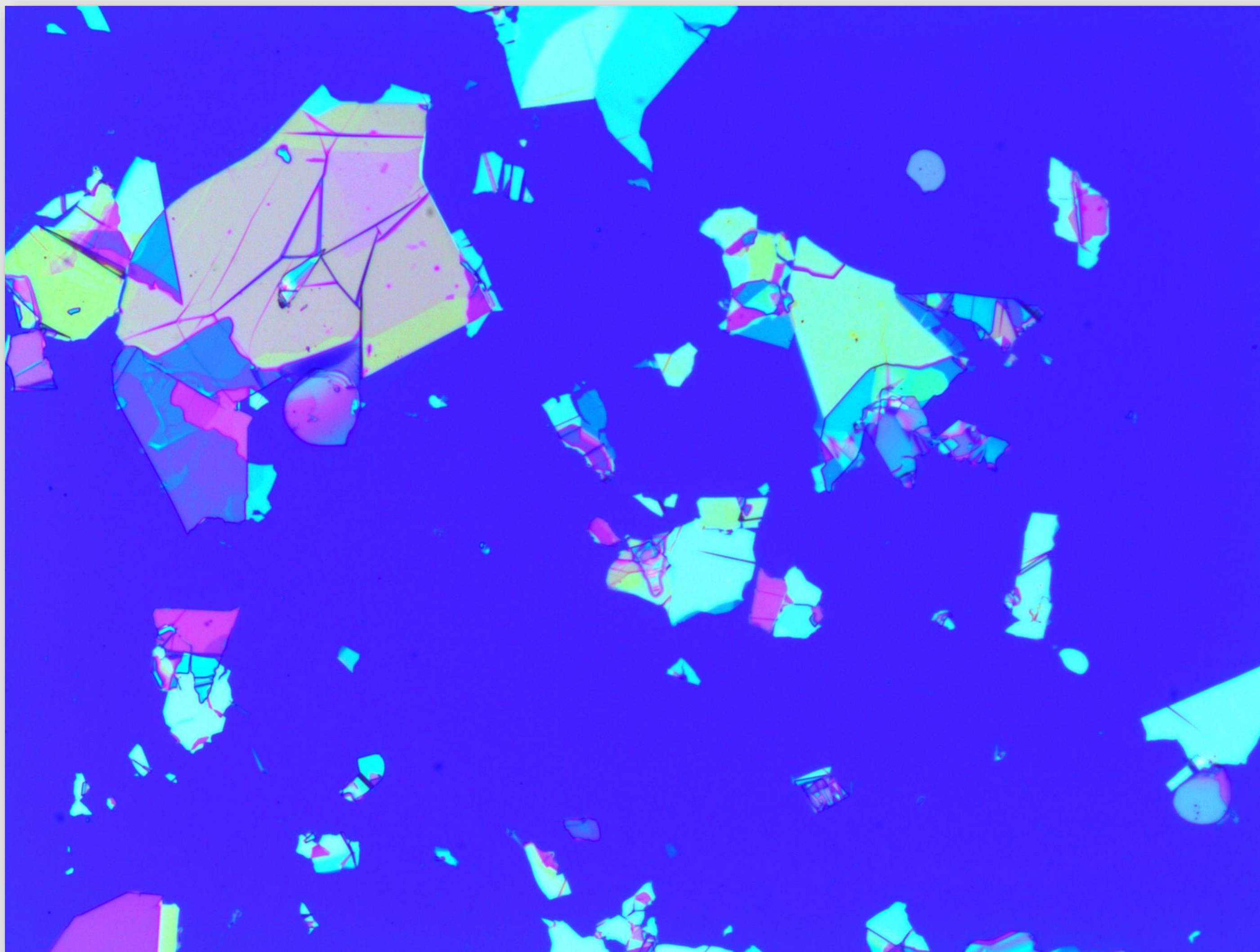
Novoselov, K.S., A. K. Geim, S. V. Morozov, D. Jiang, Y. Zhang, S. V. Dubonos, et al., *Electric Field Effect in Atomically Thin Carbon Films*. Science, 2004.



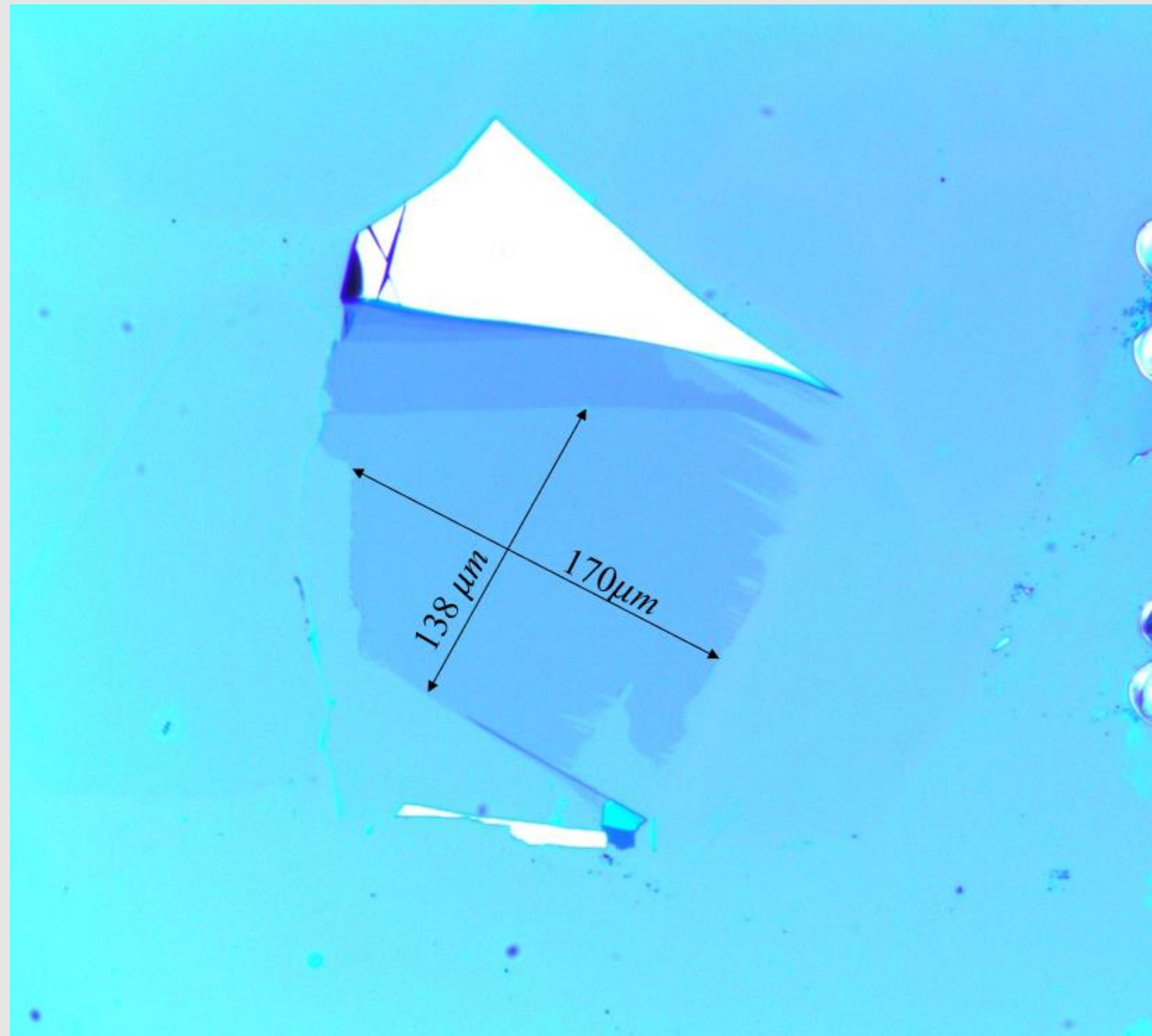
Izolacija grafena z luščanjem grafita



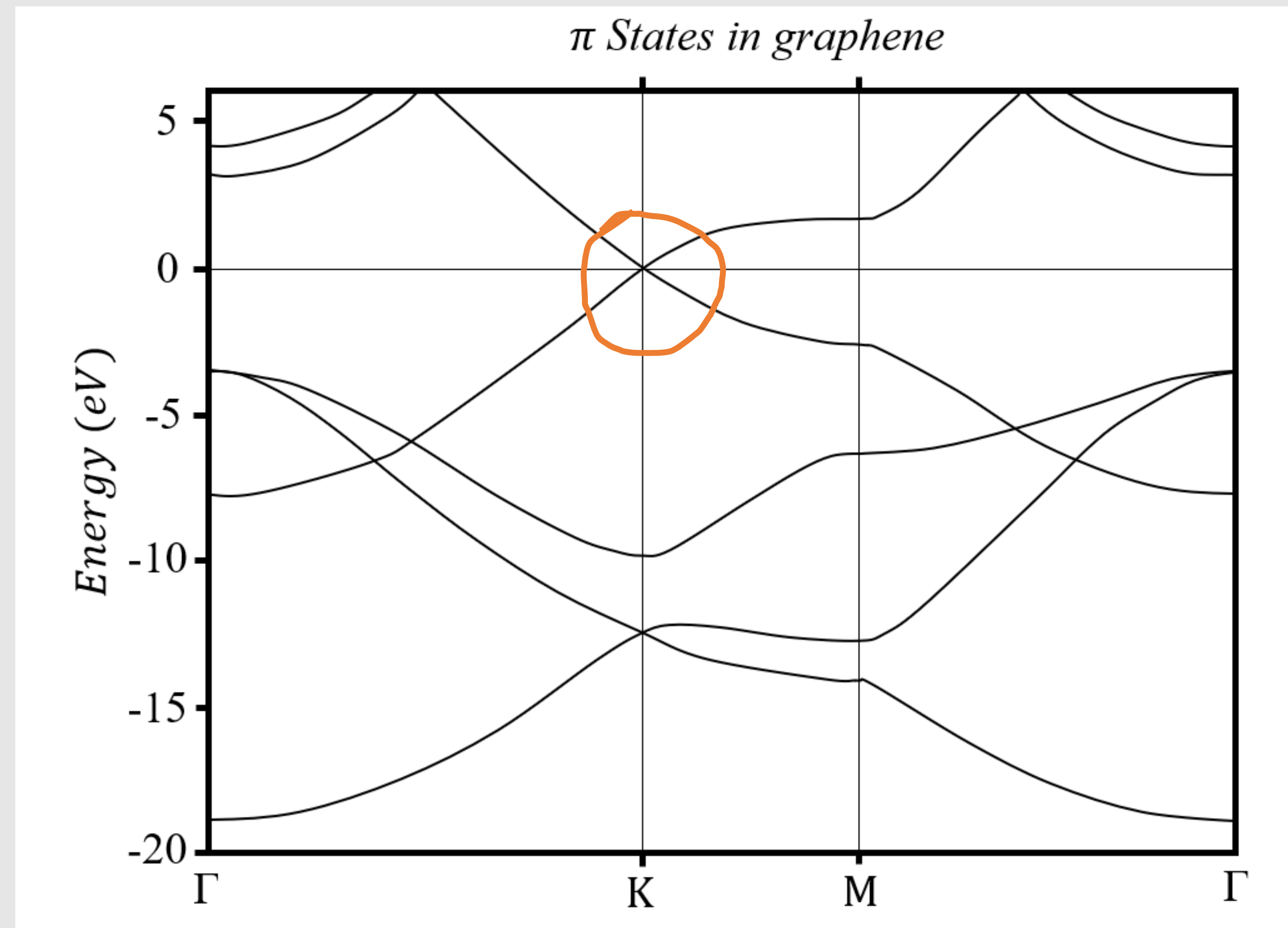
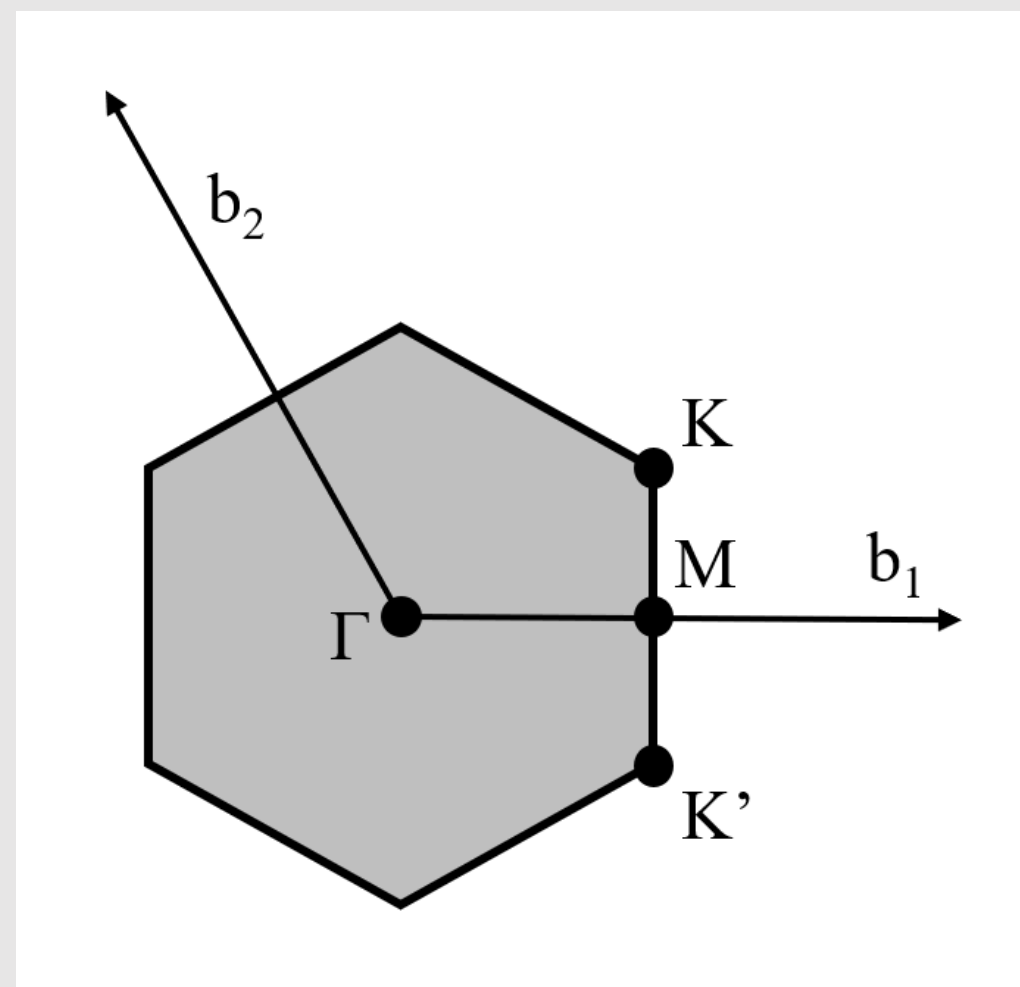
Večslojni grafen na podlogi SiO₂



