AKADEMIA GÓRNICZO-HUTNICZA
IM. STANISŁAWA STASZICA W KRAKOWIE
AGH UNIVERSITY OF SCIENCE
AND TECHNOLOGY

AGH

Niekonwencjonalne podejście do przetwarzania informacji – od inżynierii materiałów hybrydowych do nowych efektów fizykochemicznych

Kacper Pilarczyk

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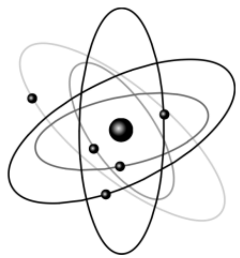


WFiIS AGH, Kraków, 4 marca 2022

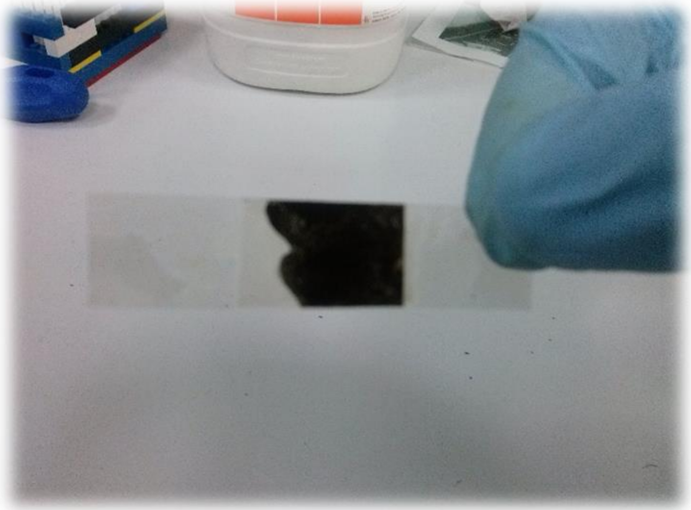
Motywacja

- Informacja jako jedna z podstawowych wielkości budujących Wszechświat:
  - „Materia, energia i informacja są trzema postaciami masy (…), mogą przechodzić w siebie, zgodnie z prawami zachowania.”

Stanisław Lem, „Professor A. Dońda”

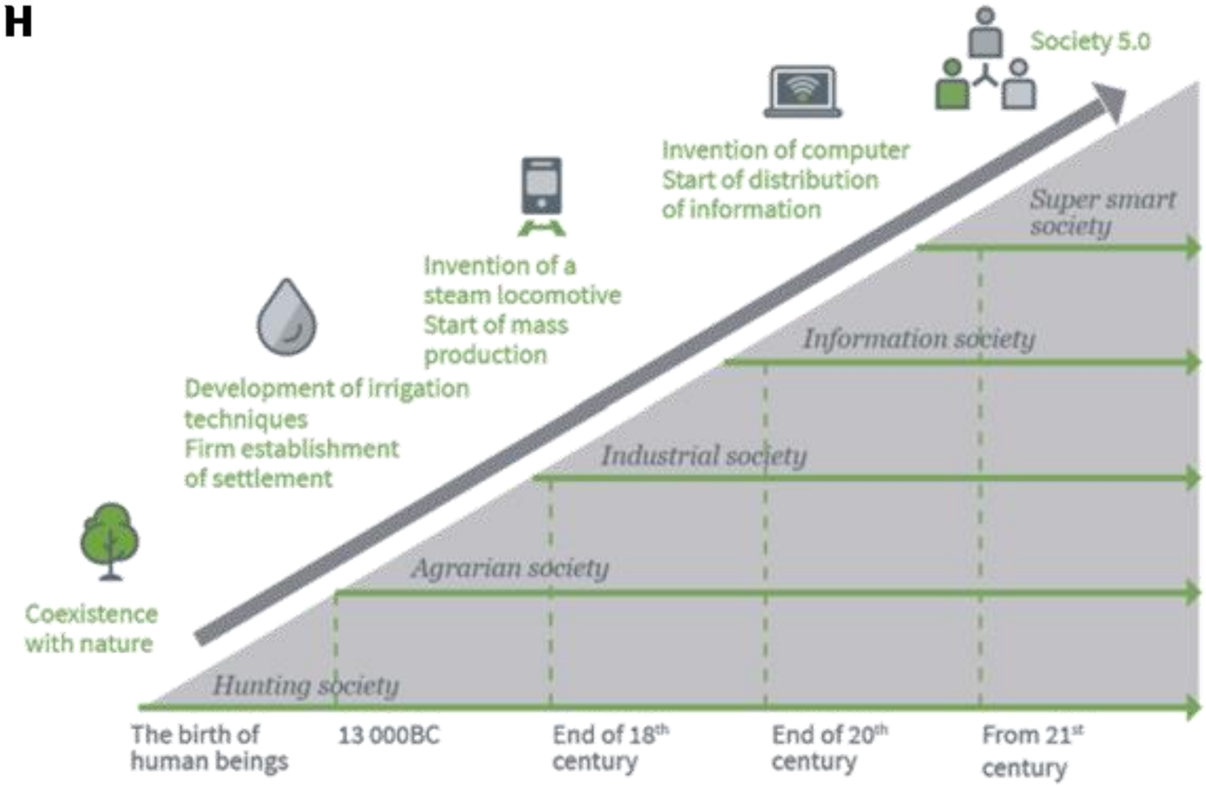
- Dalszy rozwój społeczeństwa informacyjnego:
  - „The complexity for minimum component costs has increased at a rate of roughly a factor of two per year. (…) Over the longer term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least 10 years.”

Gordon Earle Moore, Electronics Magazine 4 (1965)