Listič enoslojnega grafena pod optičnim mikroskopom

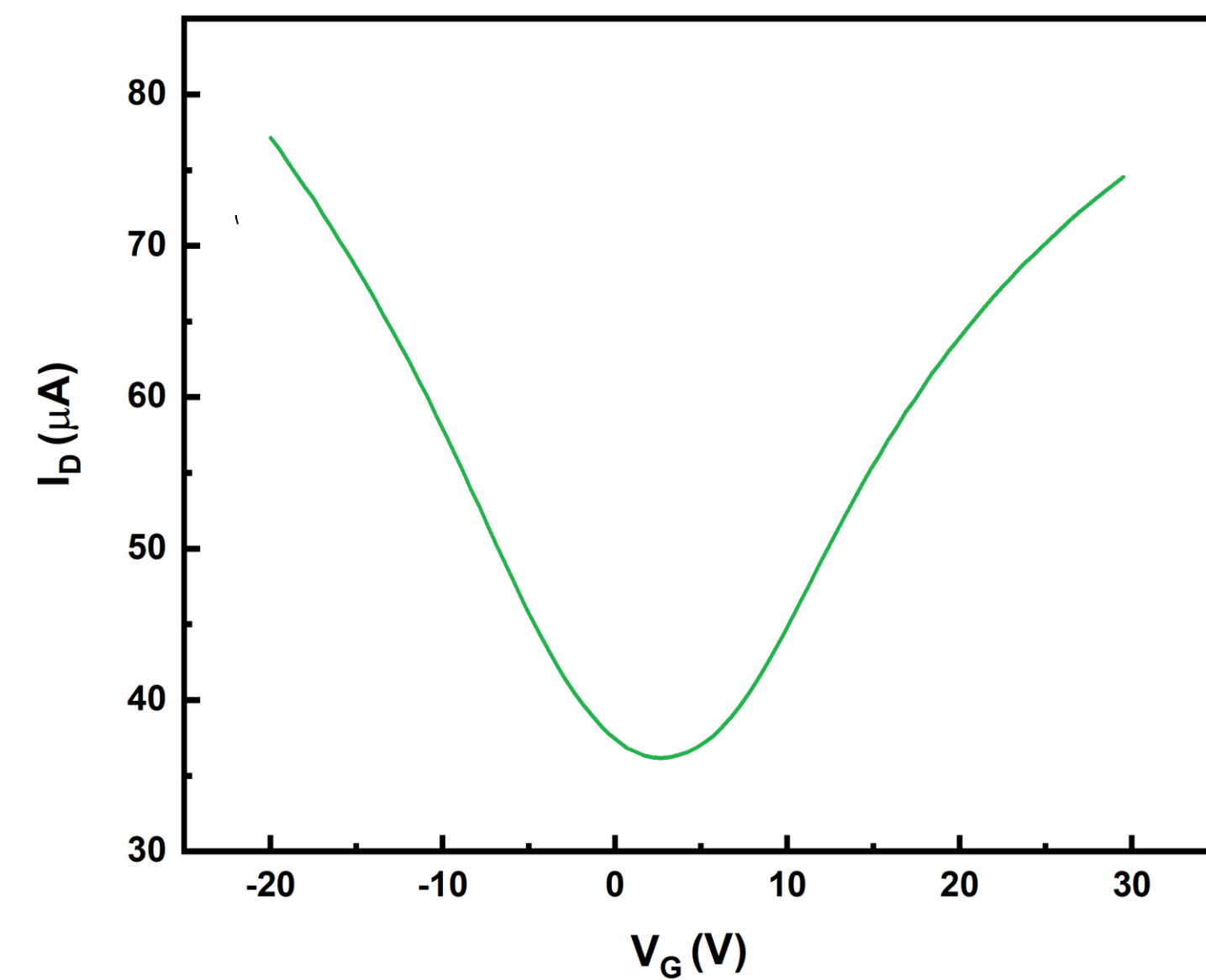
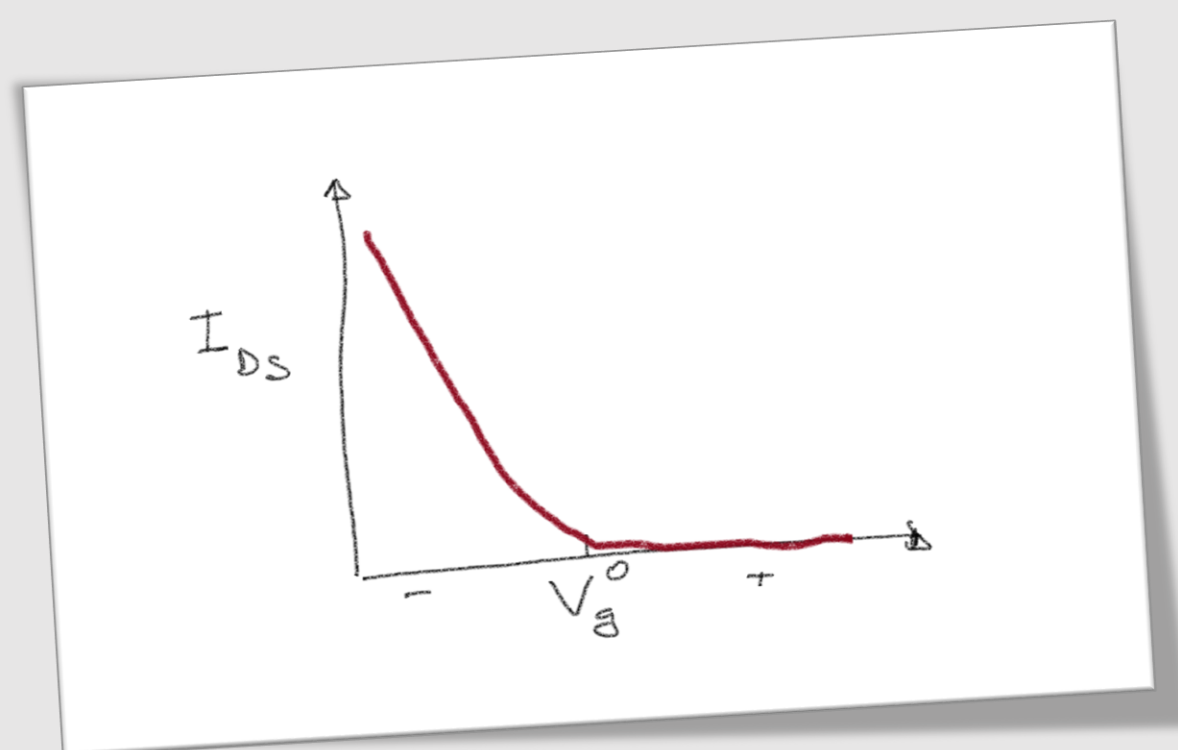
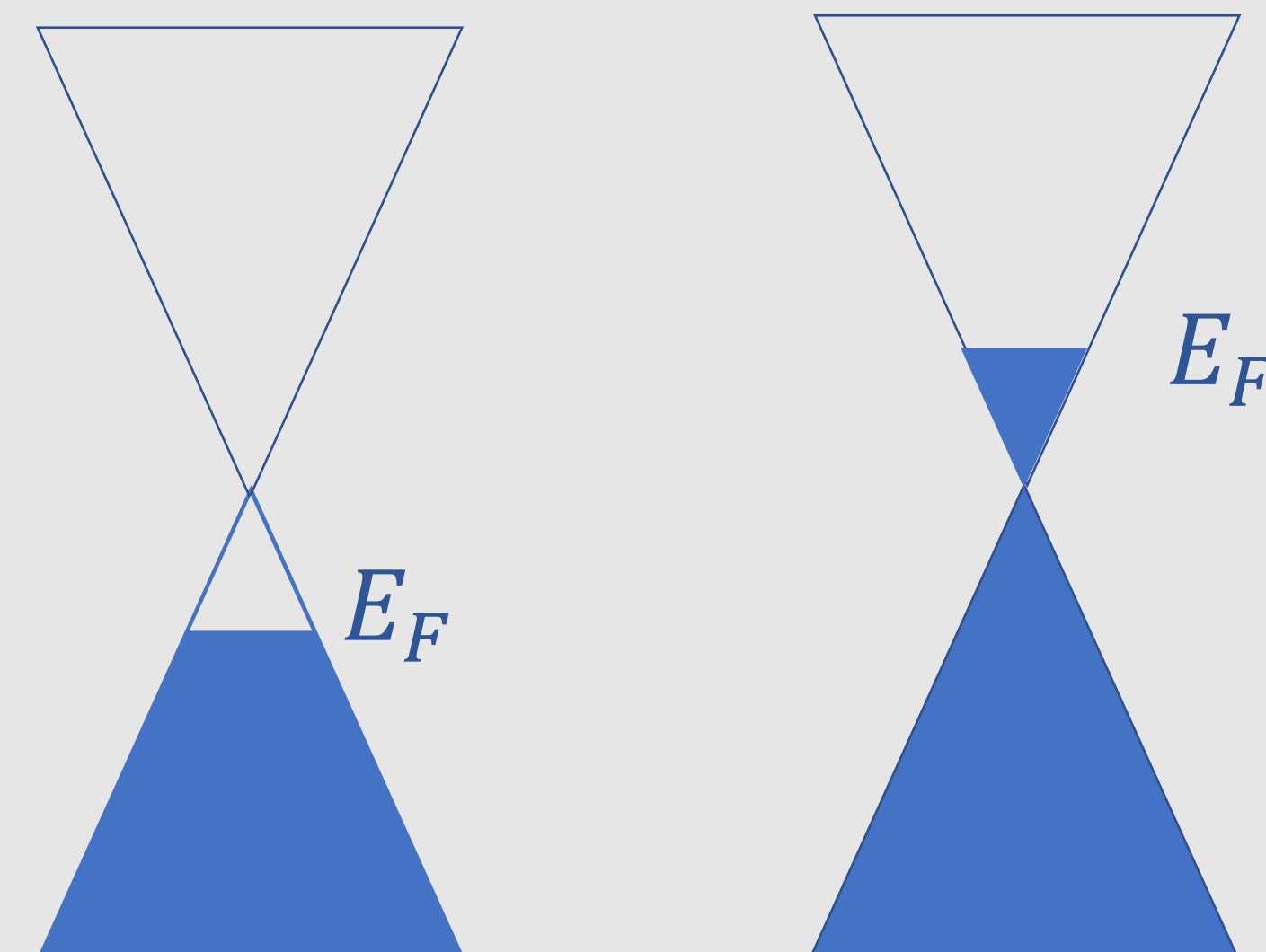
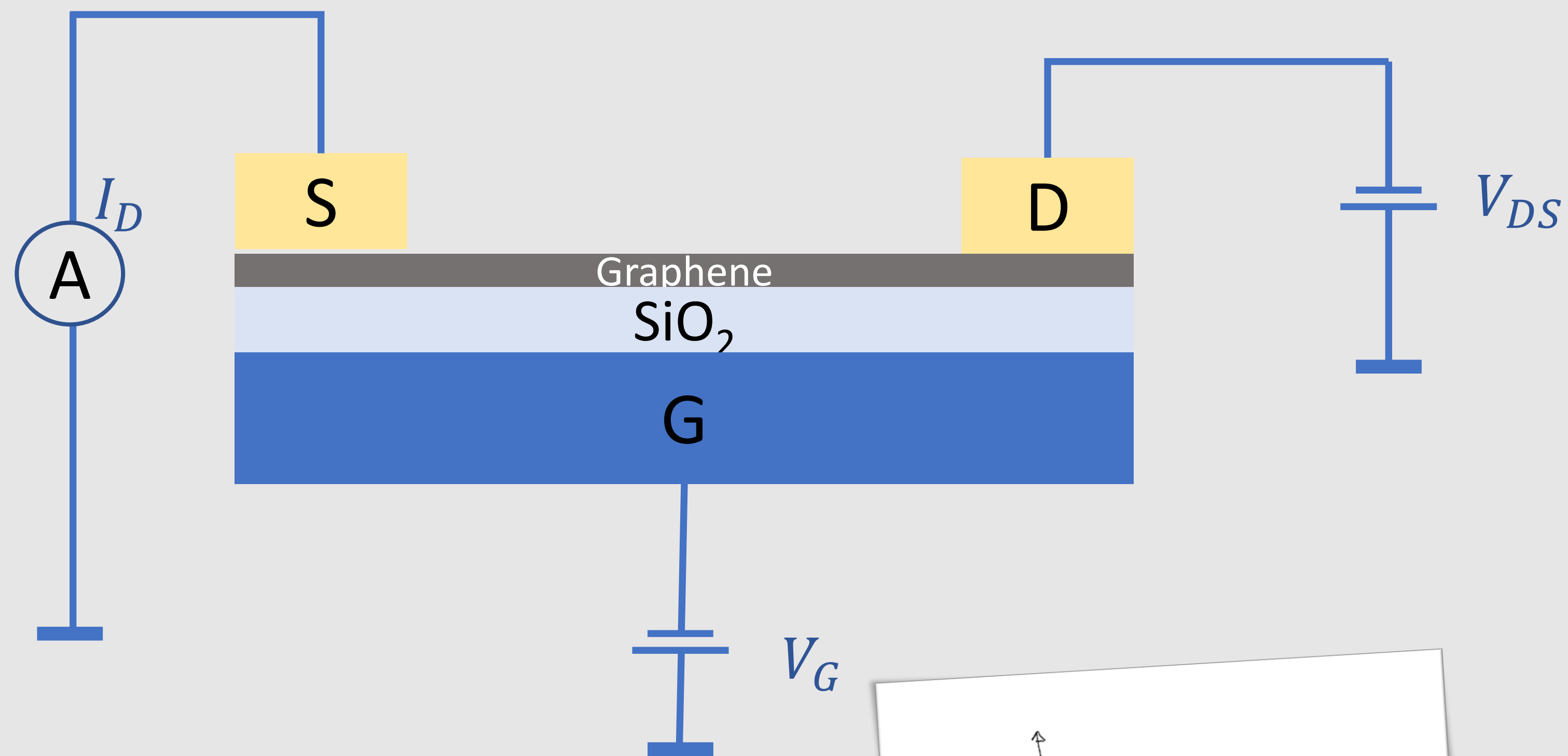


Elektronska energijska pasovna struktura grafena



D. Boukhvalov, M. Katsnelson, and A. Lichtenstein, Physical Review B 77, 035427 (2008)

Grafenski tranzistor



Organski polprevodniki in grafen: idealen par?

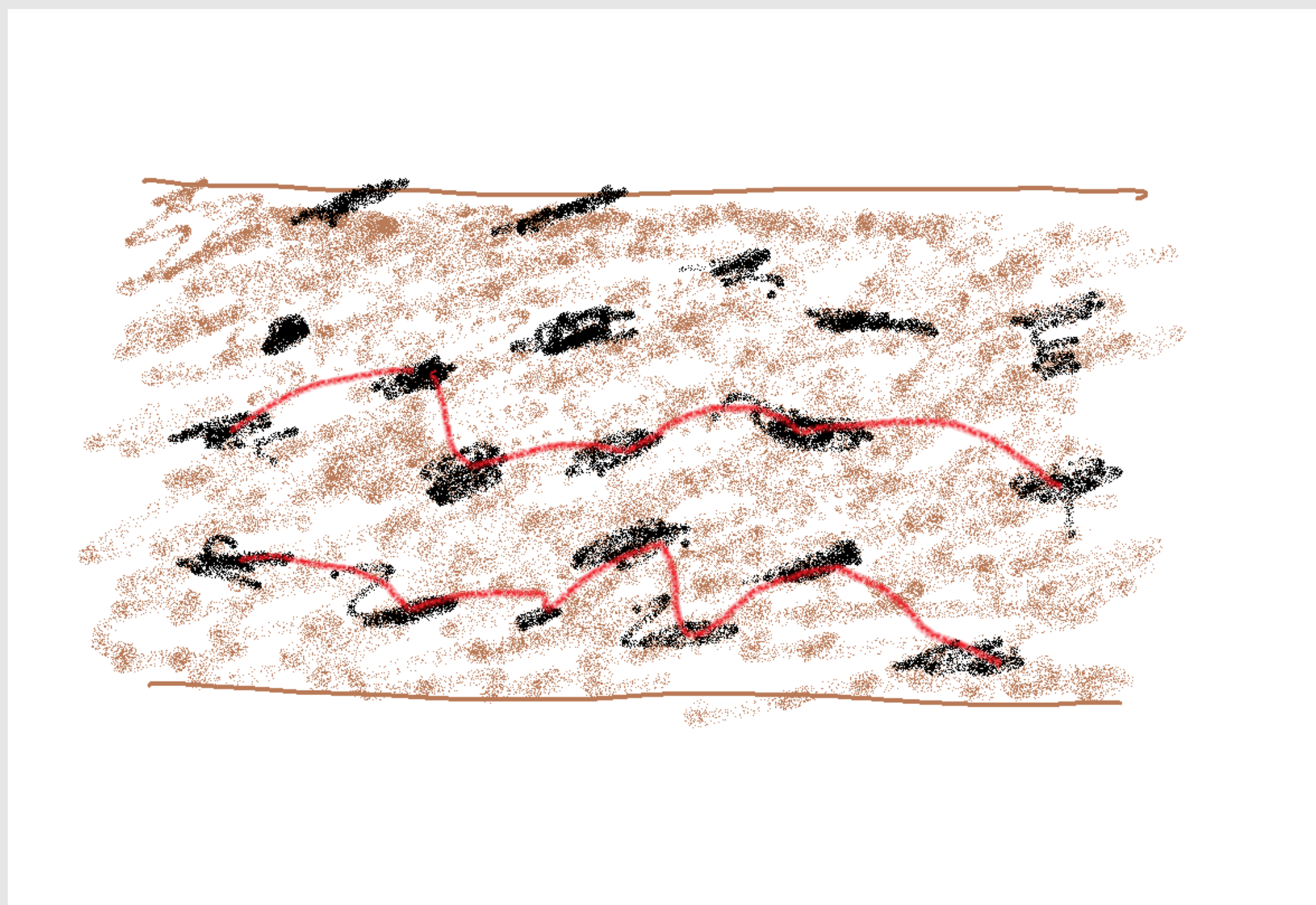
- Grafen

- Visoka gibljivost elektronov
- *Odsotnost energijske špranje*

- Organski polprevodniki

- *Nizka gibljivost elektronov*
- Energijska špranja prisotna

Mešanica OP + grafen



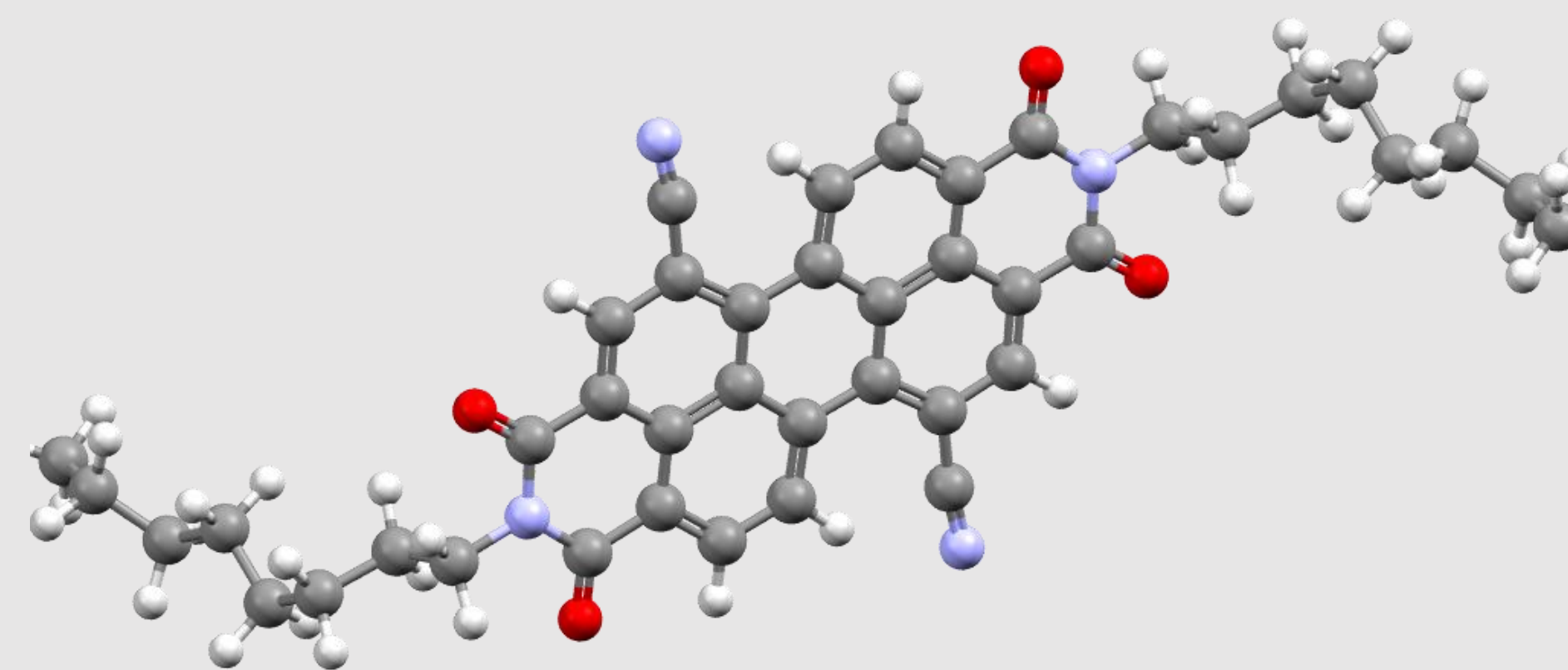
- Priprava tankega sloja ($0,01\mu\text{m}$) iz raztopine
 - Disperzija organskih molekul in grafenskih lističev
- Grafenski lističi: hitra avtocesta za elektrone

Izboljšanje gibljivosti nosilcev naboja v organskih polprevodnikih z grafenom

THE JOURNAL OF
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Article

pubs.acs.org/JPCC



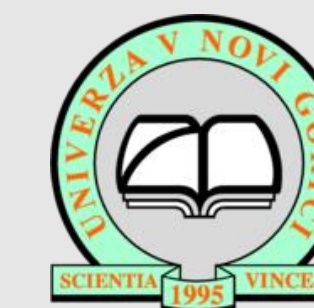
Graphene-Induced Enhancement of n-Type Mobility in Perylenediimide Thin Films

Srinivasa Rao Pathipati,[†] Egon Pavlica,[†] Andrea Schlierf,[‡] Mirella El Gemayel,[§] Paolo Samorì,[§] Vincenzo Palermo,[‡] and Gvido Bratina^{*,†}

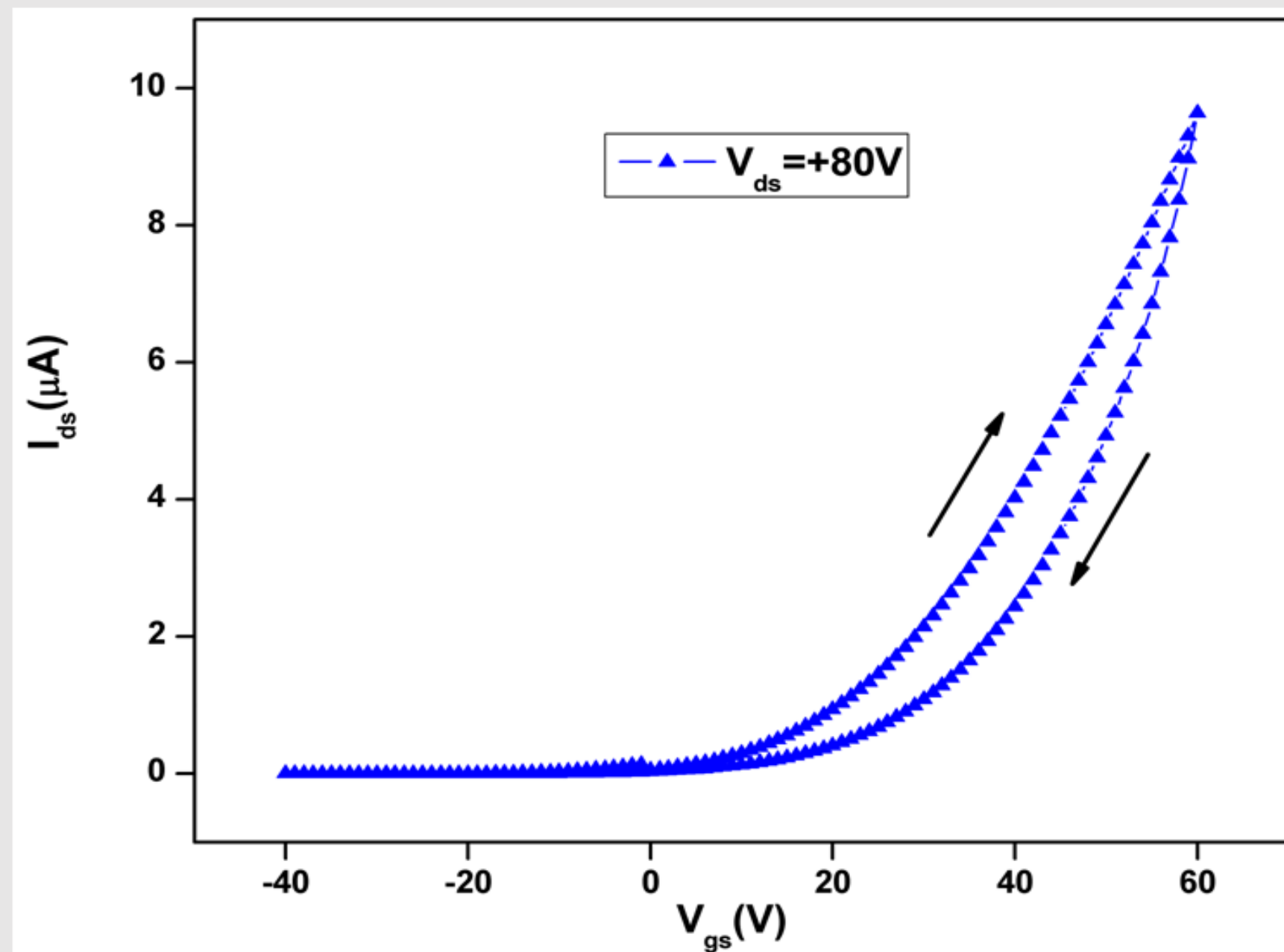
[†]Laboratory of Organic Matter Physics, University of Nova Gorica, Vipavska 13, SI-5000 Nova Gorica, Slovenia

[‡]Istituto per la Sintesi Organica e la Fotoreattività, Consiglio Nazionale delle Ricerche (ISOF-CNR), via Gobetti 101, 40129 Bologna, Italy

[§]Nanochemistry Laboratory, Institut de Science et d'Ingénierie Supramoléculaires (ISIS) and International Center for Frontier Research in Chemistry (icFRC), Université de Strasbourg, Centre National de la Recherche Scientifique (CNRS), 8 allée Gaspard Monge, 67000 Strasbourg, France



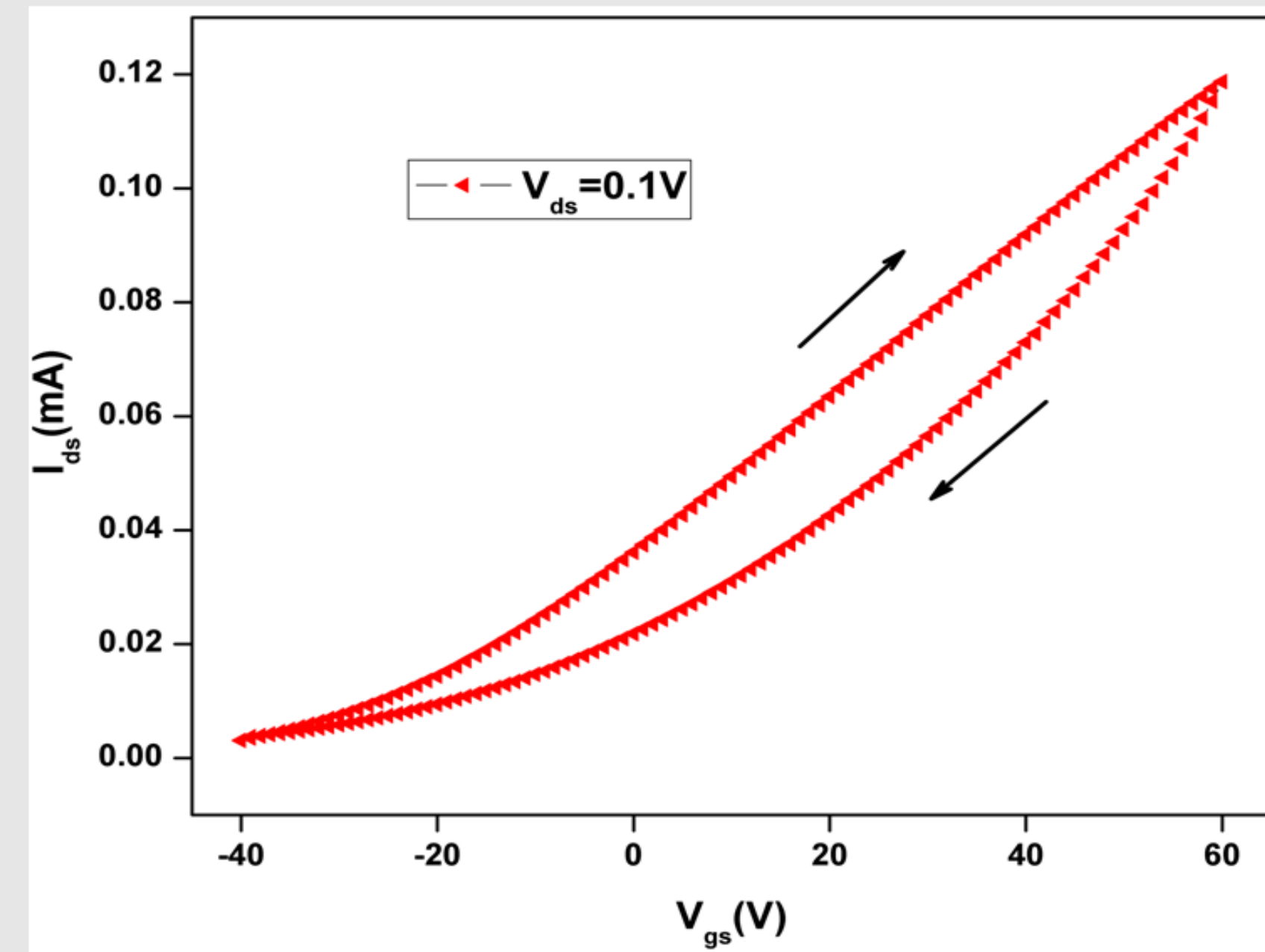
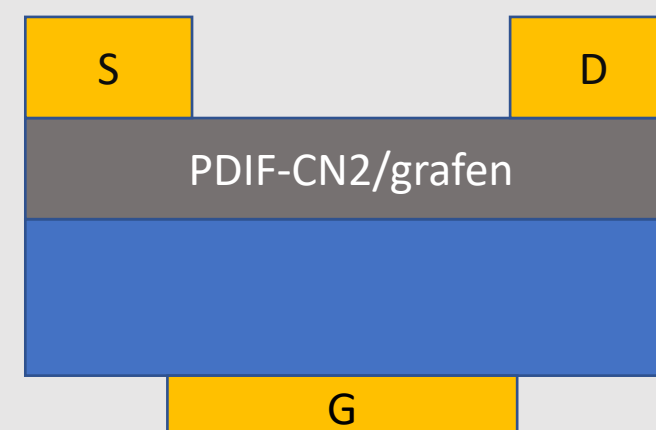
Prenosna karakteristika tankoslojnih tranzistorjev



Čist sloj PDI8

$$\mu = 1 \times 10^{-4} \text{ cm}^2/\text{Vs}$$

$$I_{on}/I_{off} = 10^5$$



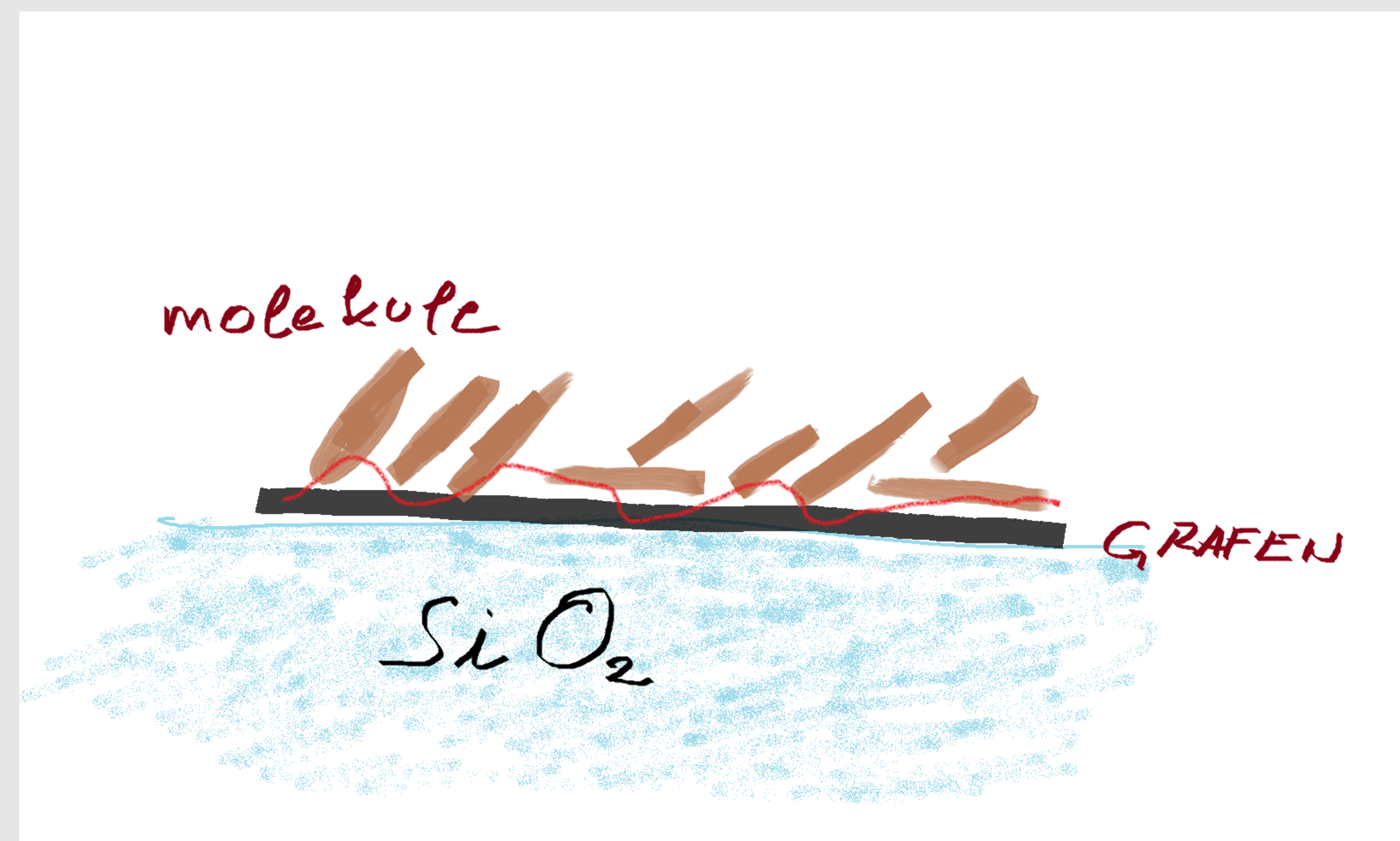
Mešanica PDI8/grafen

$$\mu = 6 \text{ cm}^2/\text{Vs}$$

$$I_{on}/I_{off} = 10^2$$

Namesto mešanice dva sloja

- Grafen na SiO_2
- PDI8-CN2 na grafenu
- Vakuumsko naparevanje
- Pomembna vloga orientacije molekul na površini.



Orientacija organskih molekul na površini grafena učinkuje na transportne lastnosti tranzistorjev

Organic Electronics 87 (2020) 105933



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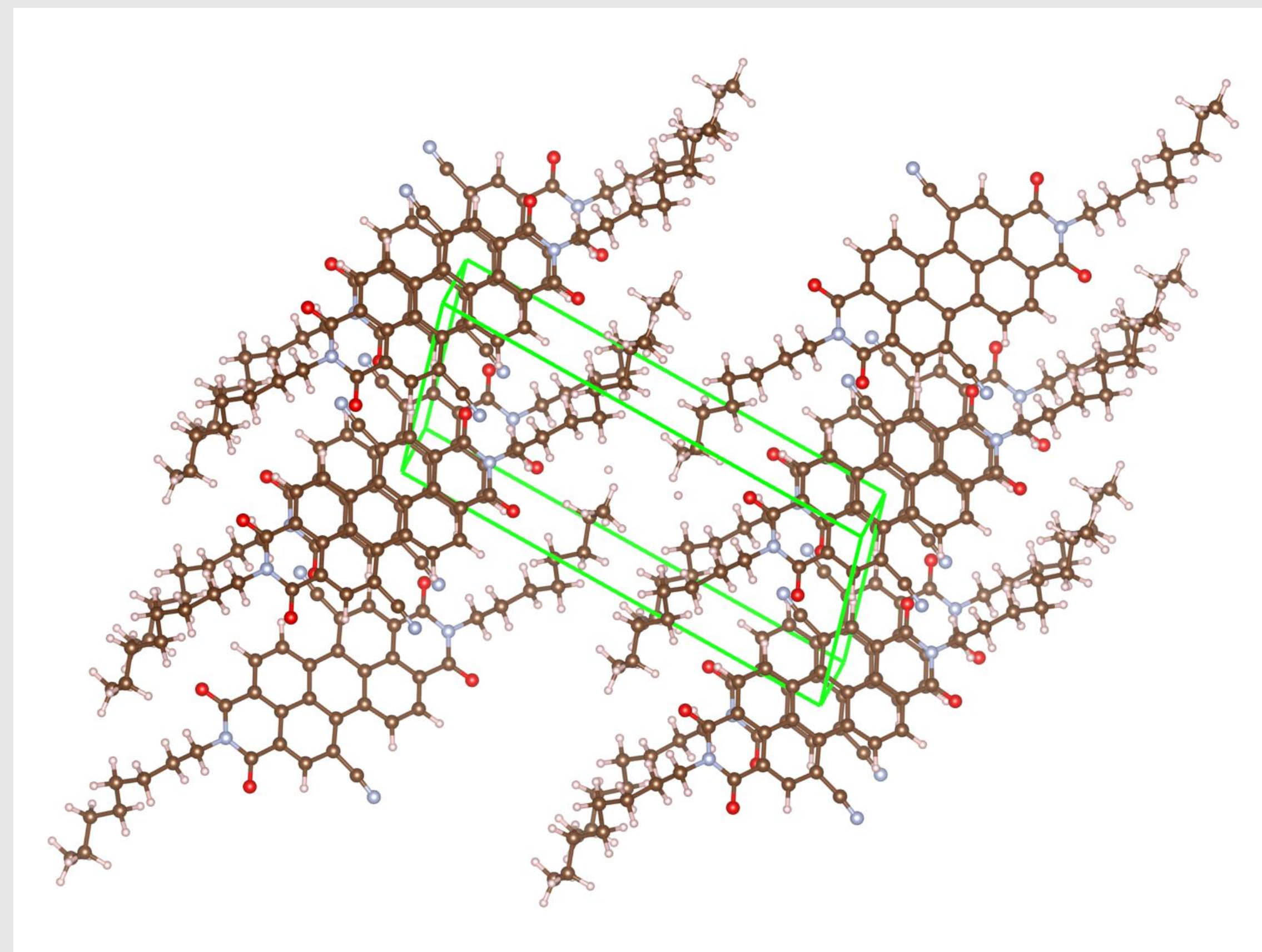
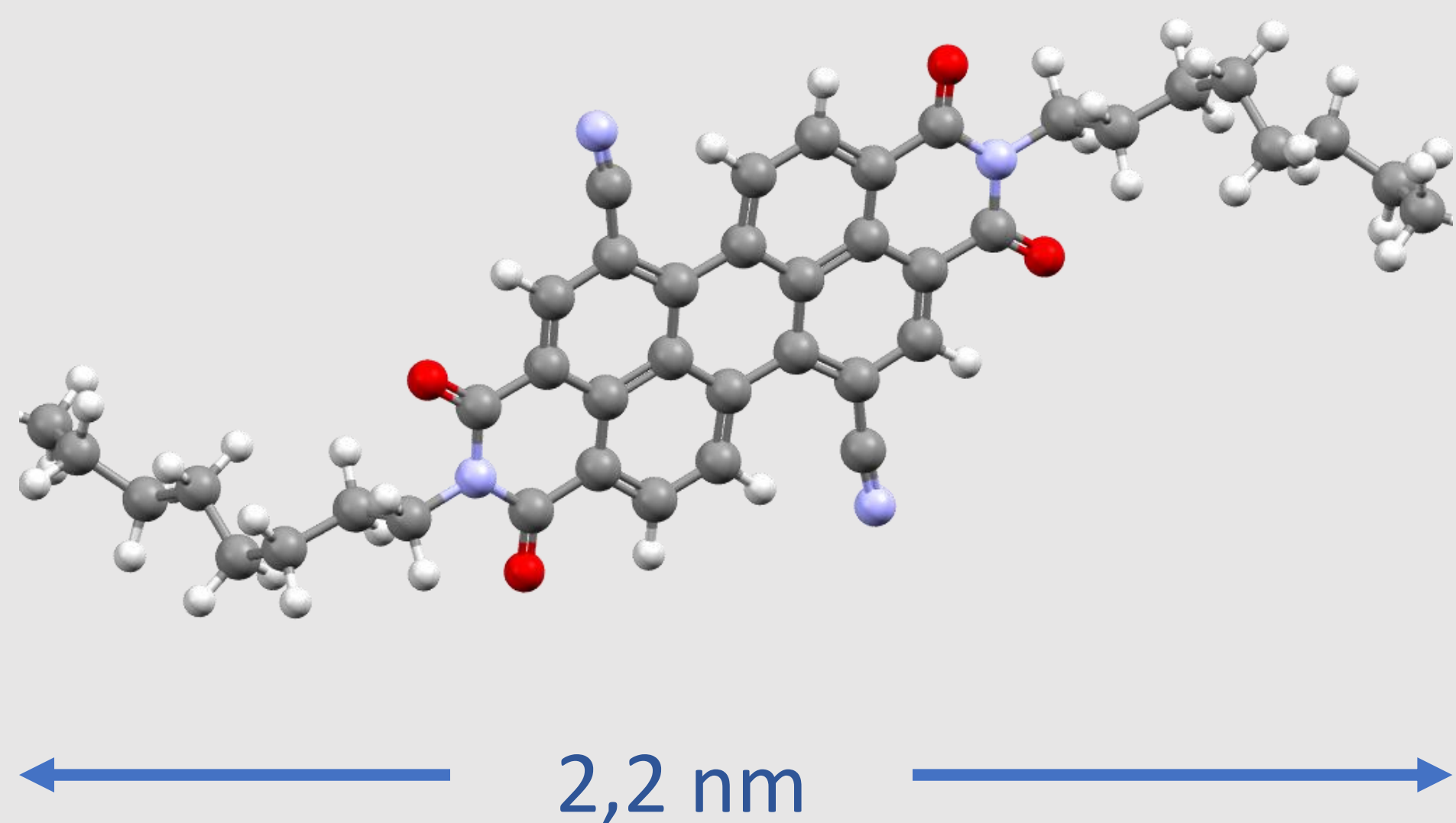
Molecular alignment on graphene surface determines transport properties of graphene/organic semiconductor transistors