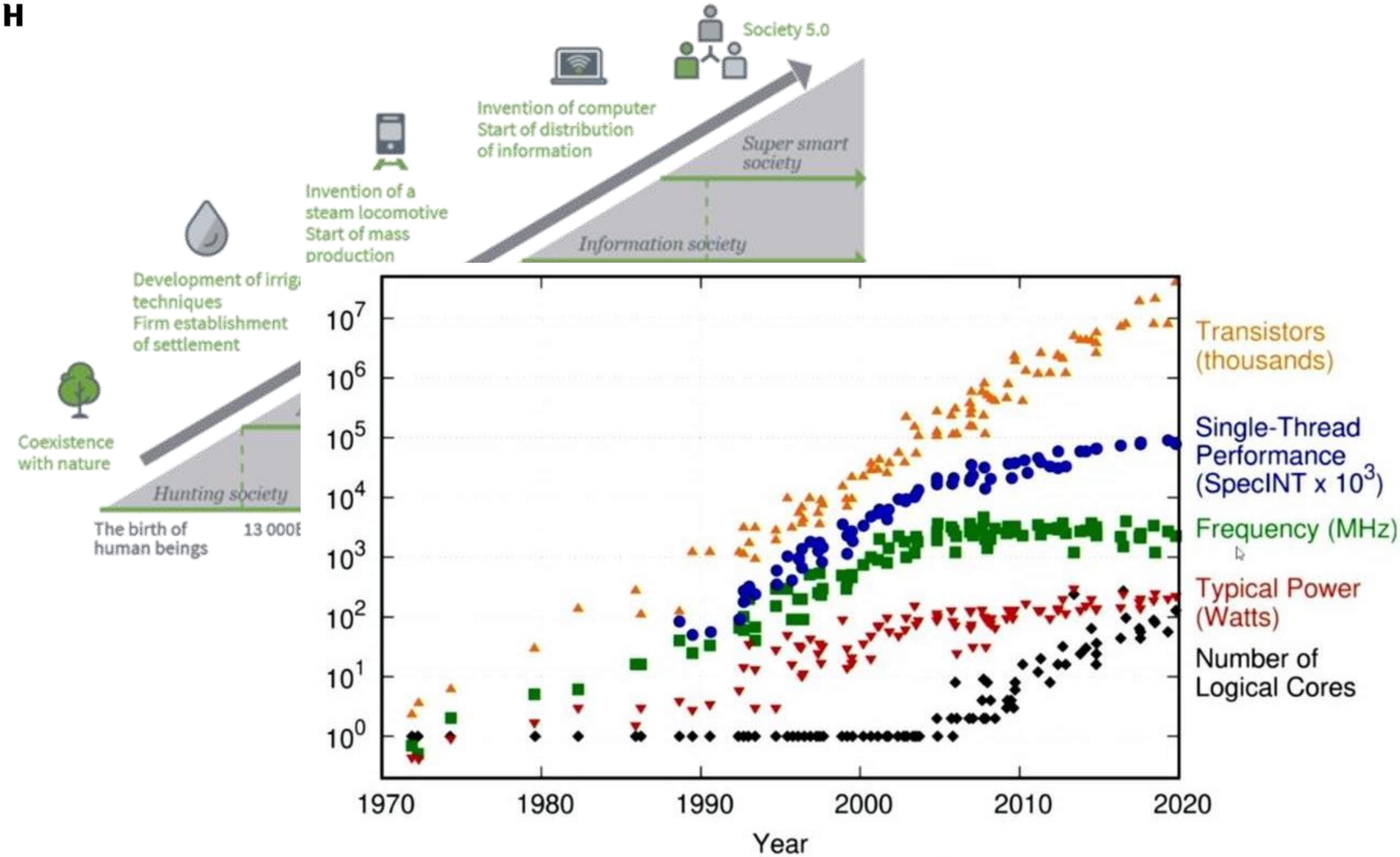
- http://geology.com/

Motywacja



- Nippon Keidanren - Japońska Federacja Organizacji Gospodarczych, 2016 r.
- S. Borkar, Senior director of technology at Qualcomm Inc., SC20 Invited Talk, 2020 r.

Motywacja



- Nippon Keidanren - Japońska Federacja Organizacji Gospodarczych, 2016 r.
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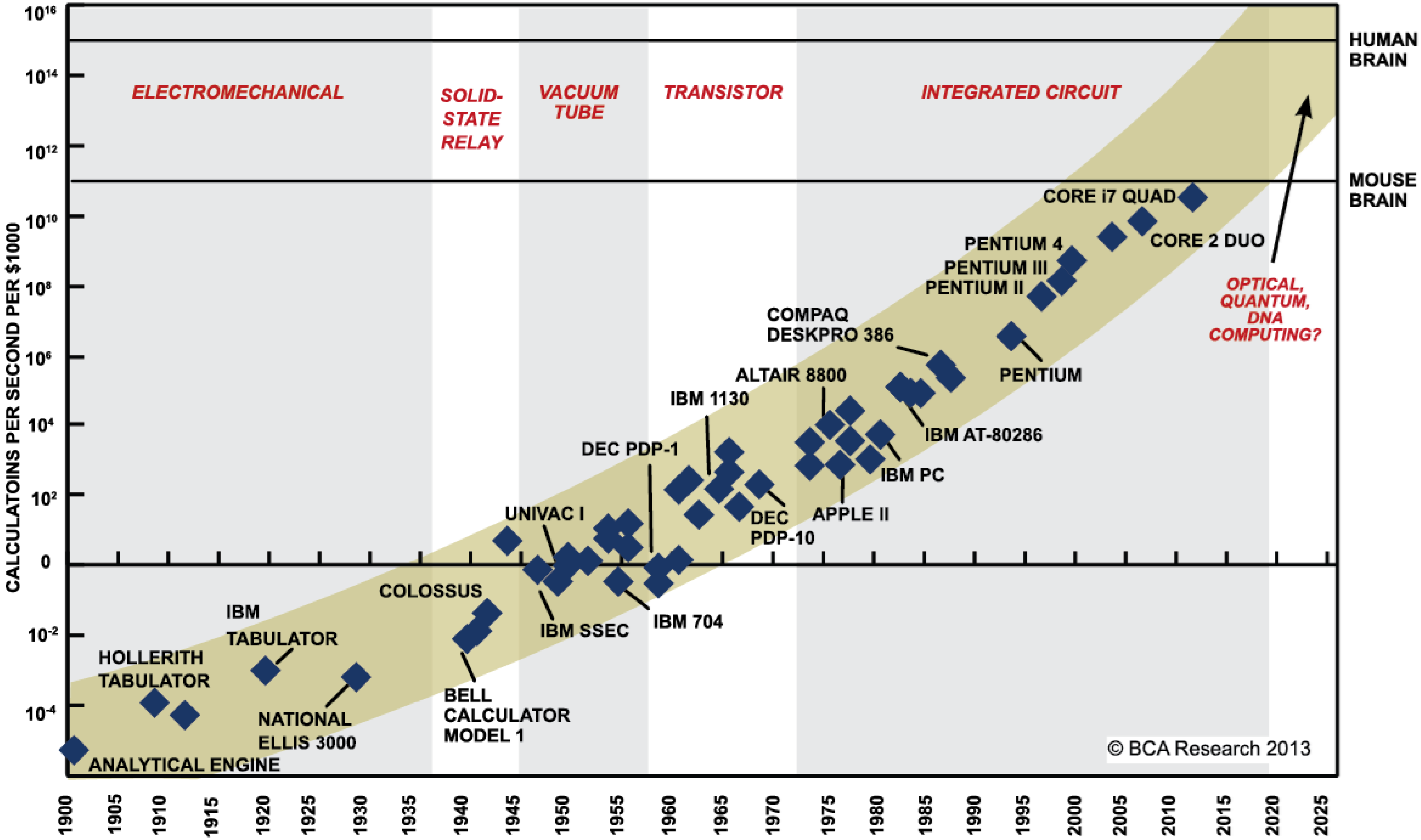

SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, *THE VIKING PRESS*, 2006. DATAPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

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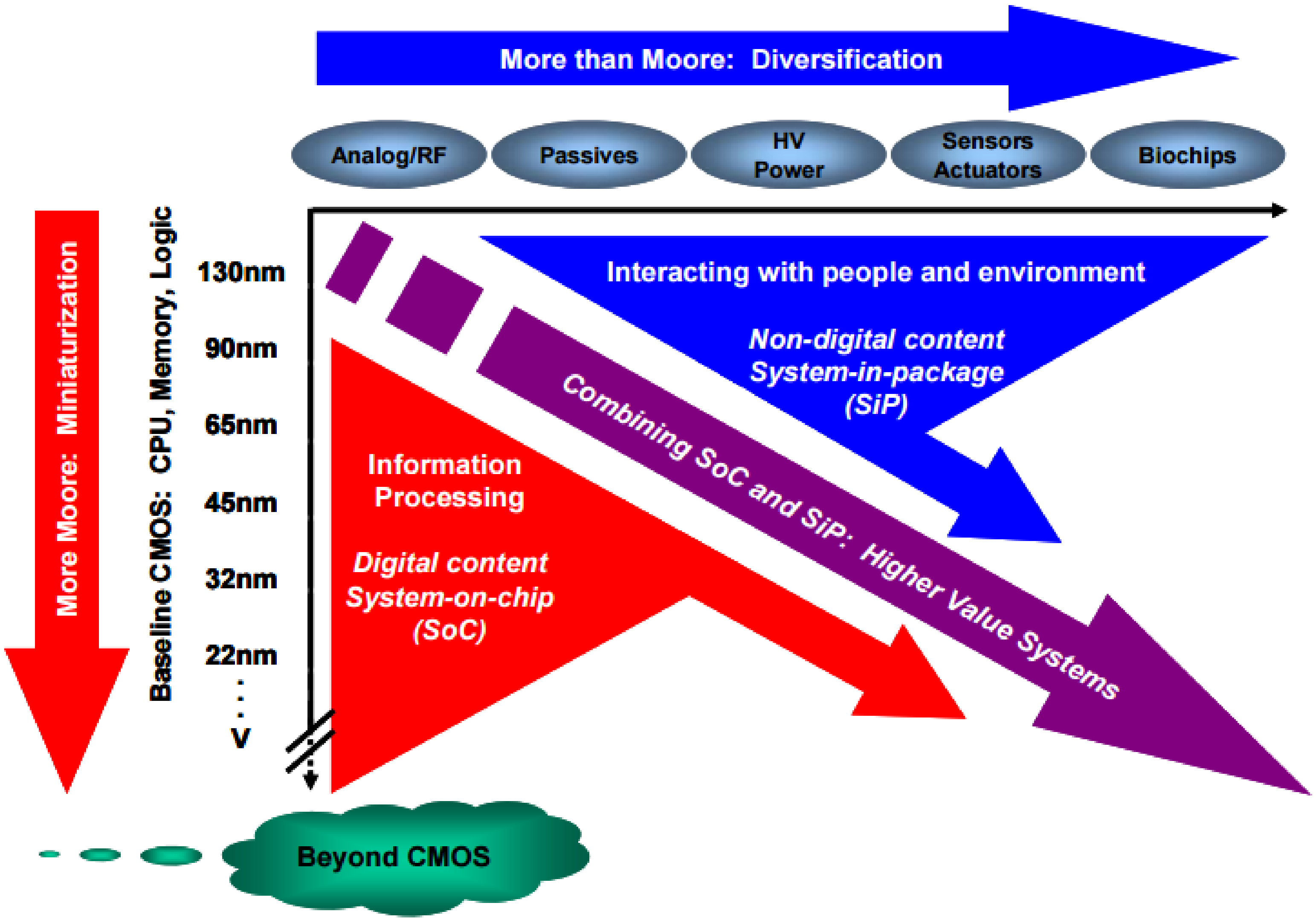
Motywacja – alternatywne rozwiązania

- Czy dalszy rozwój wymaga odejścia od klasycznej elektronice krzemowej?



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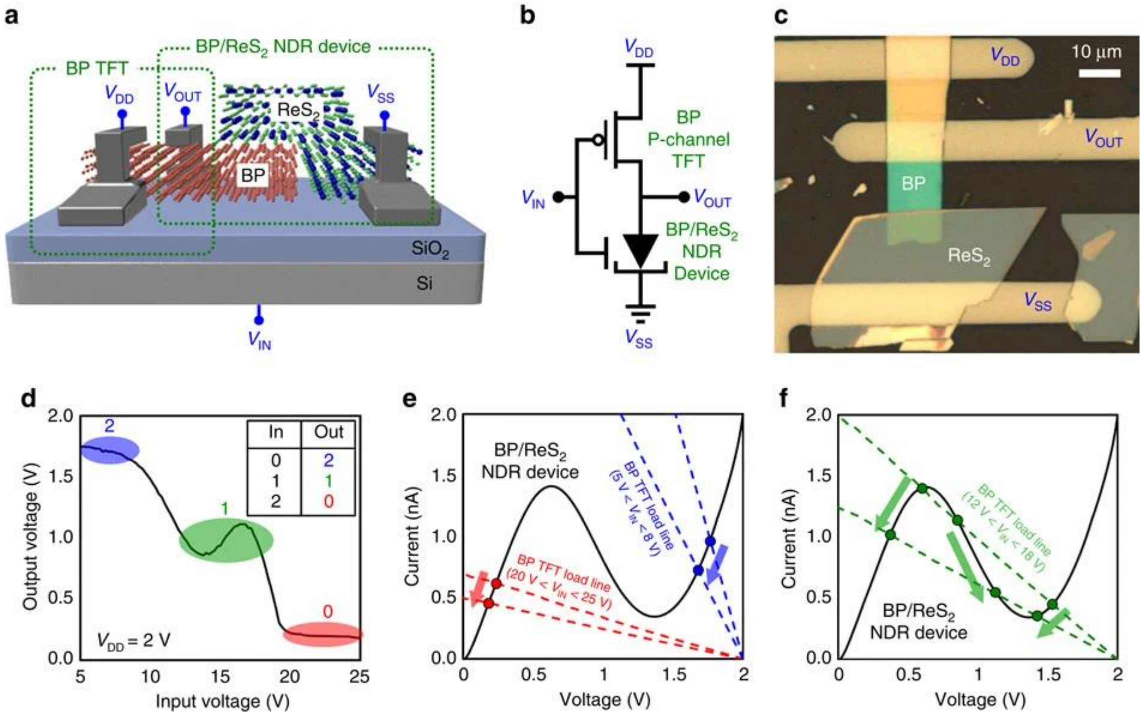
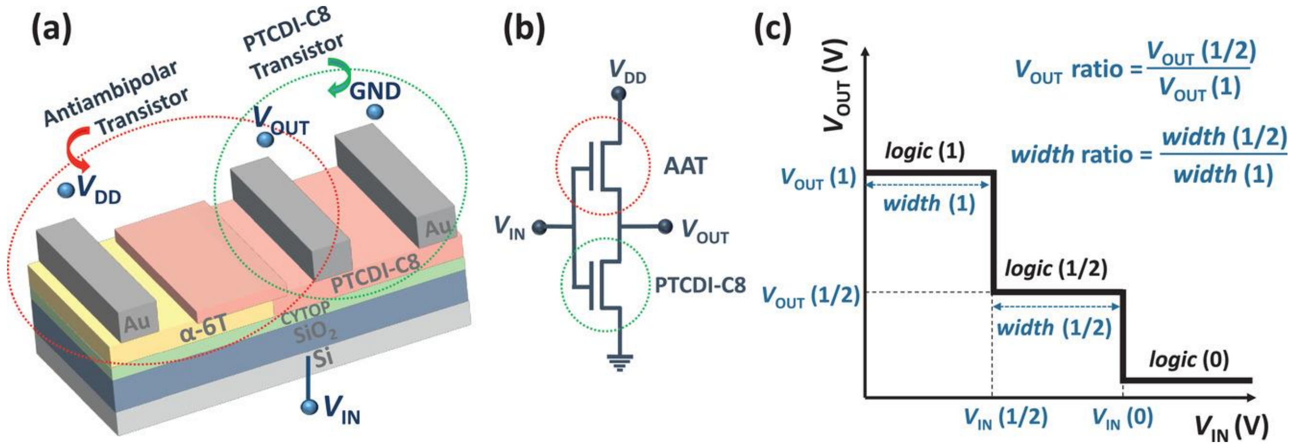
Motywacja – „klasyczne” alternatywne rozwiązania