Vadym Tkachuk, Egon Pavlica, Gvido Bratina*

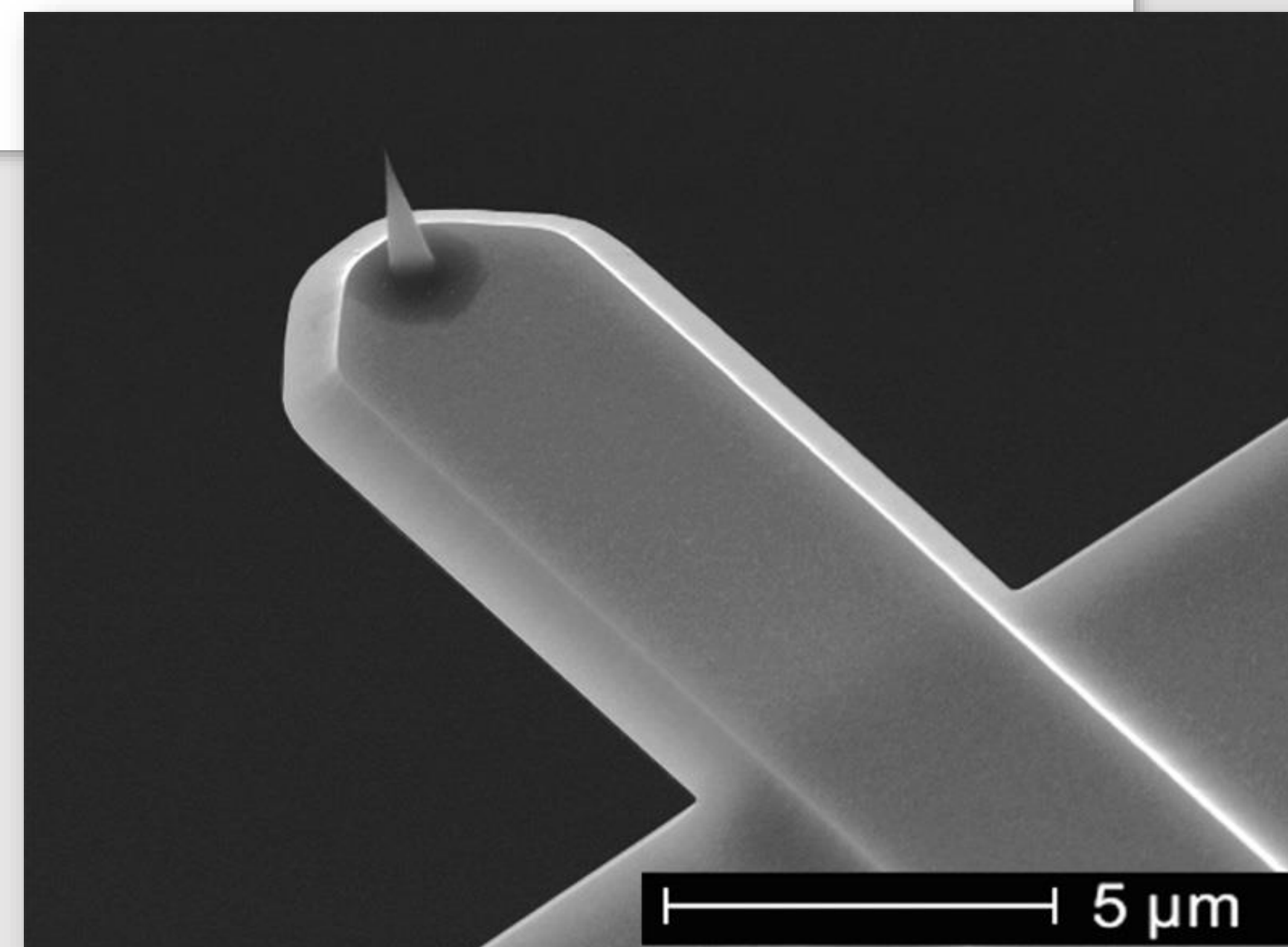
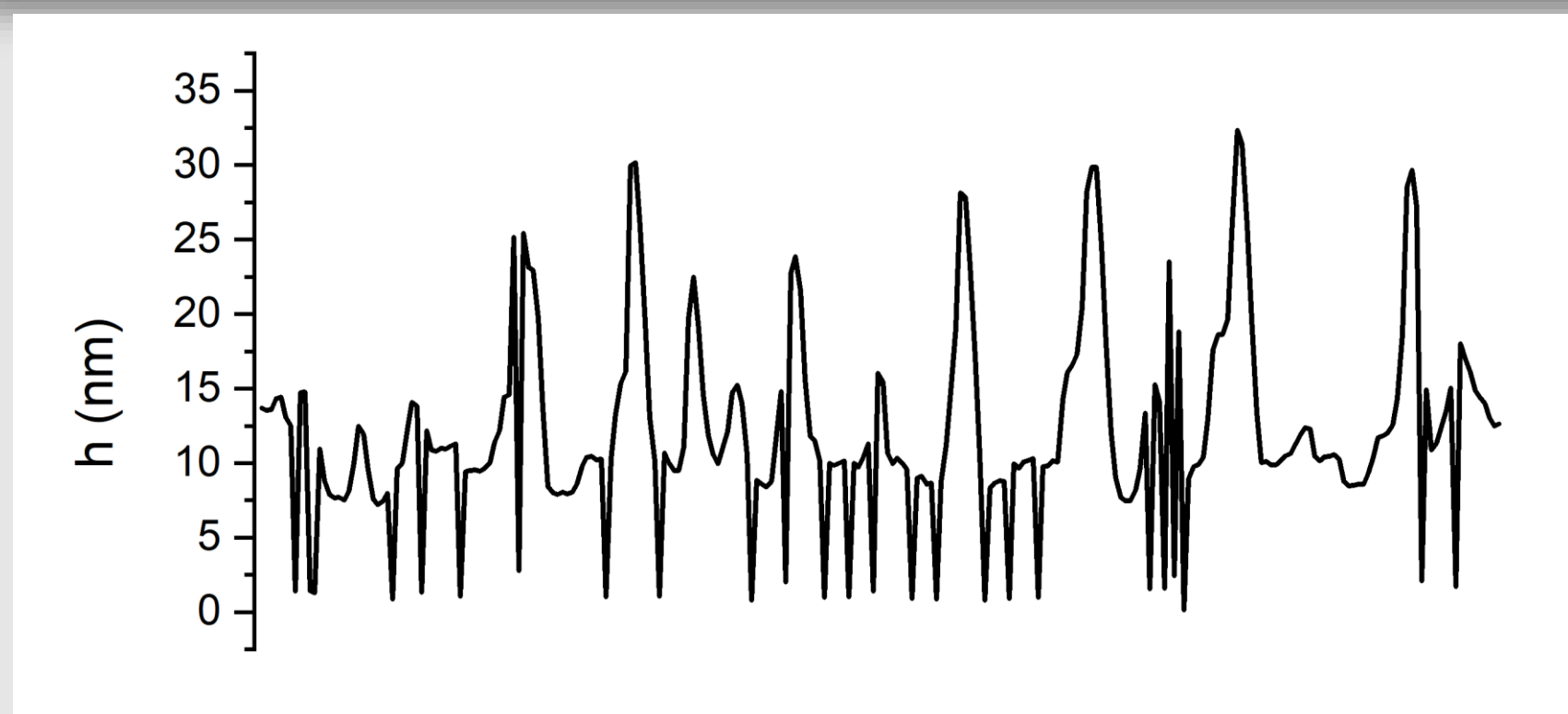
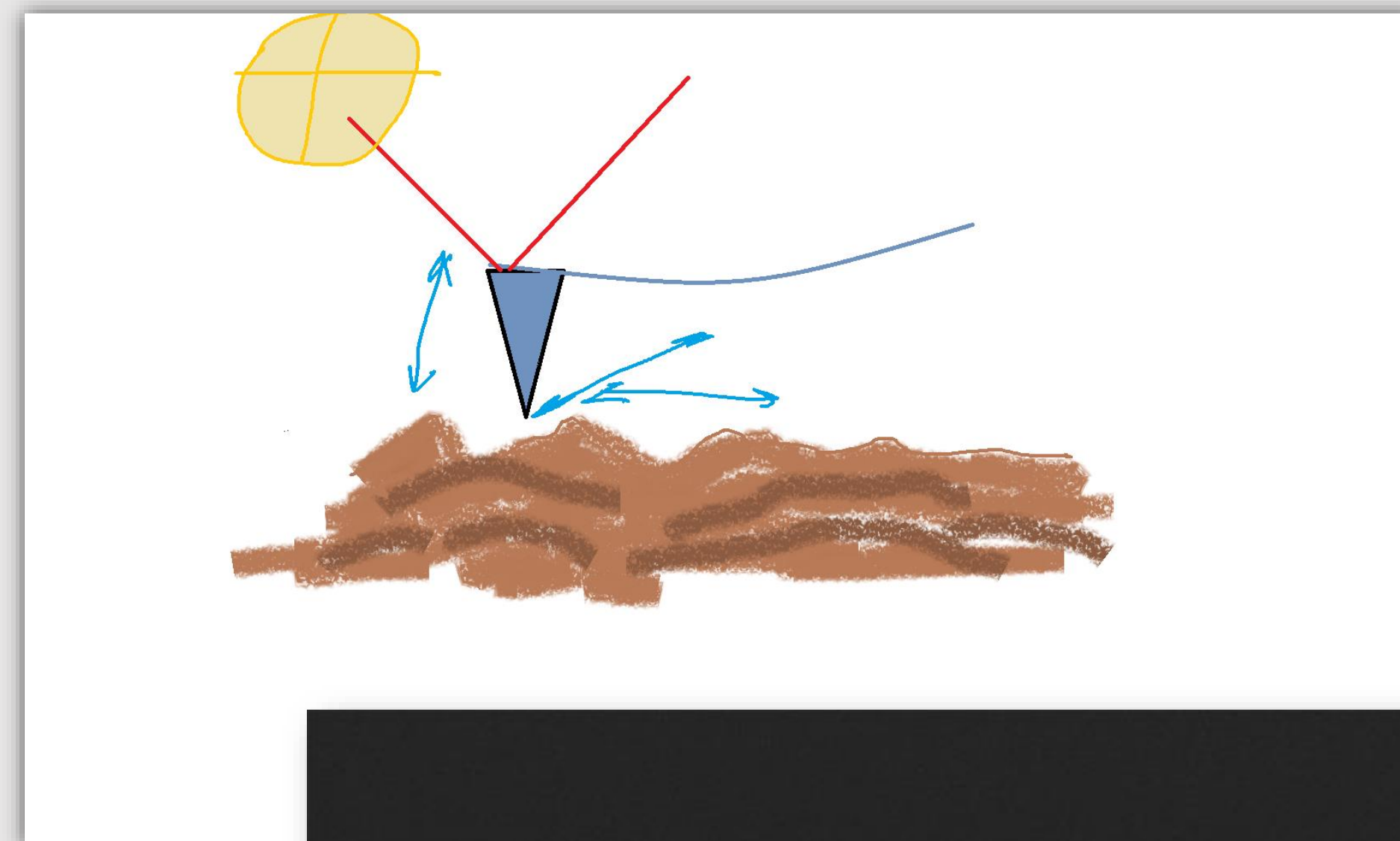
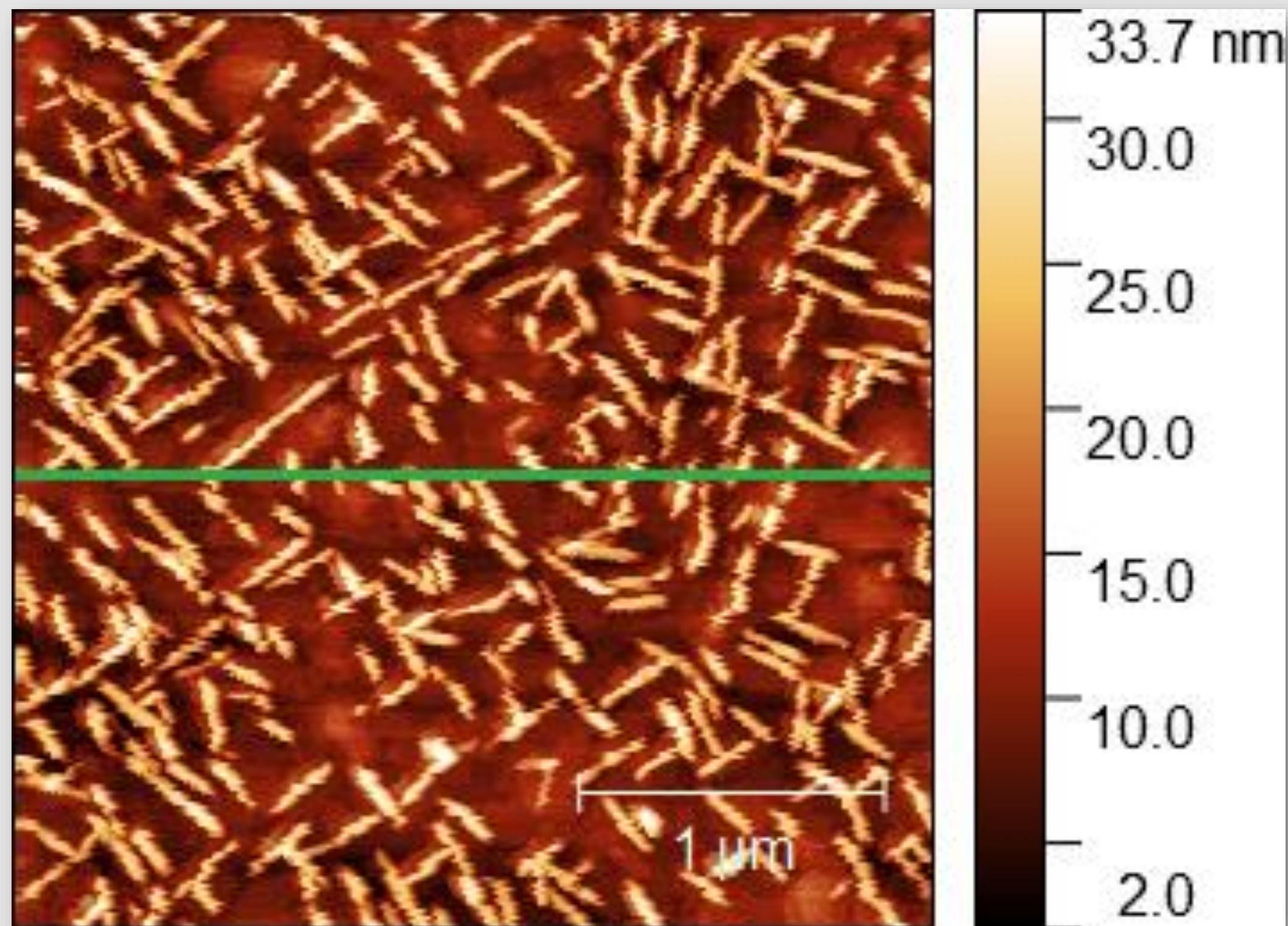
Laboratory for Organic Matter Physics, University of Nova Gorica, Vipavska 13, SI-5000, Nova Gorica, Slovenia



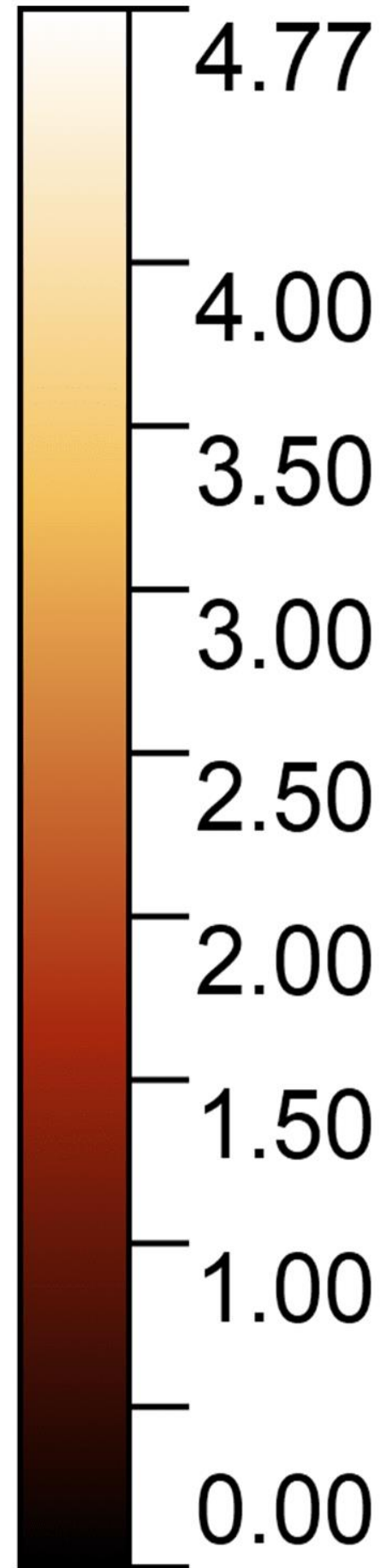
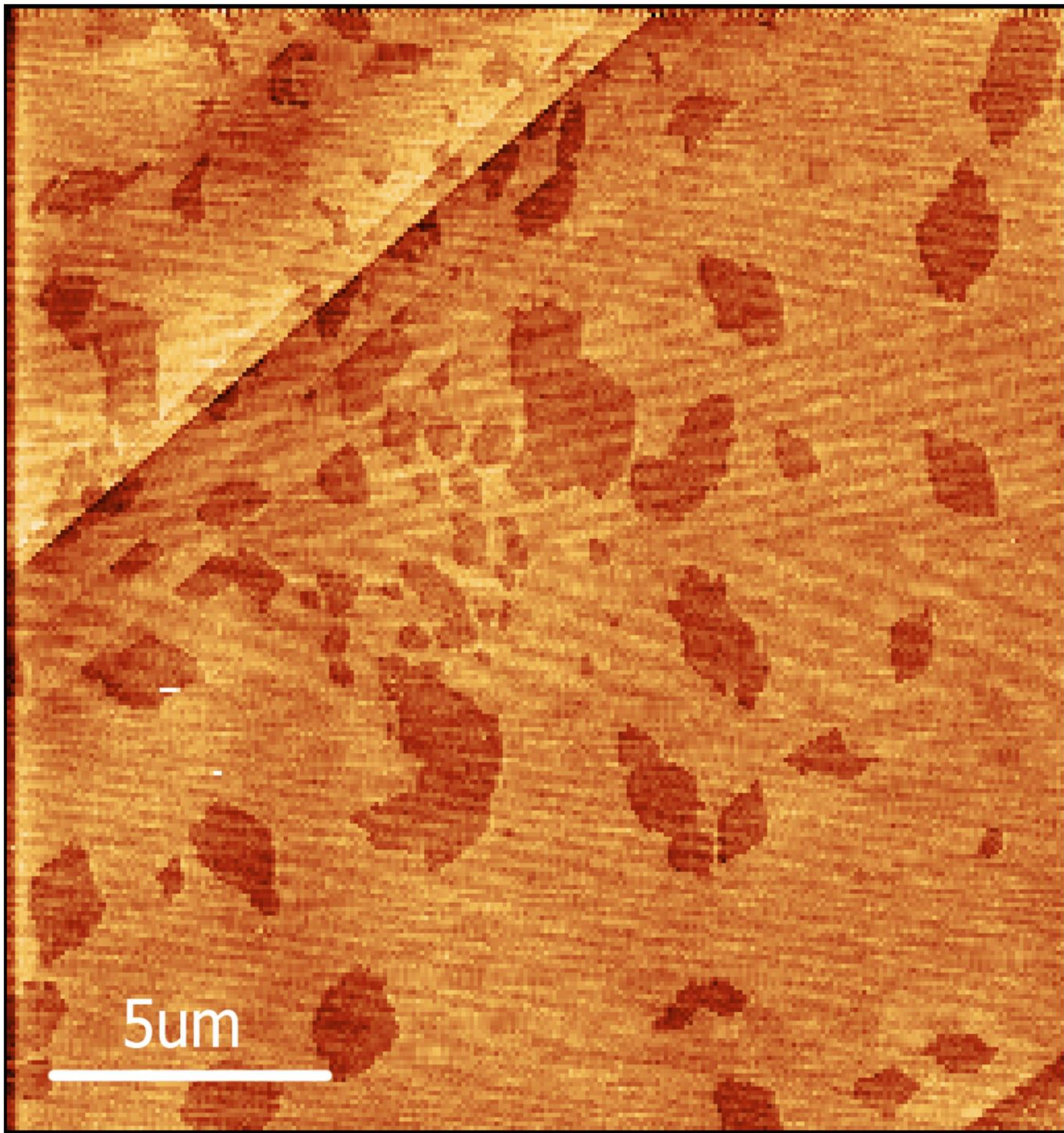
Molekula PDI8-CN2