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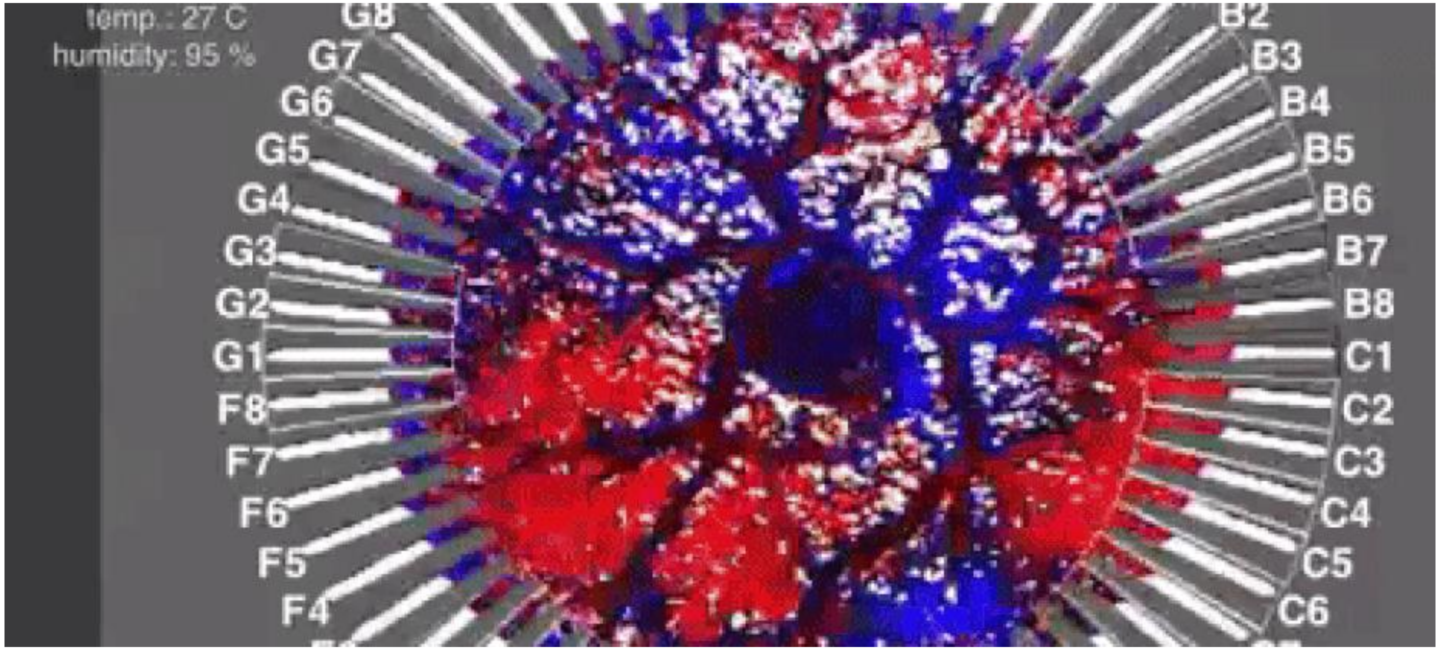
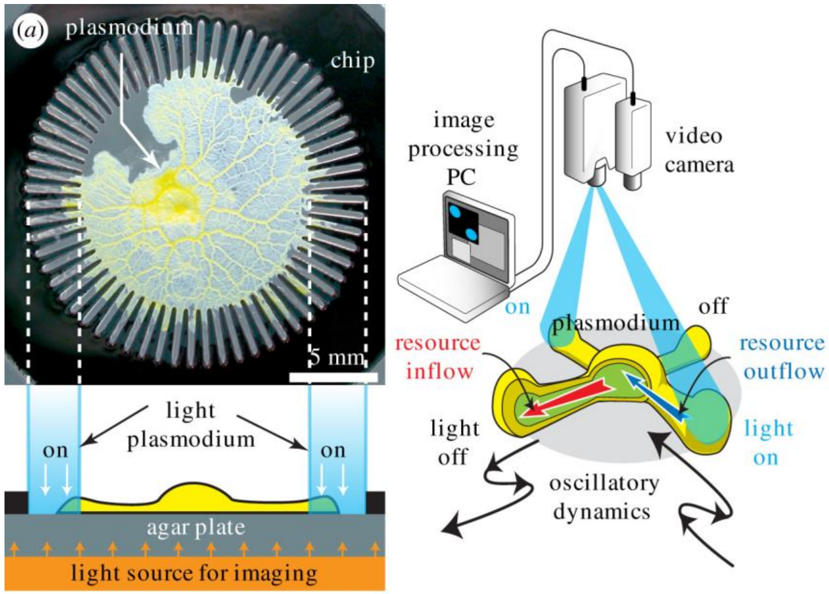
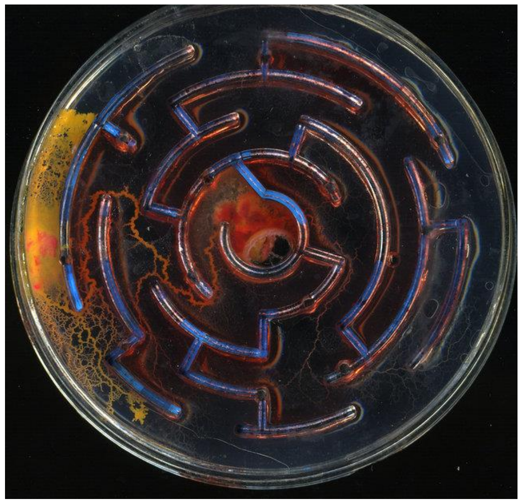
Motywacja – „alternatywne” alternatywne rozwiązania







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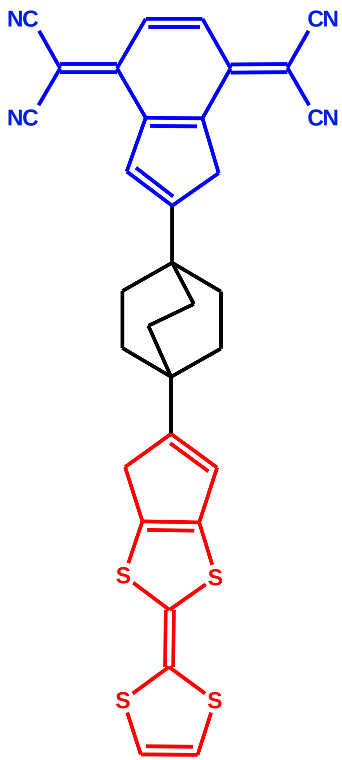
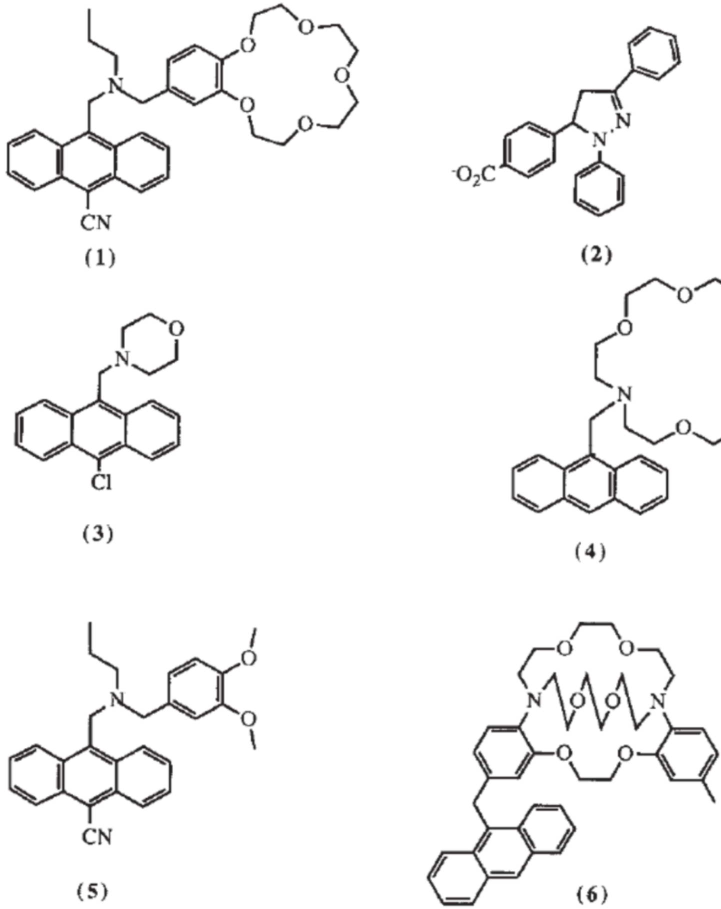
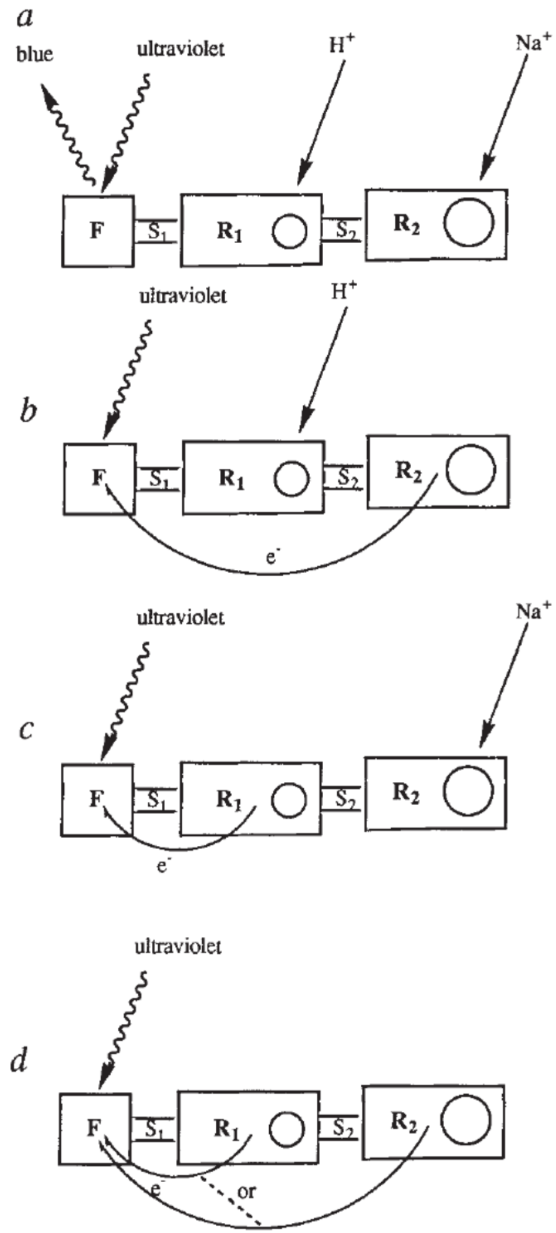
Inspiracja