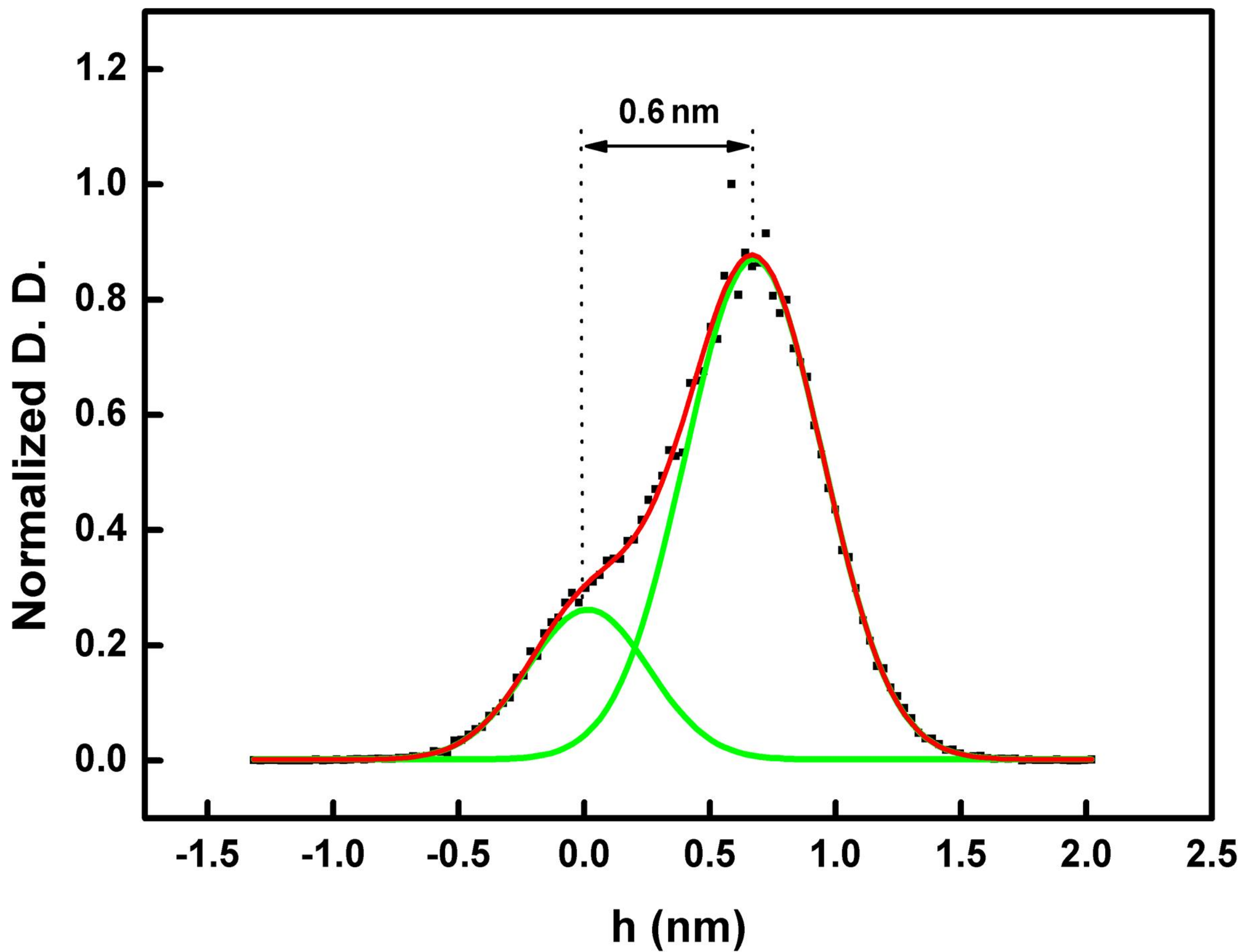
Površina z mikroskopom na atomsko silo



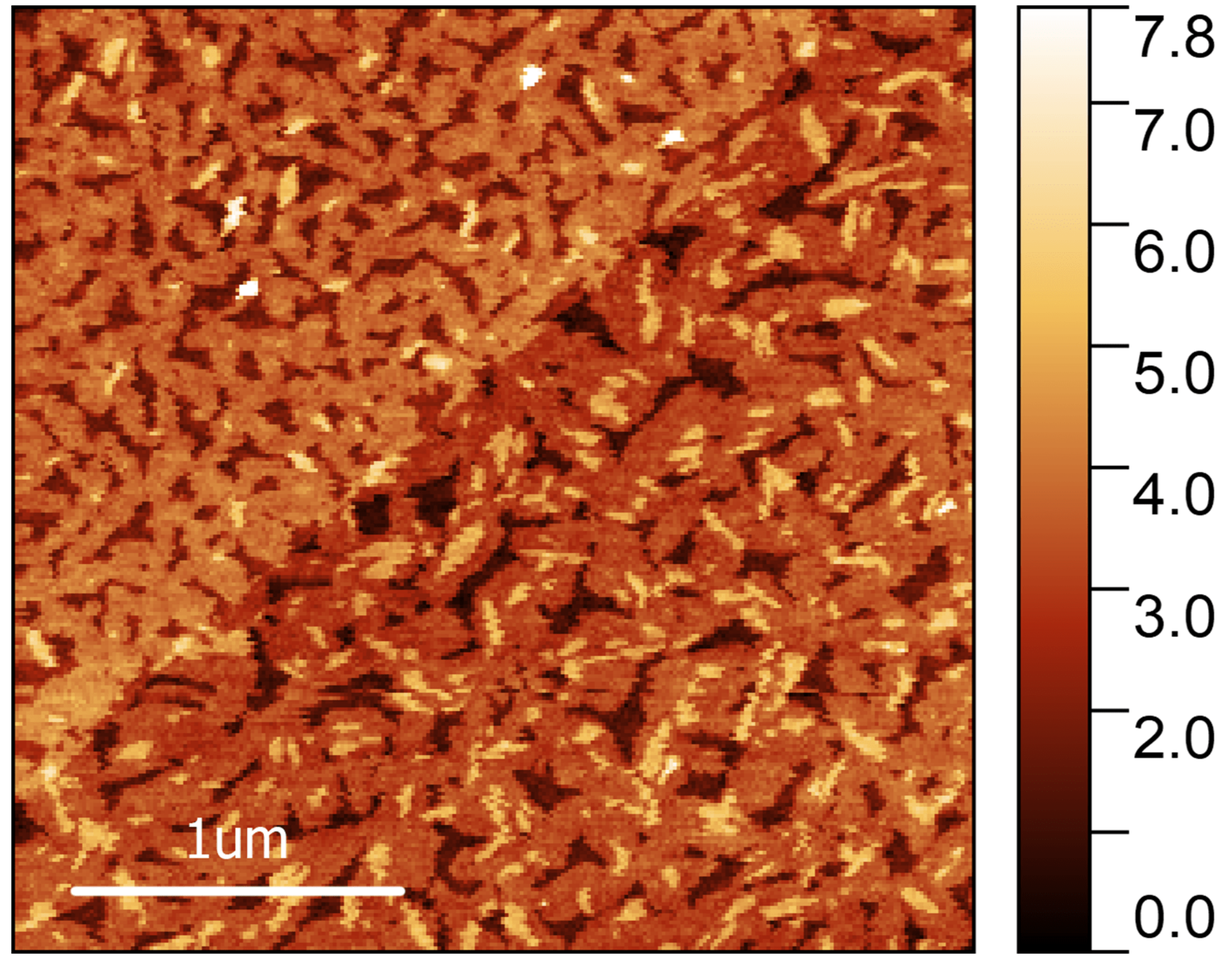
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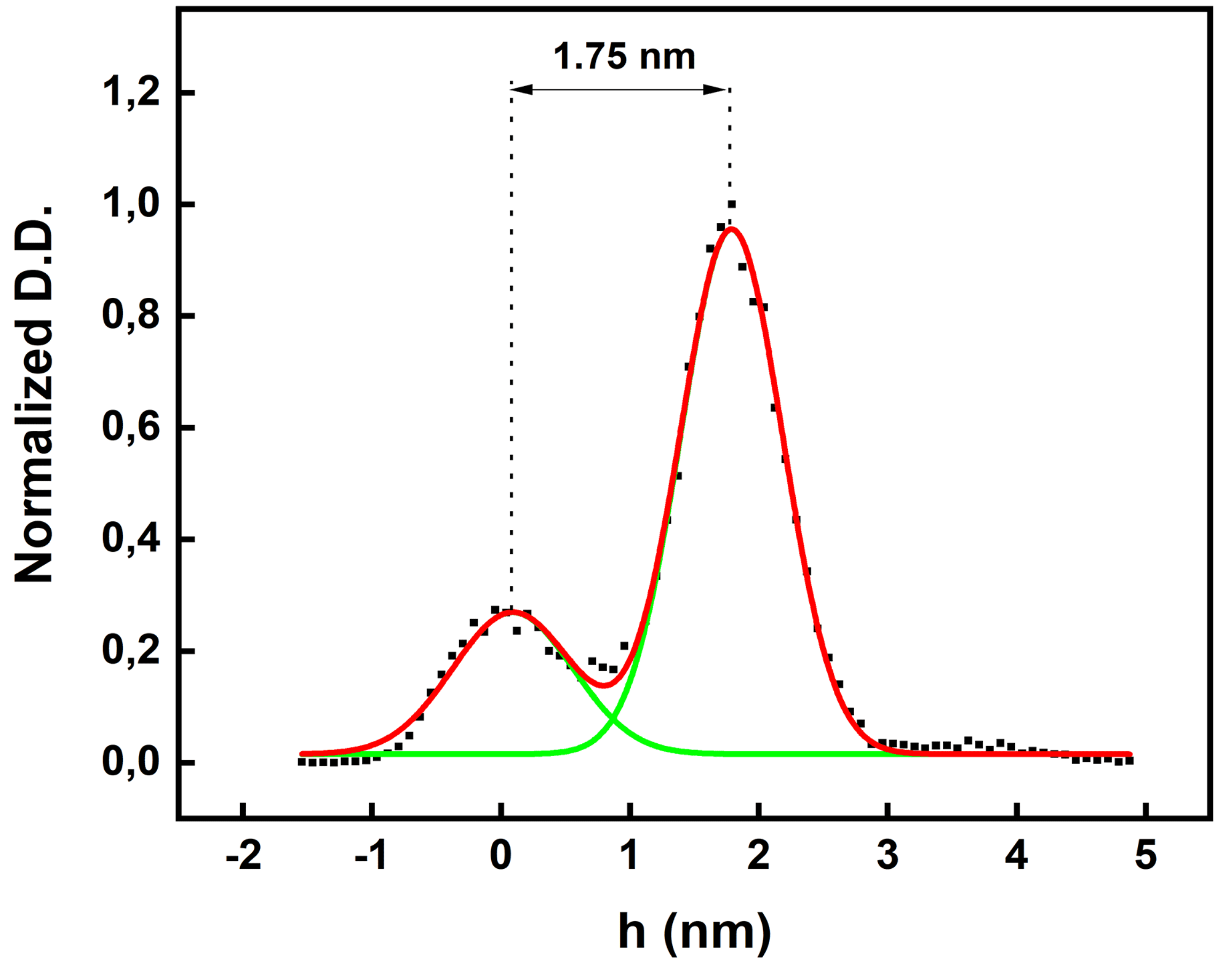
b)

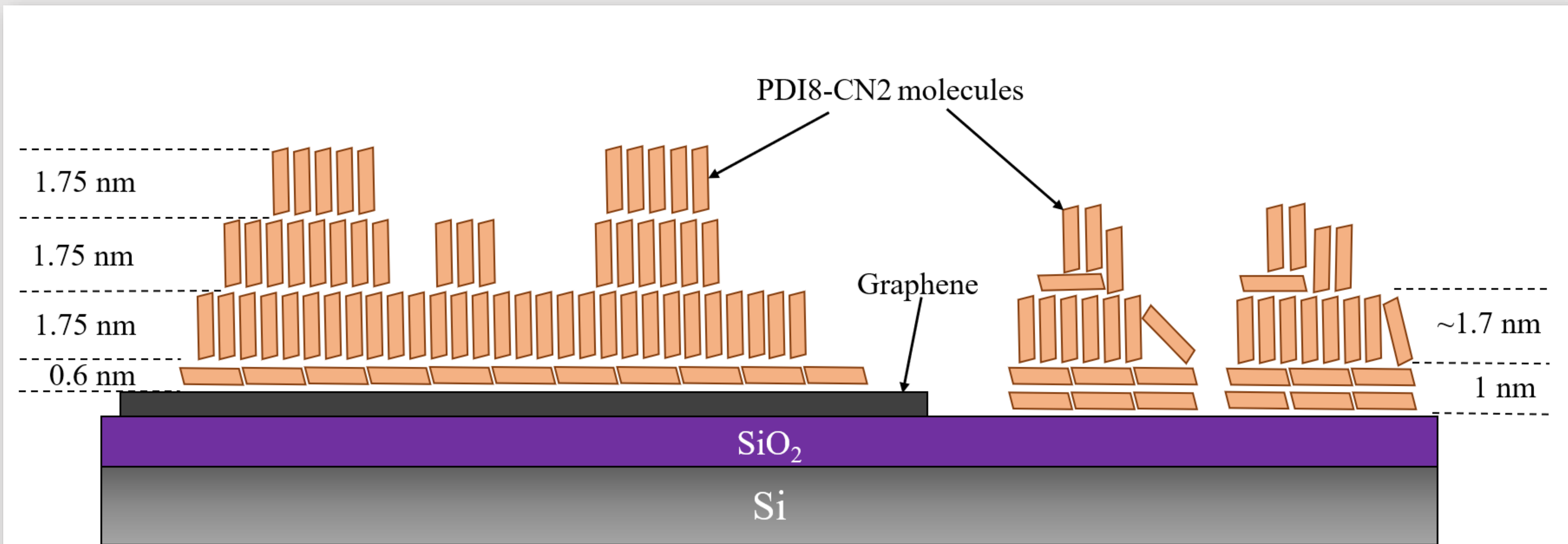
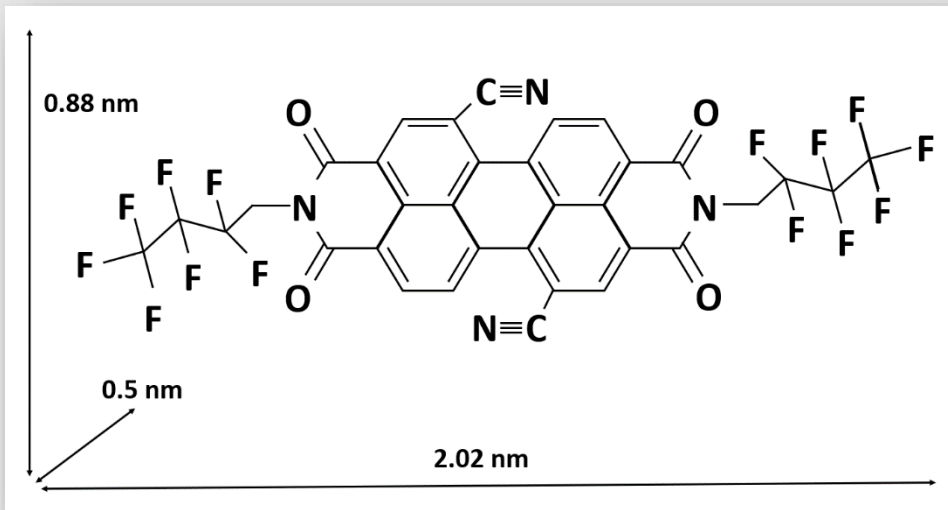


a)

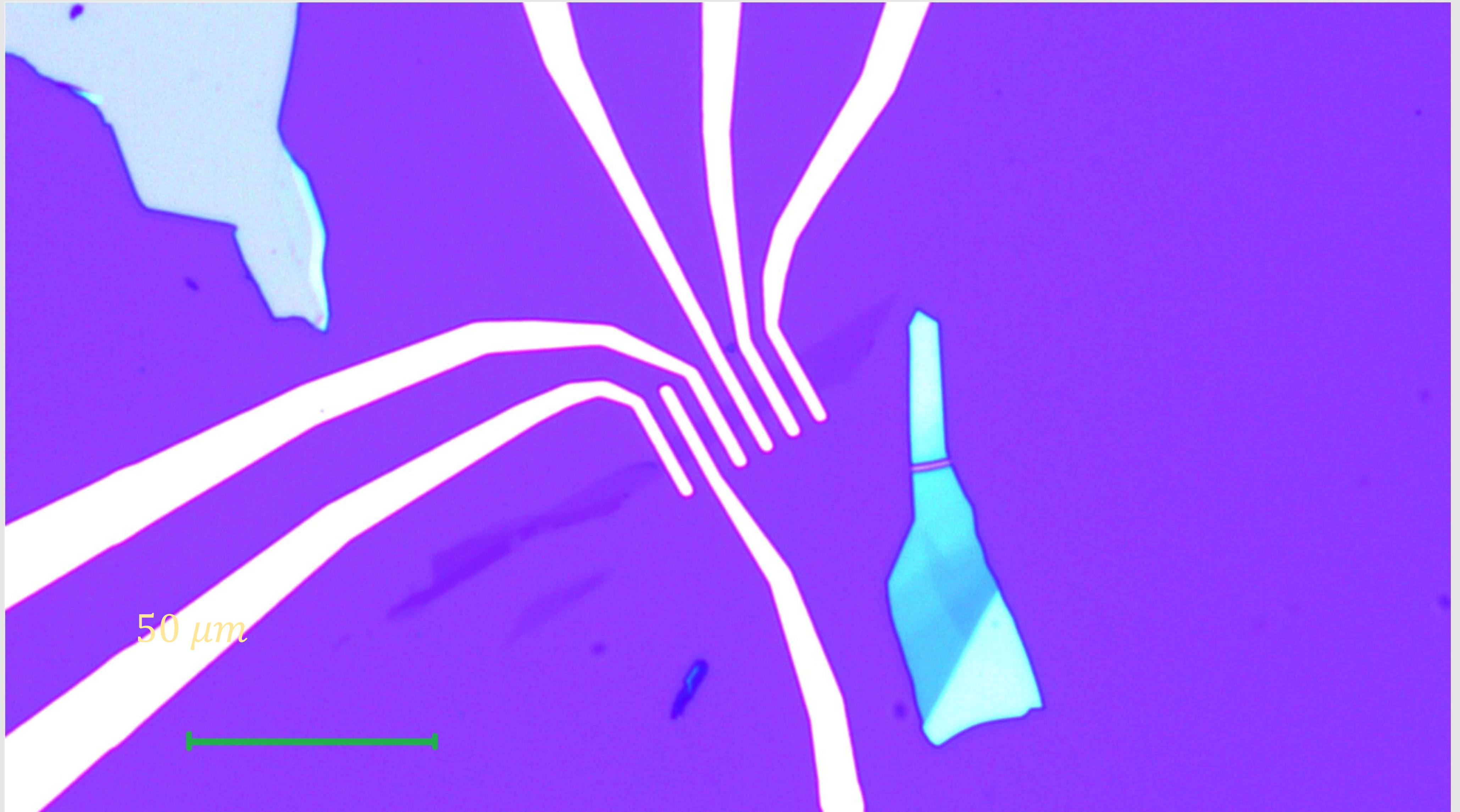


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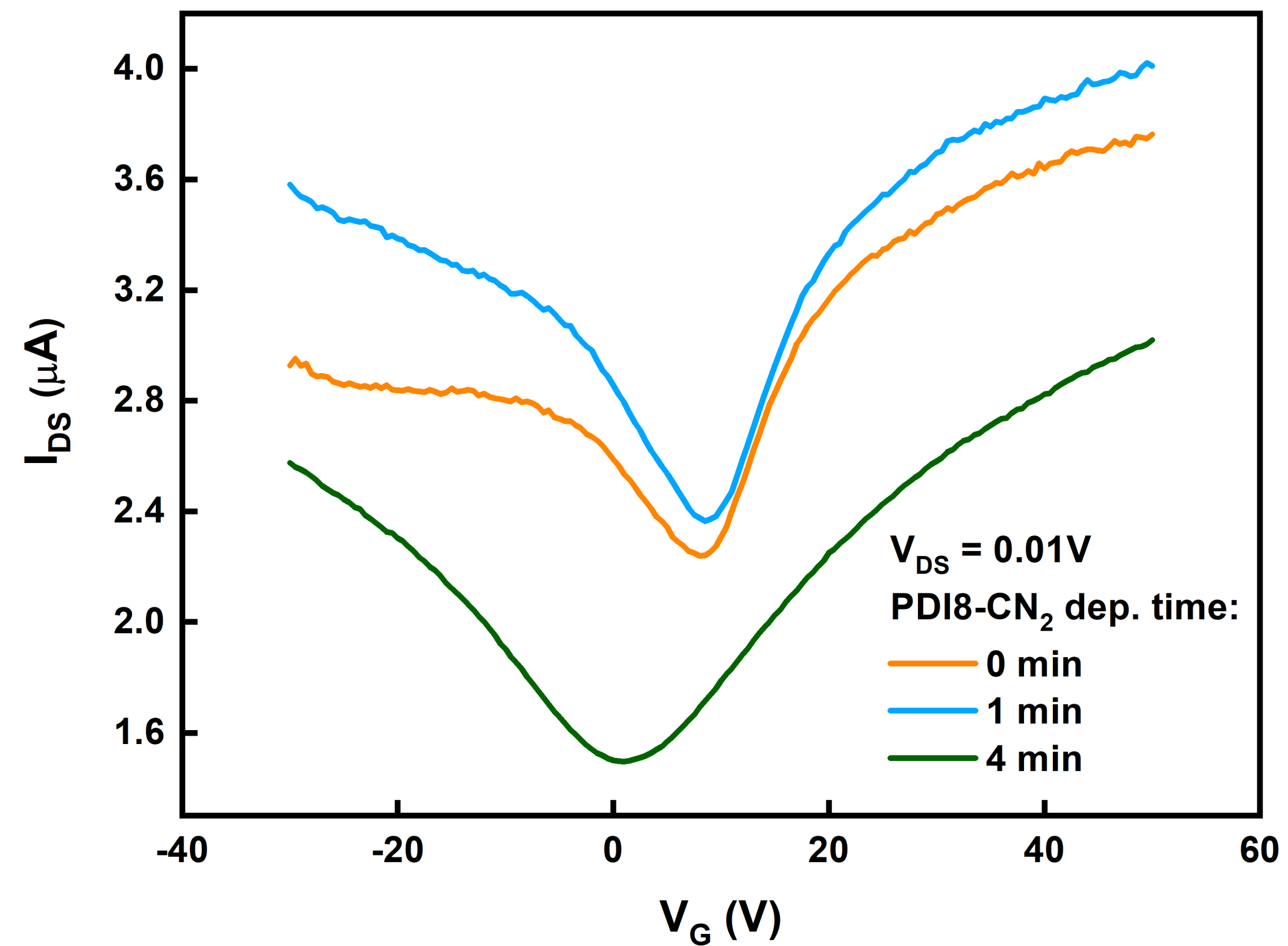




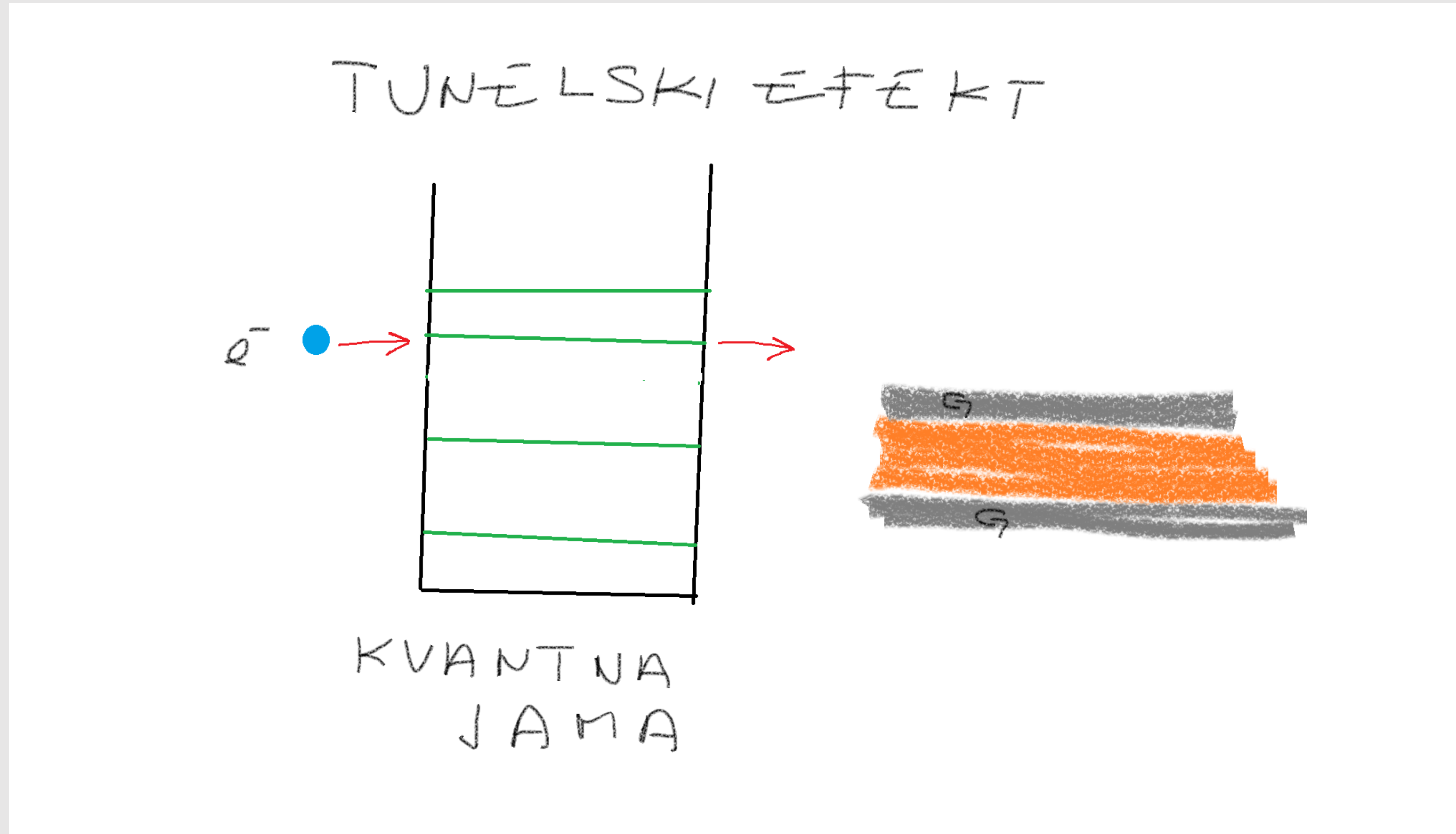
Optična litografija za izdelavo tranzistorskih struktur



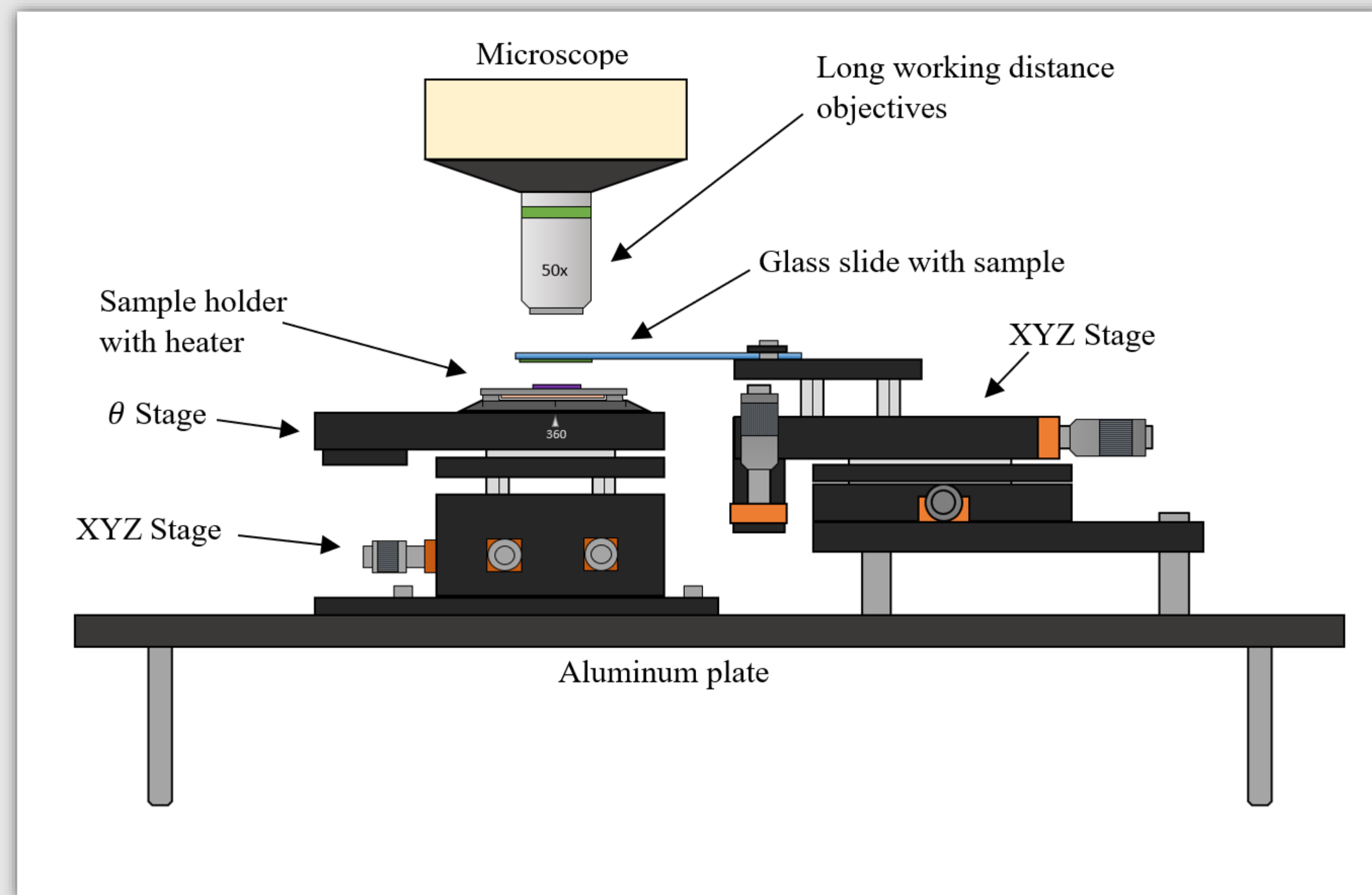
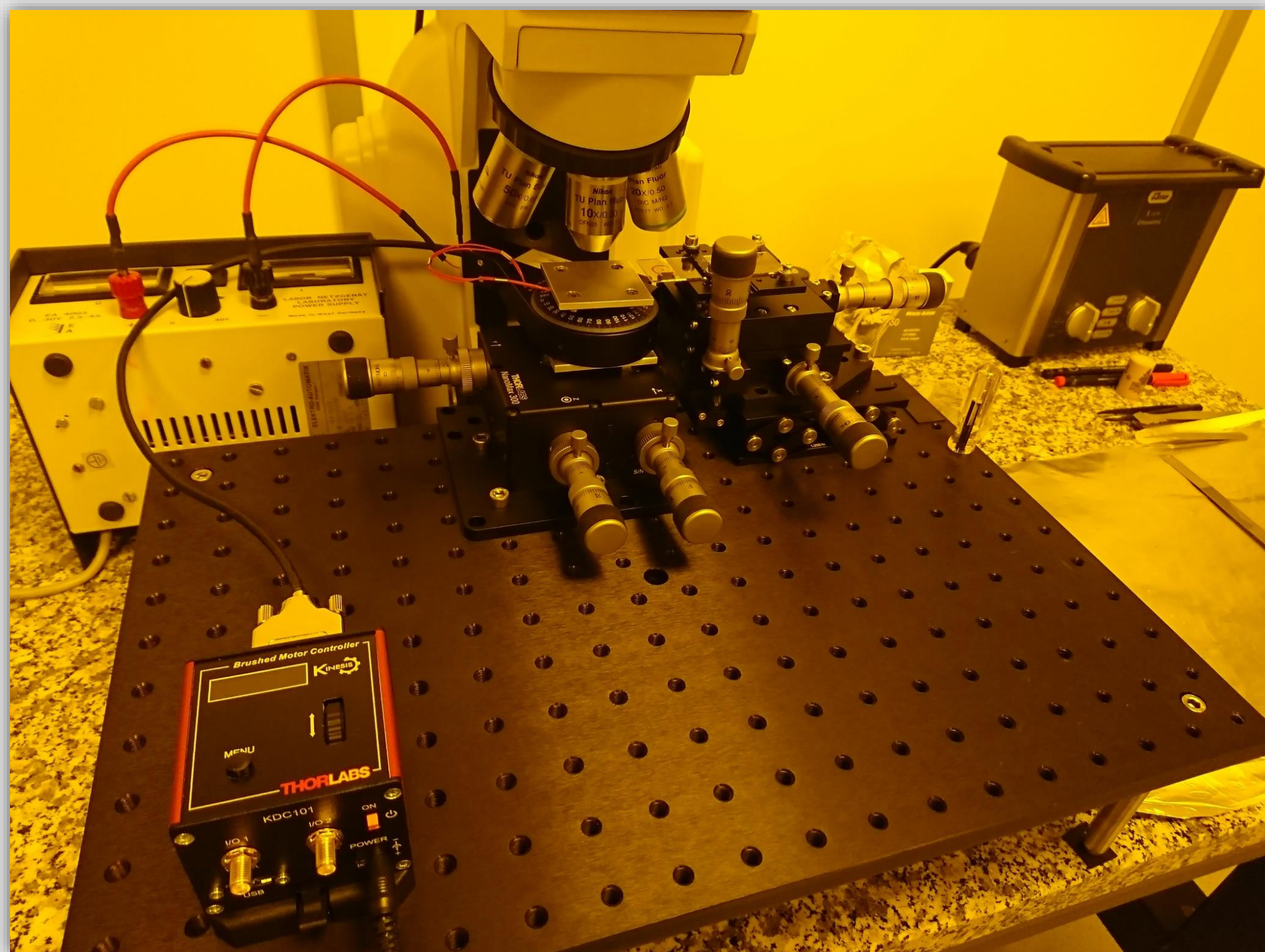
Prenosne karakteristike tranzistorjev