www.agh.edu.pl

Elektronika molekularna i bramki logiczne

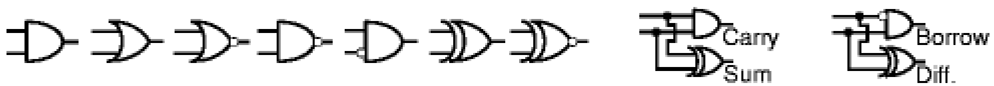






Inputs (A)	(B)	Output AND	OR	NOR	NAND	INHIBIT	XOR	XNOR	Half-adder (Carry)	(Sum)	Half-subtractor (Borrow)	(Diff.)
0	0	0	0	1	1	0	0	1	0	0	0	0
0	1	0	1	0	1	0	1	0	0	1	1	1
1	0	0	1	0	1	1	1	0	0	1	0	1
1	1	1	1	0	0	0	0	1	1	0	0	0

Symbol



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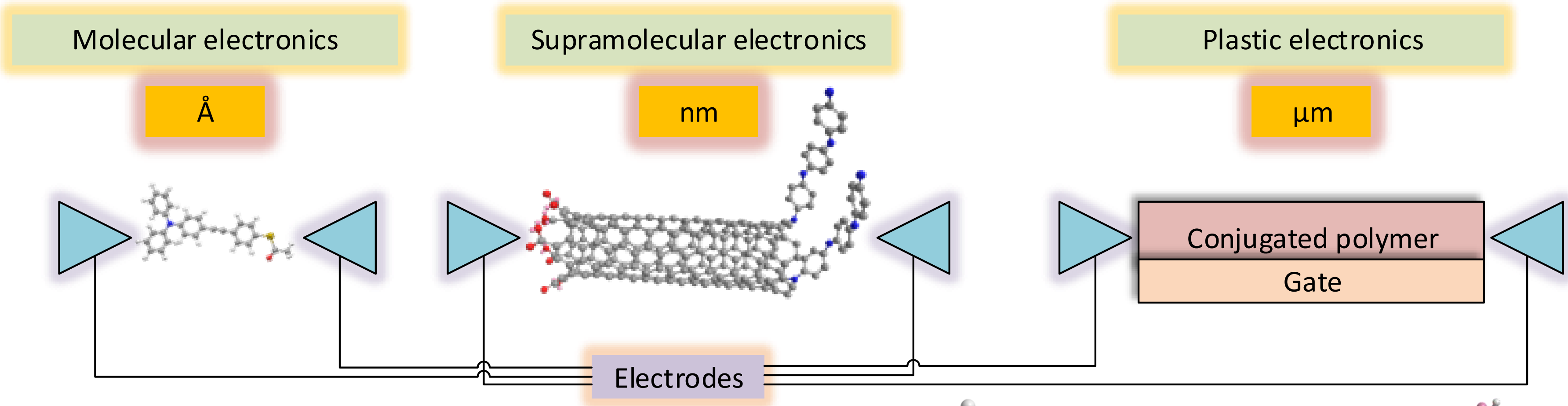
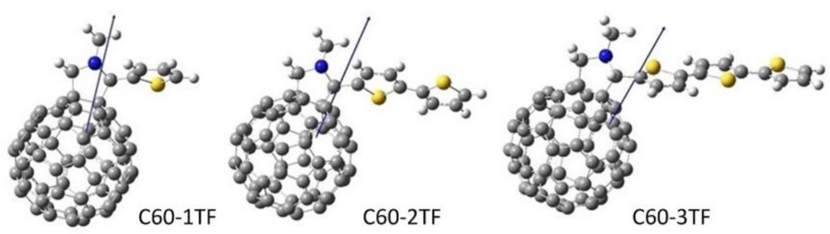
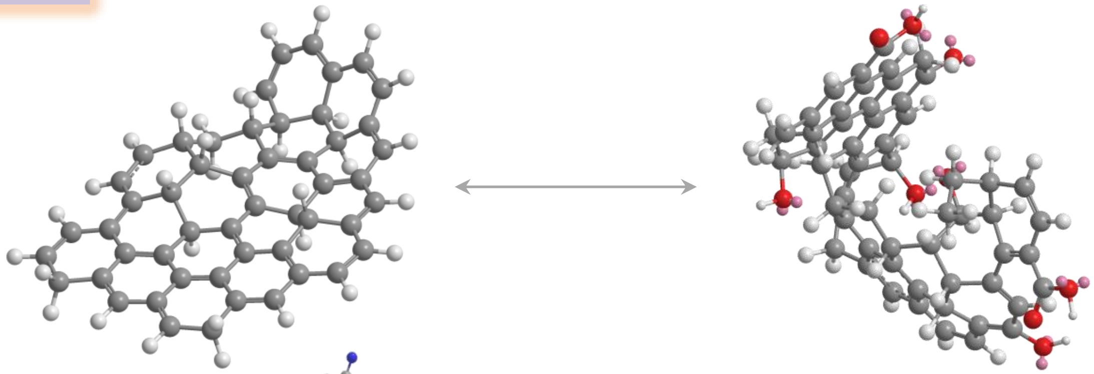
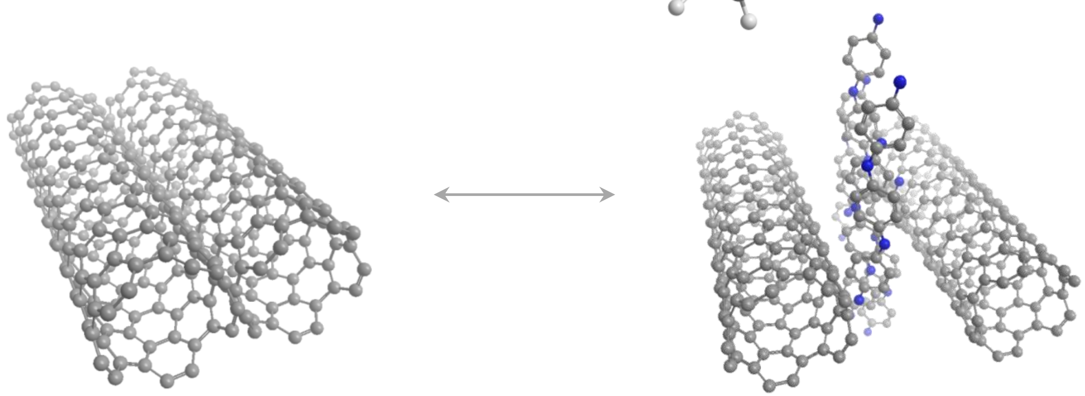
Kierunek moich dotychczasowych badań









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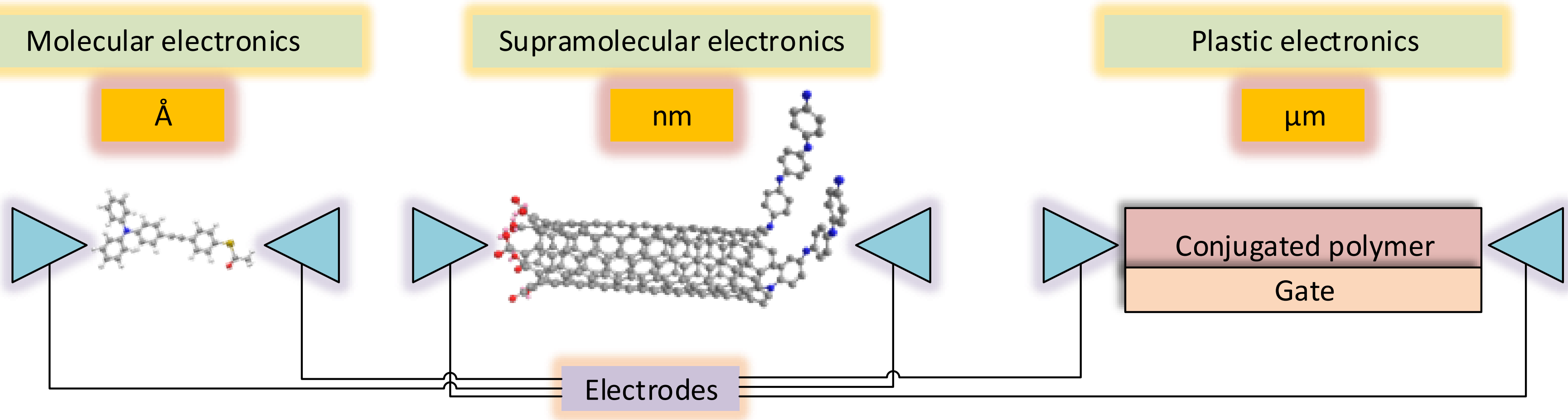

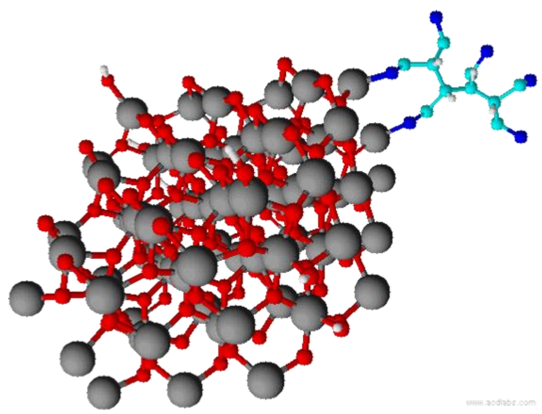

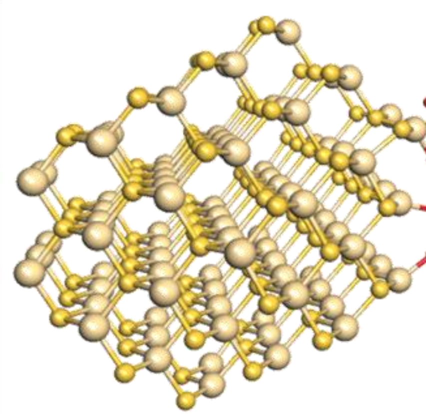

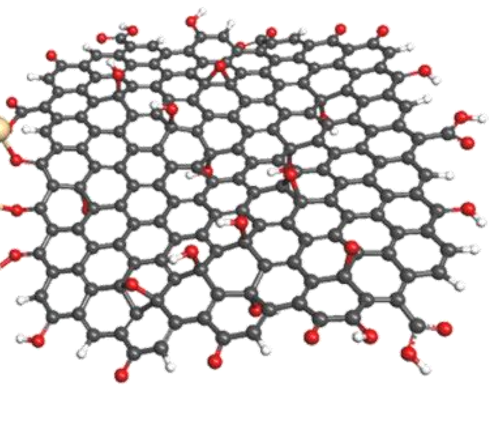

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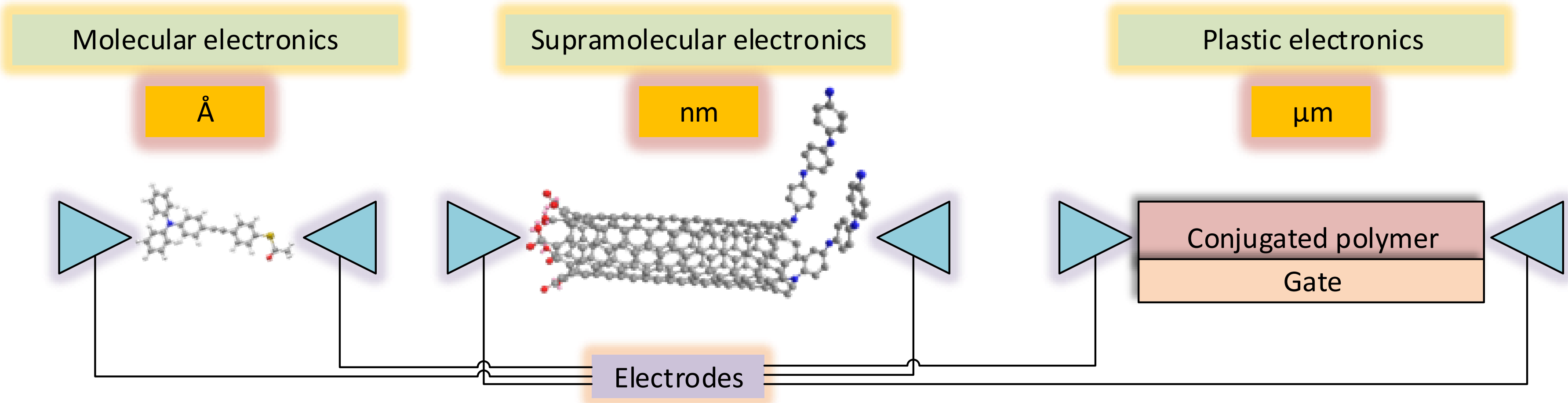