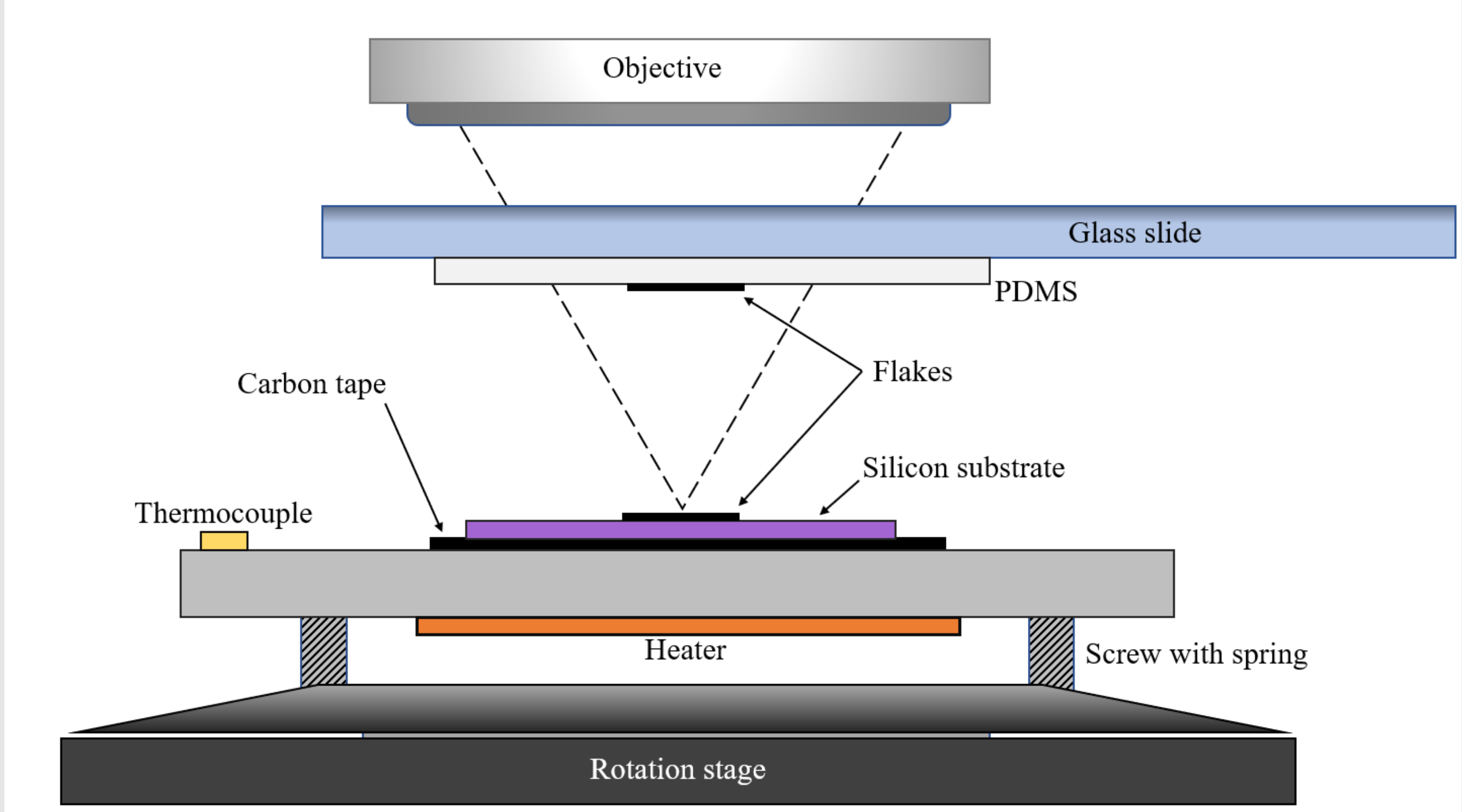


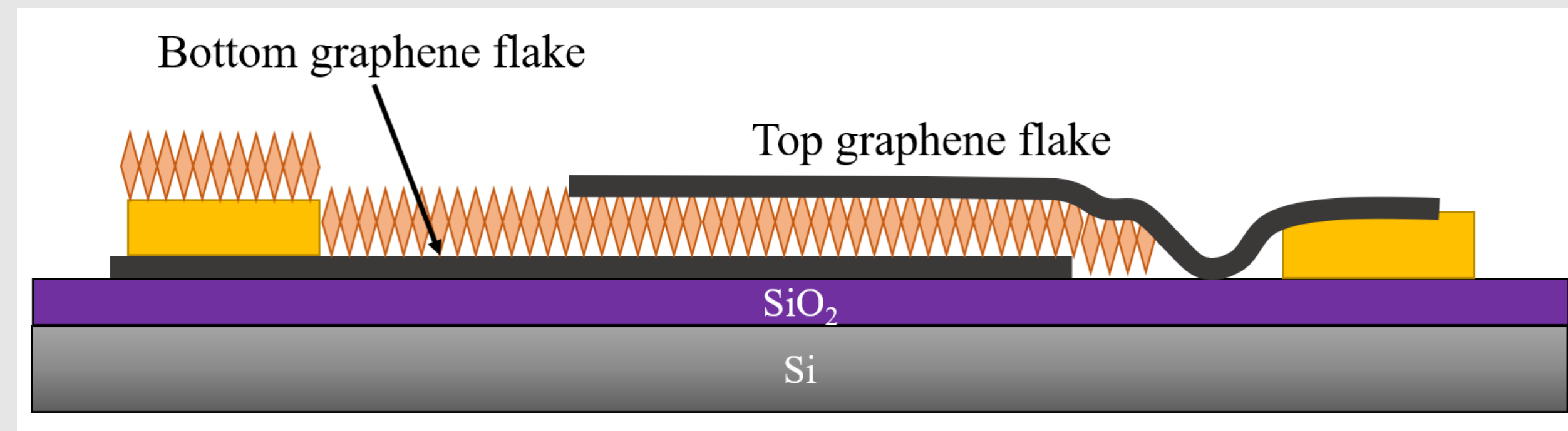
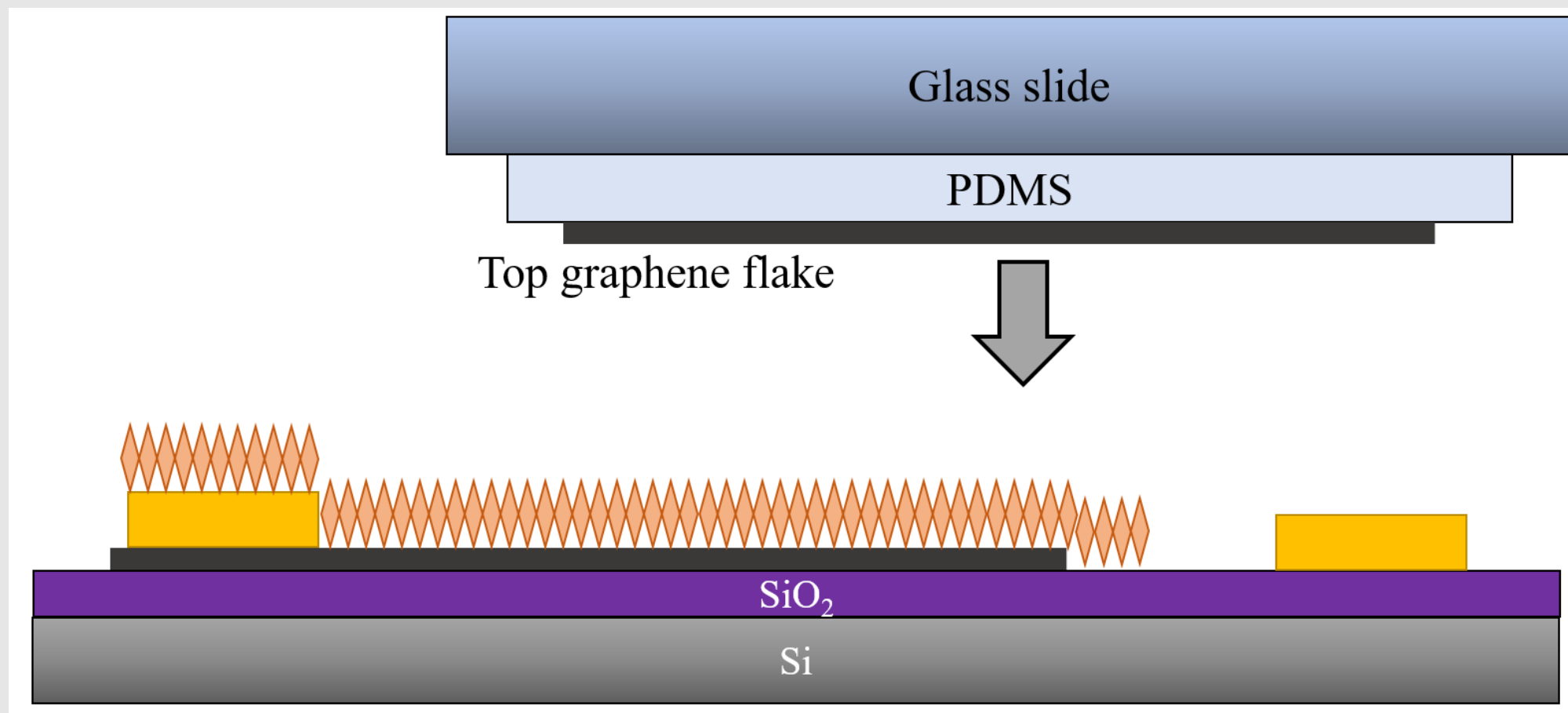
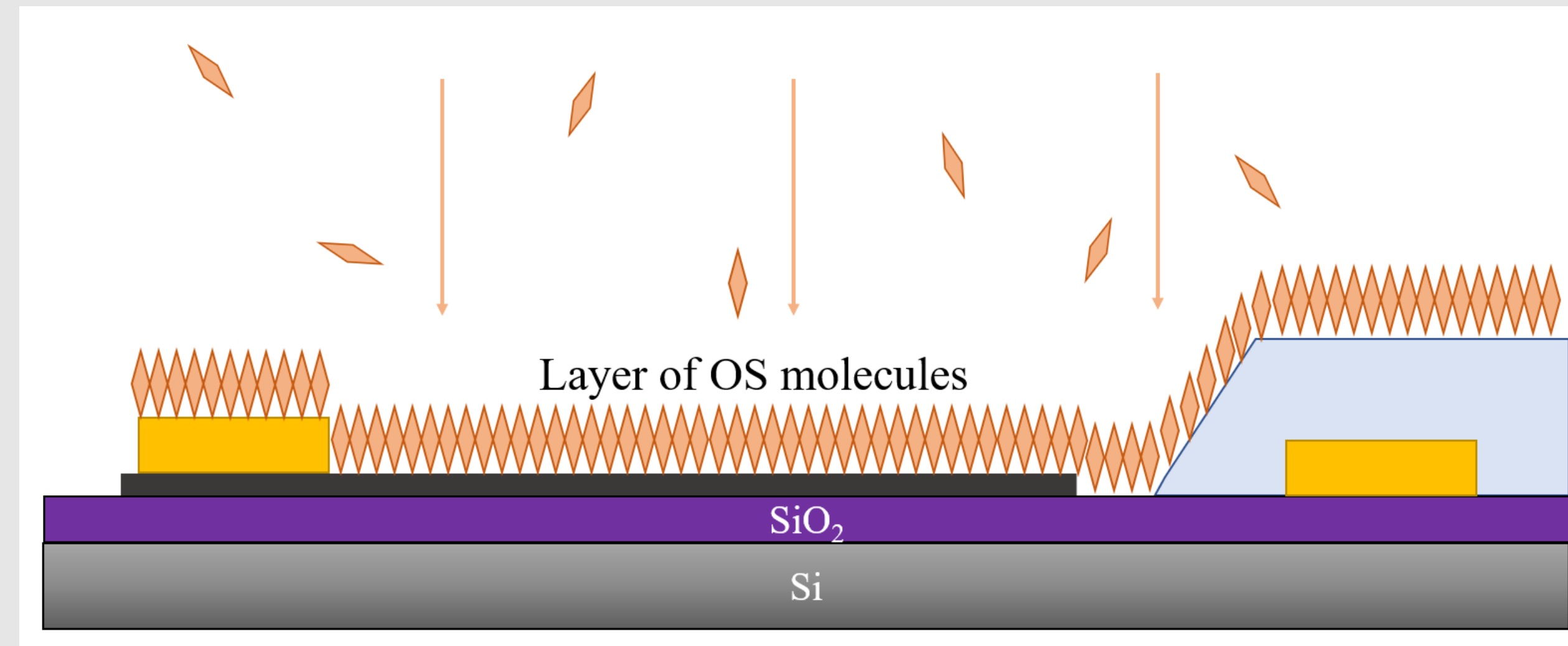
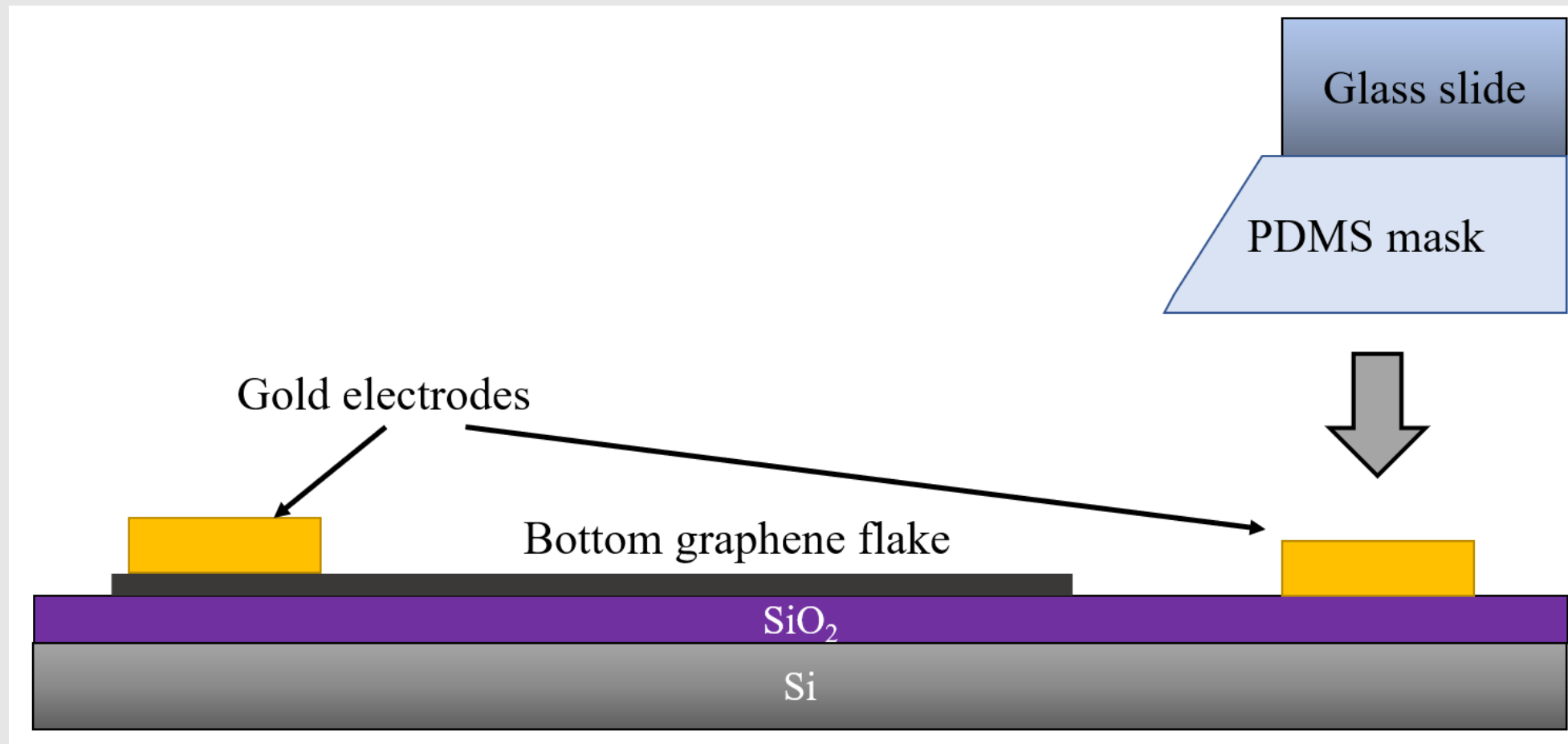
Transport nosilcev naboja v heterostrukturah grafen/OP/grafen

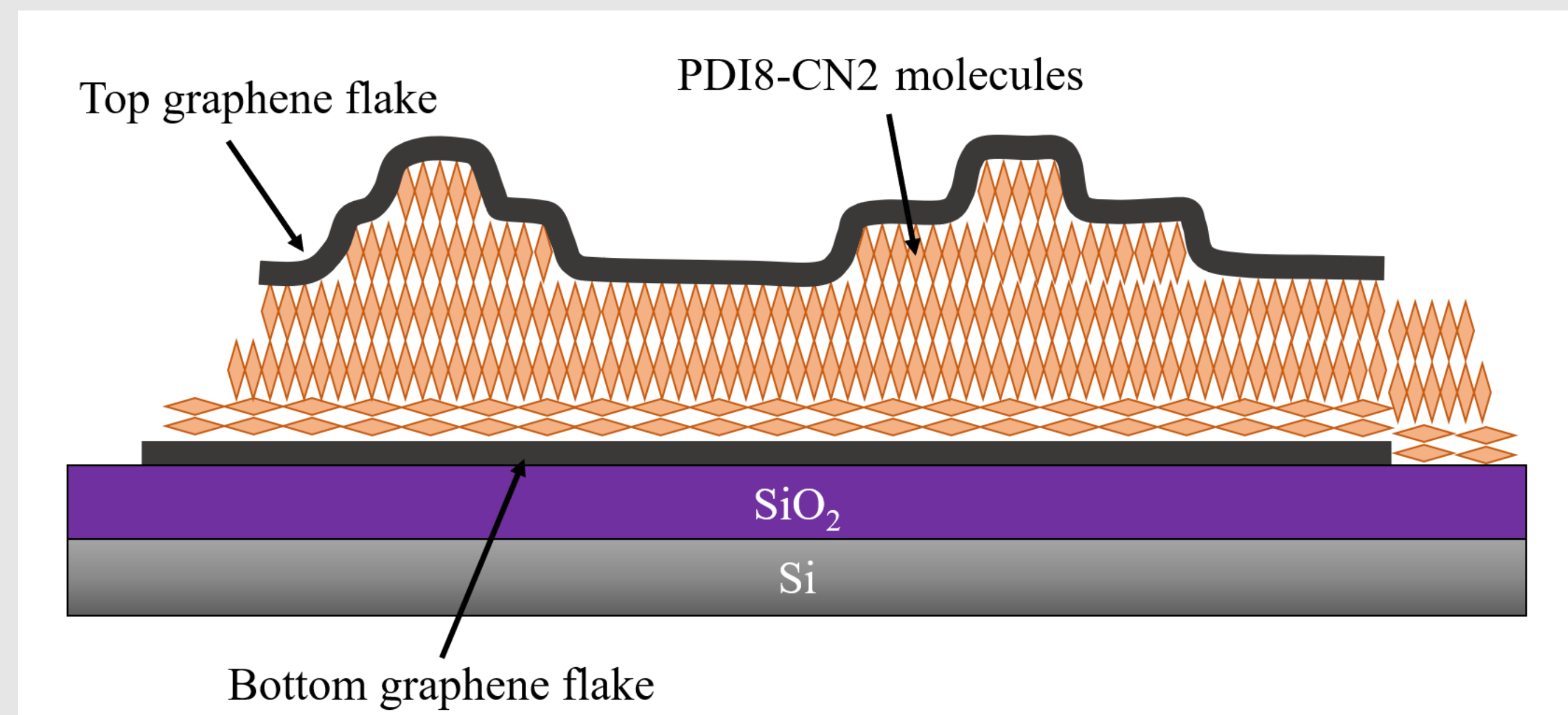
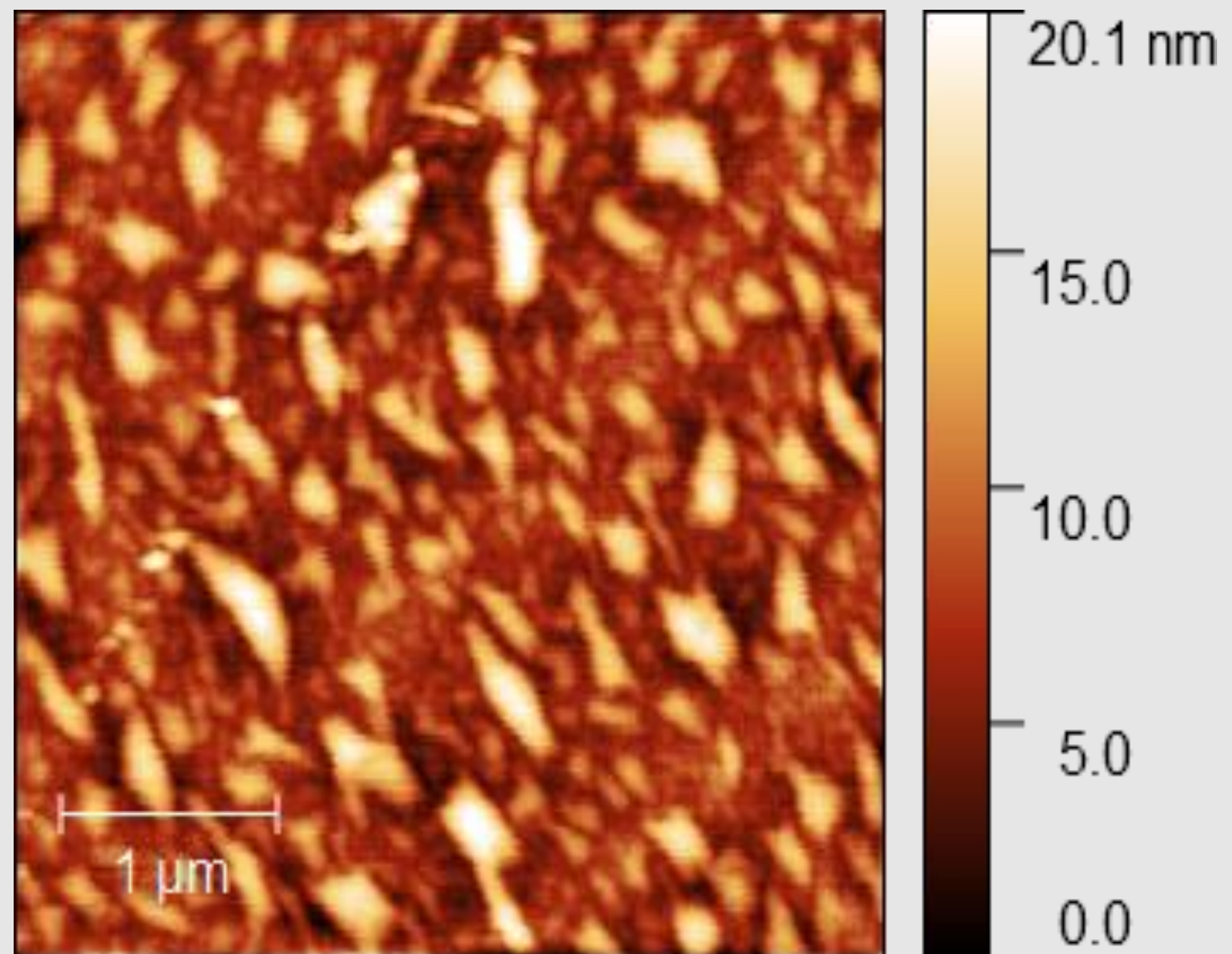


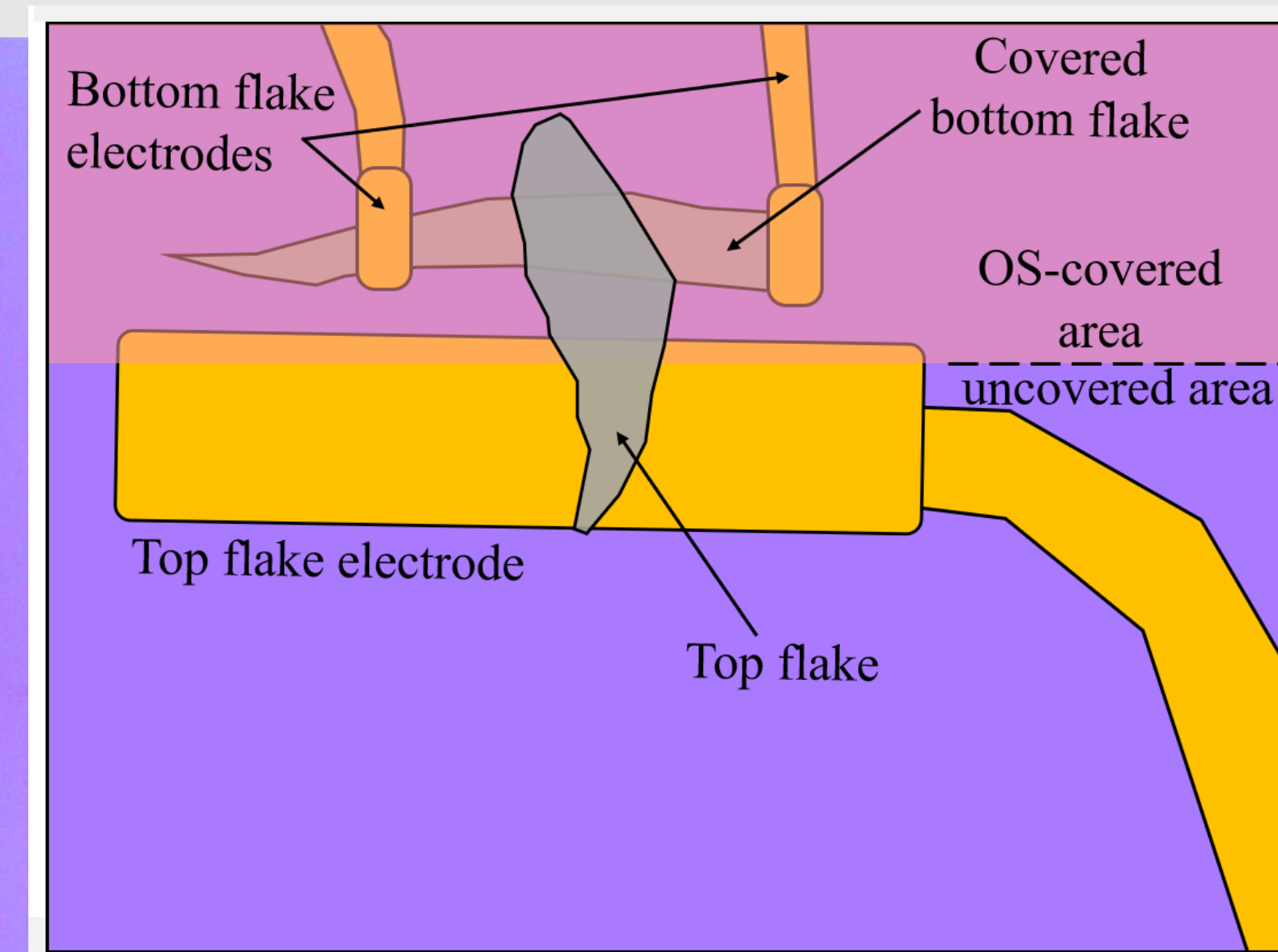
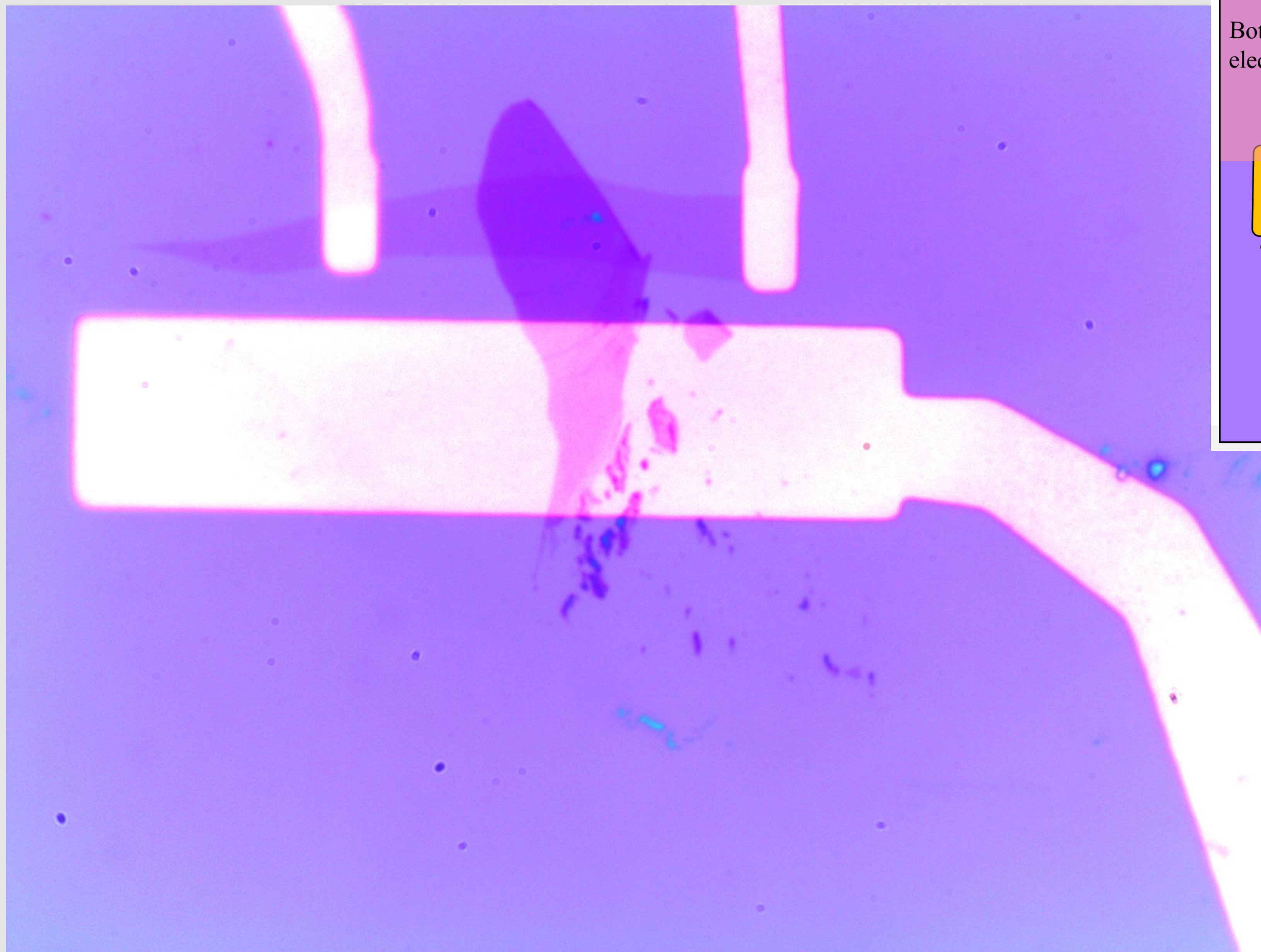
Struktura grafen/organski polprevodnik/grafen*