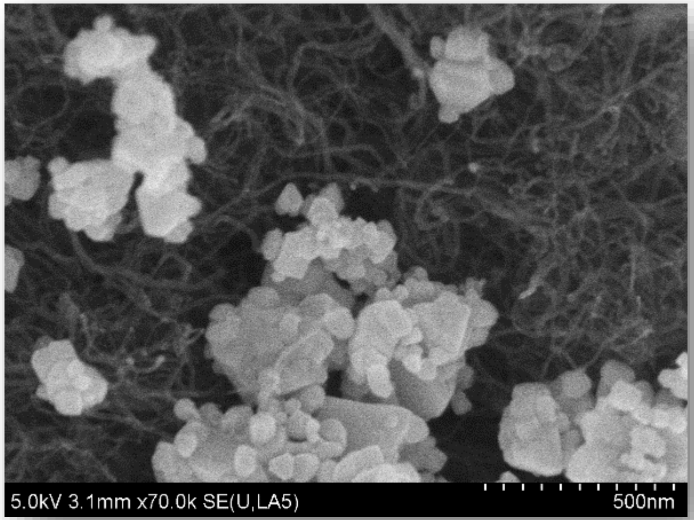

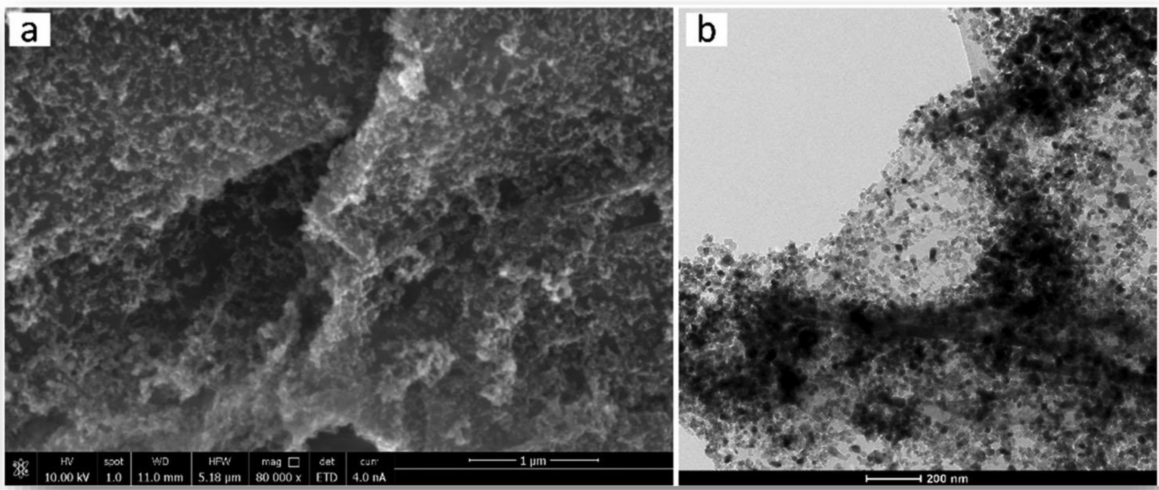

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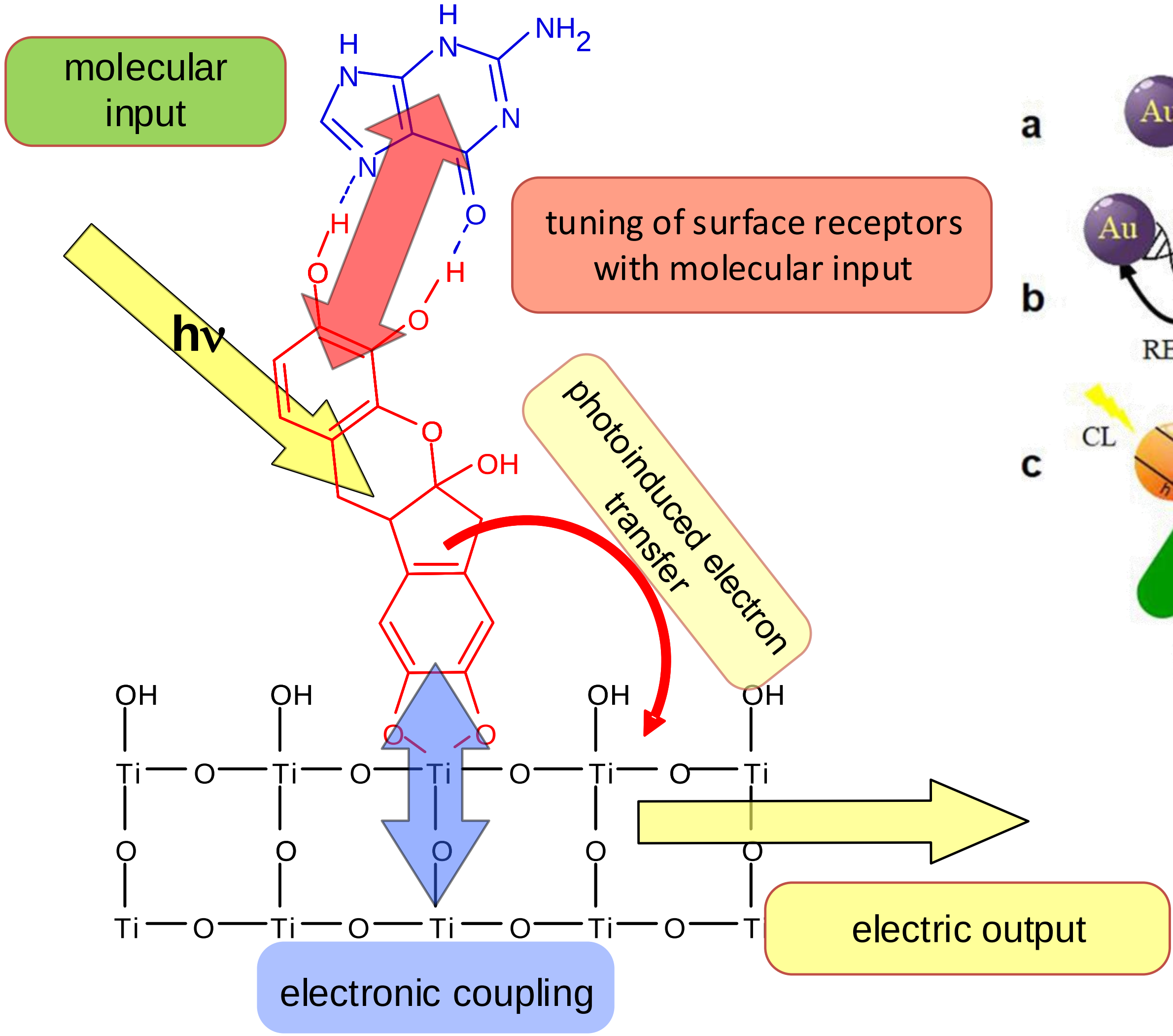
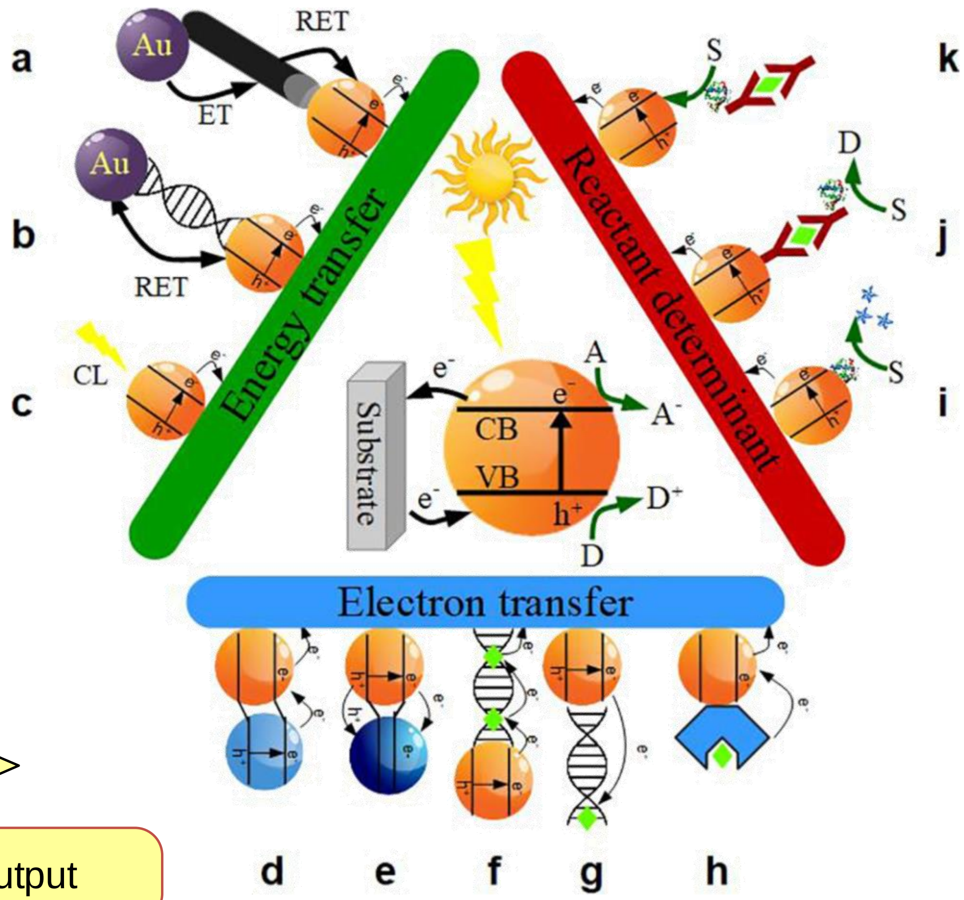
Zasada działania omawianych układów