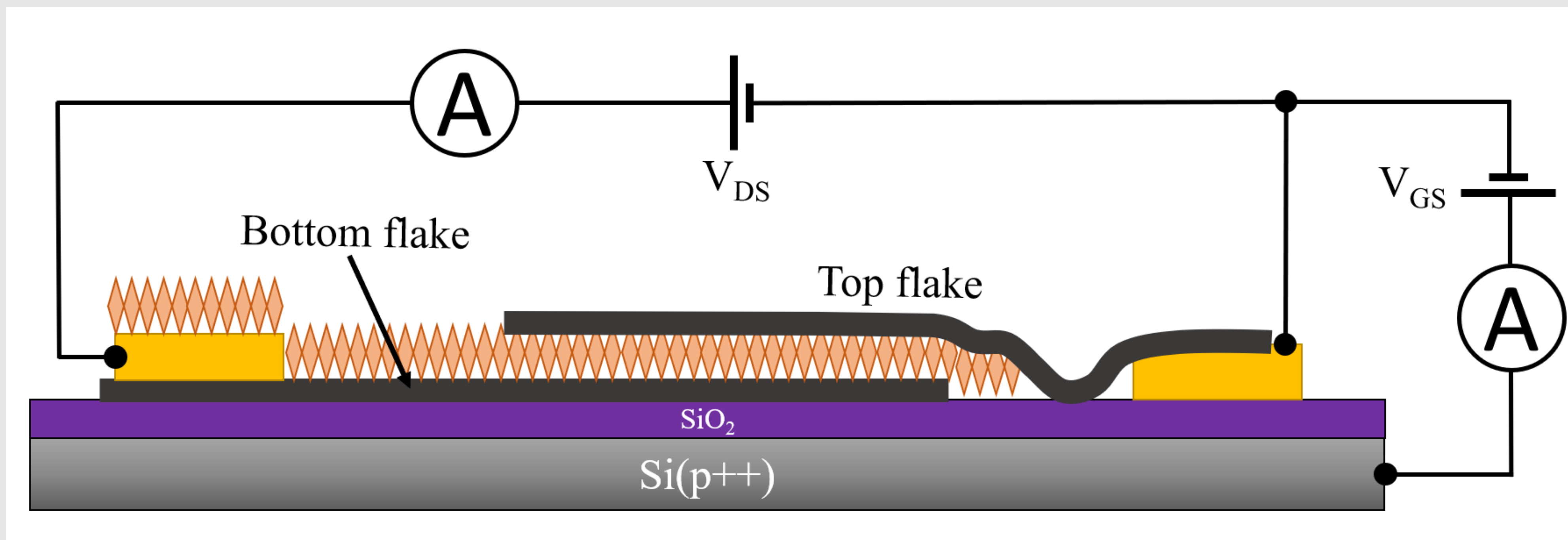


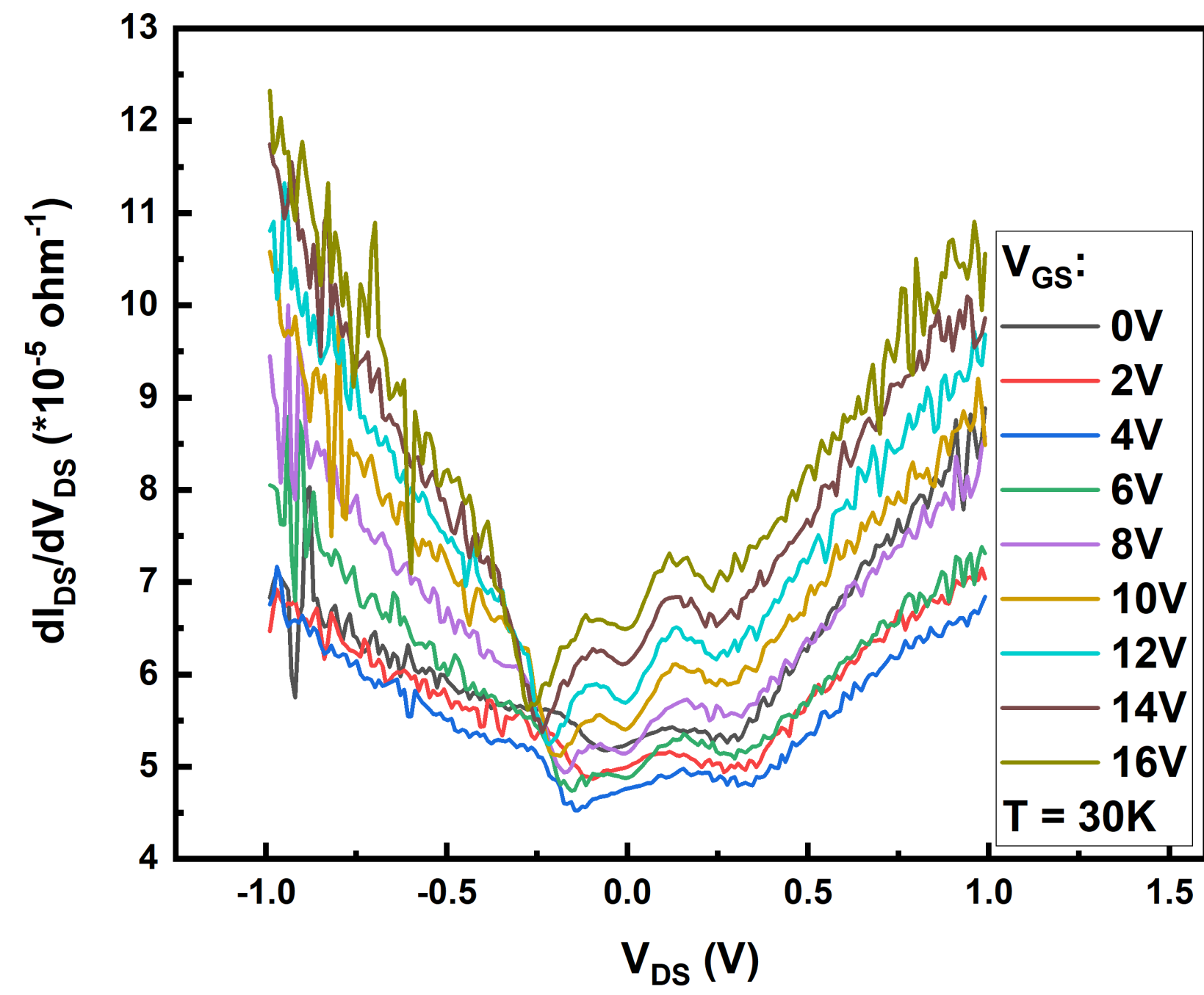
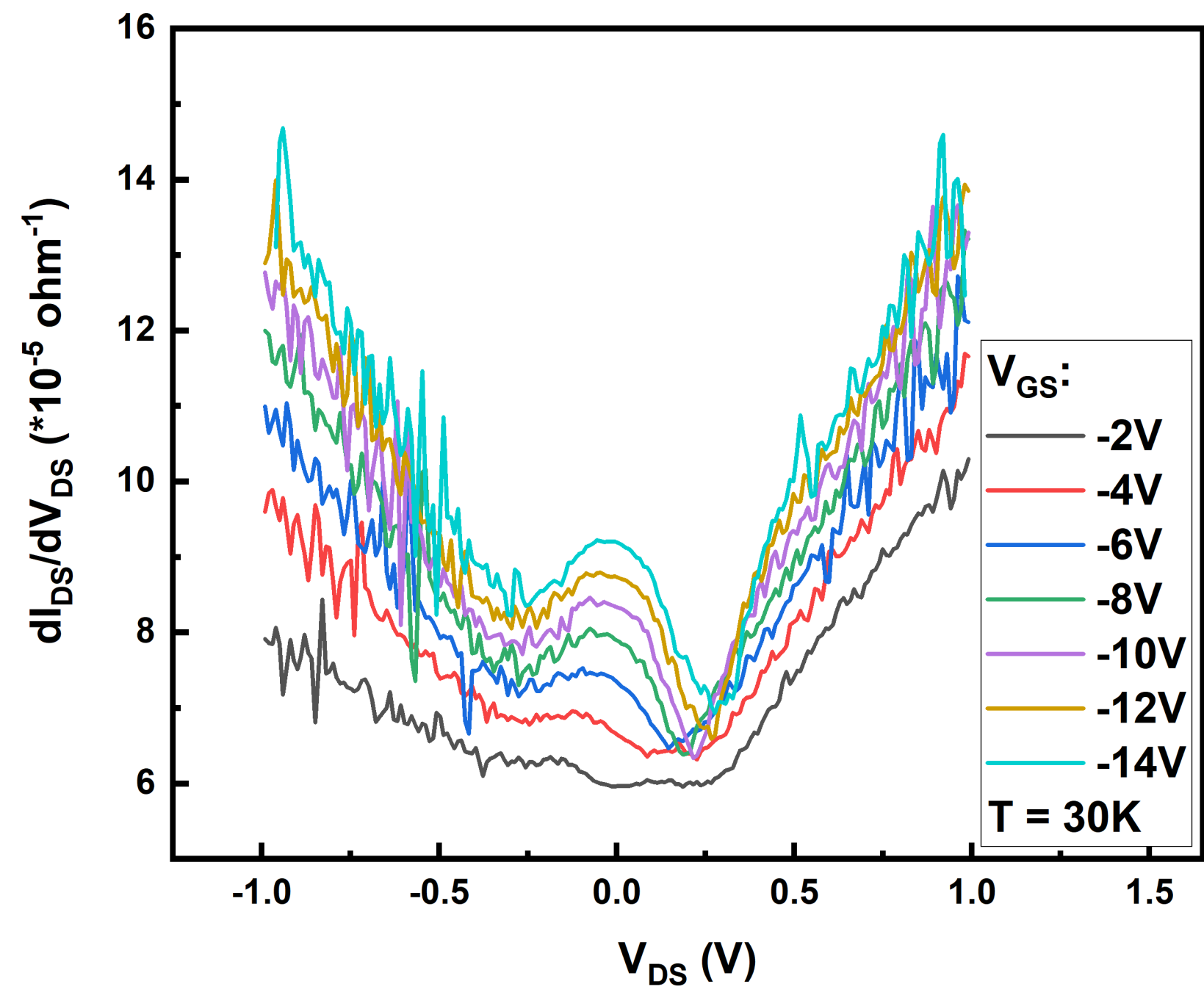


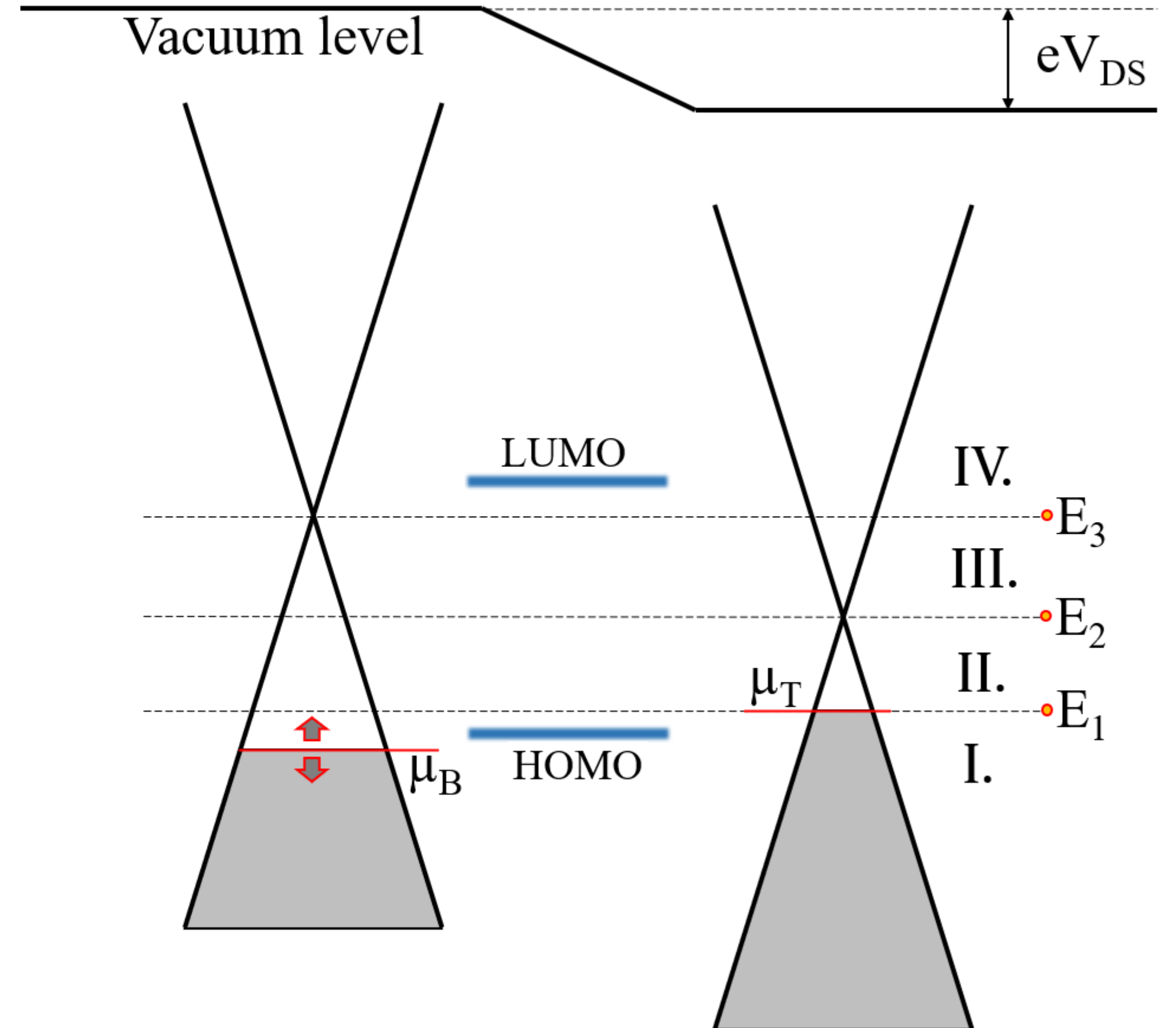
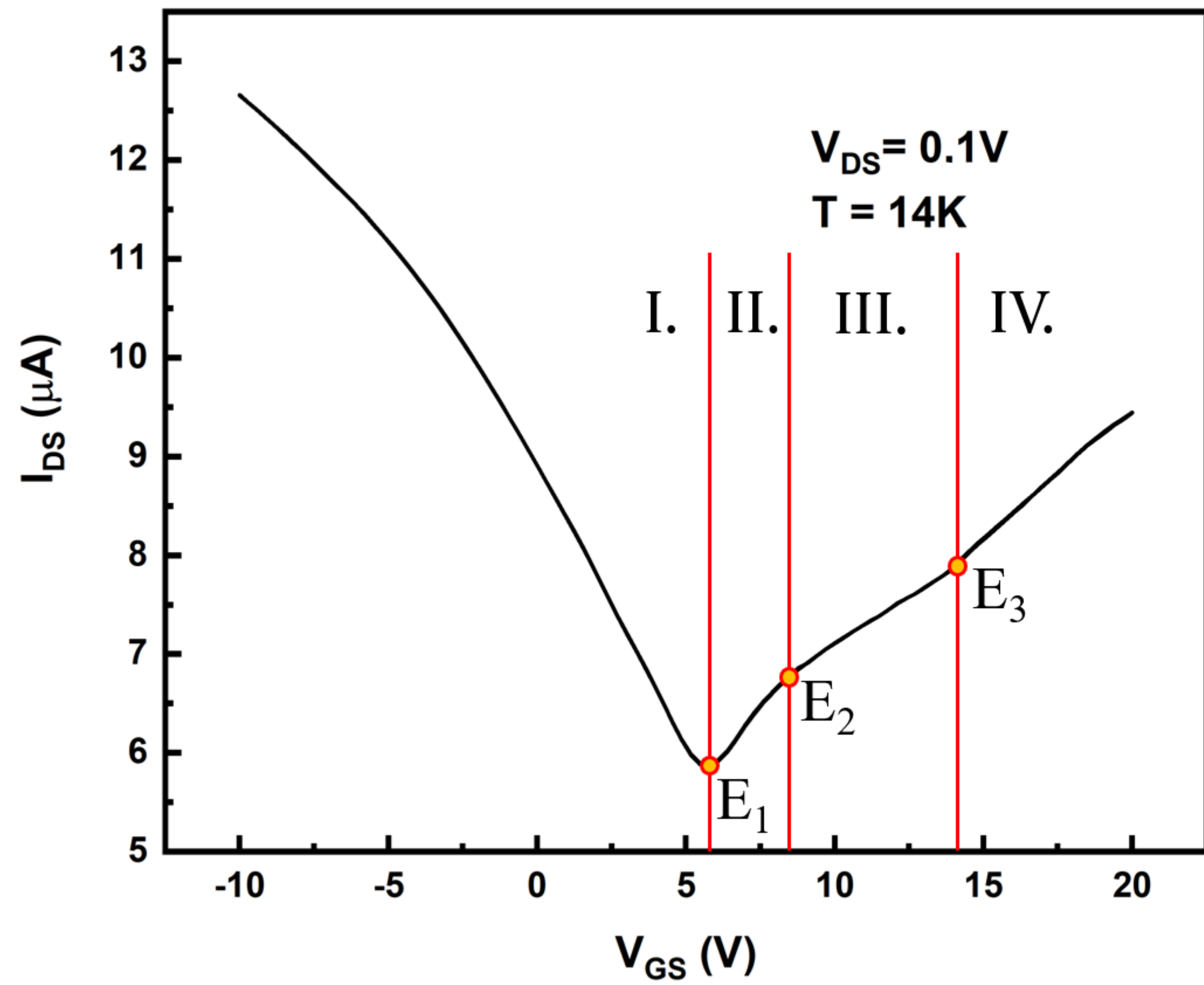












Sodelavci

- LFOS

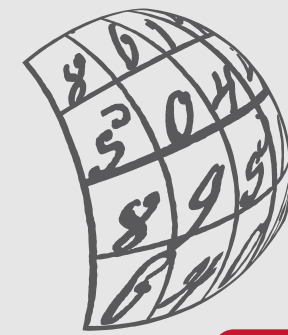
- Prof. dr. Egon Pavlica, UNG – vodja LFOS
- Dr. Vadym Tkachuk, UNG
- Erika Tomsič (MR), UNG
- Dr. S. Rao Pathipati, VFSTR, Vadlamudi, Indija
- Dr. Manisha Chhikara, UNG

- Tujina

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