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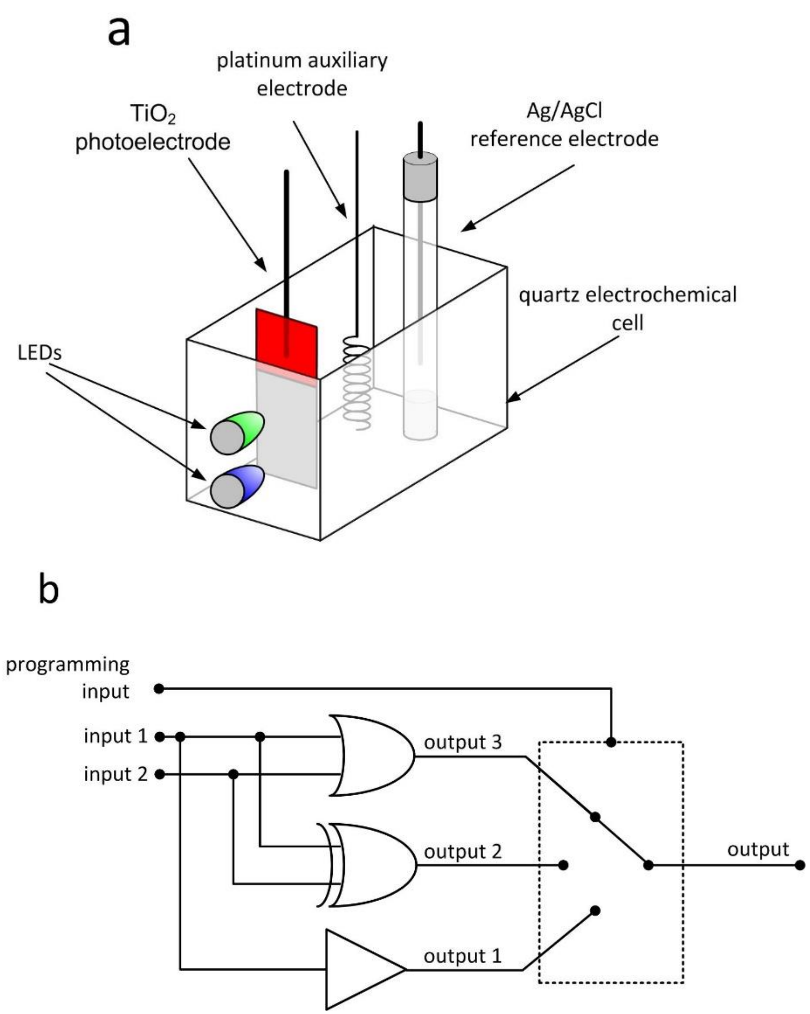
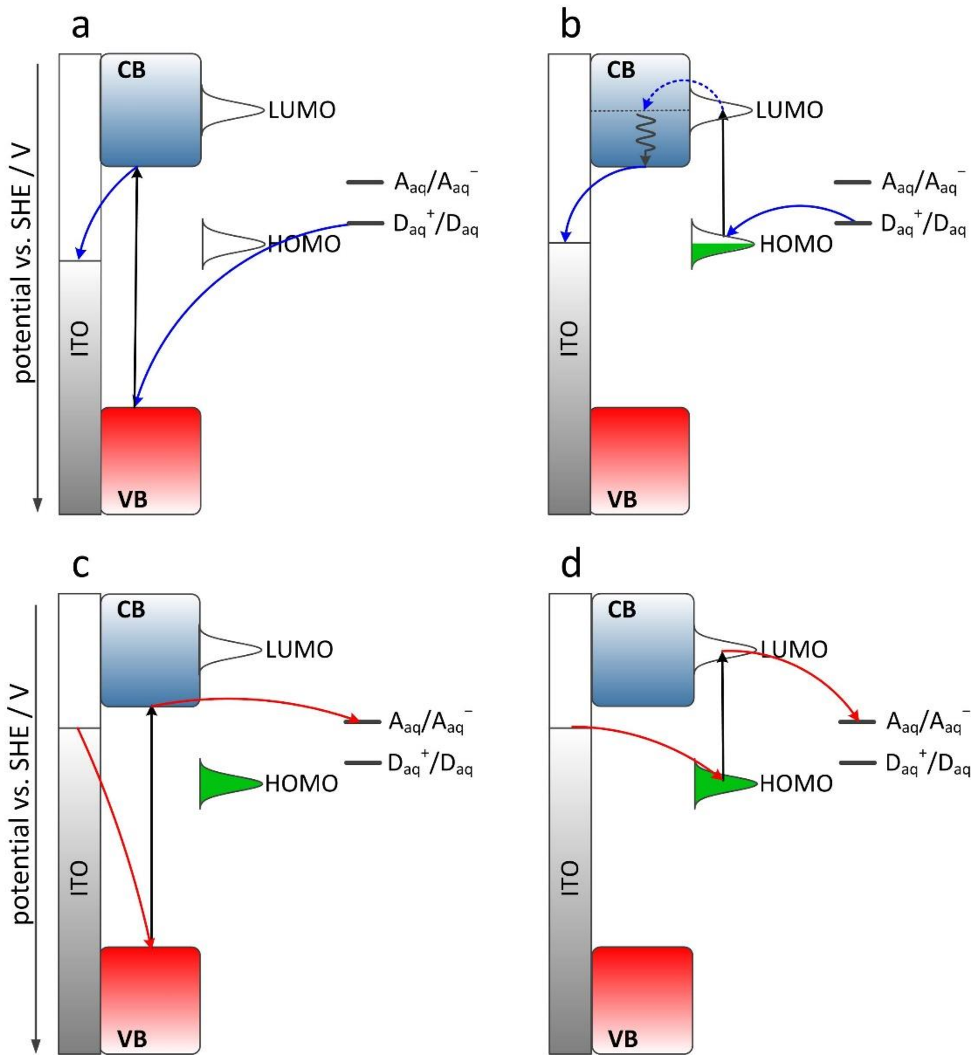
Zasada działania omawianych układów

- Efekt fotoelektrochemicznego przełączenia fotoprądu (efekt PEPS).





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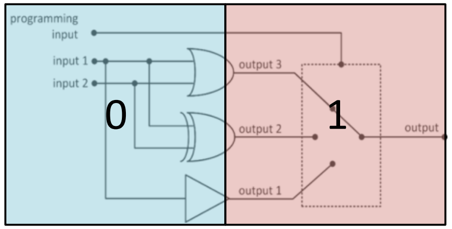
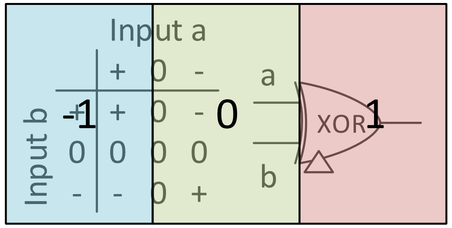
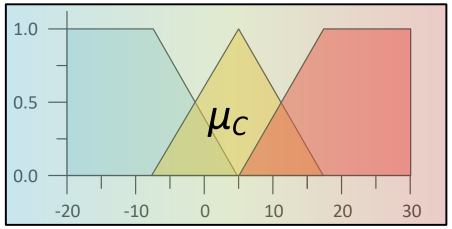
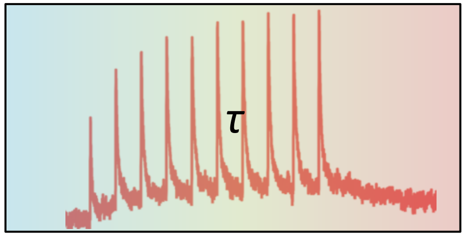
Zasada działania omawianych układów









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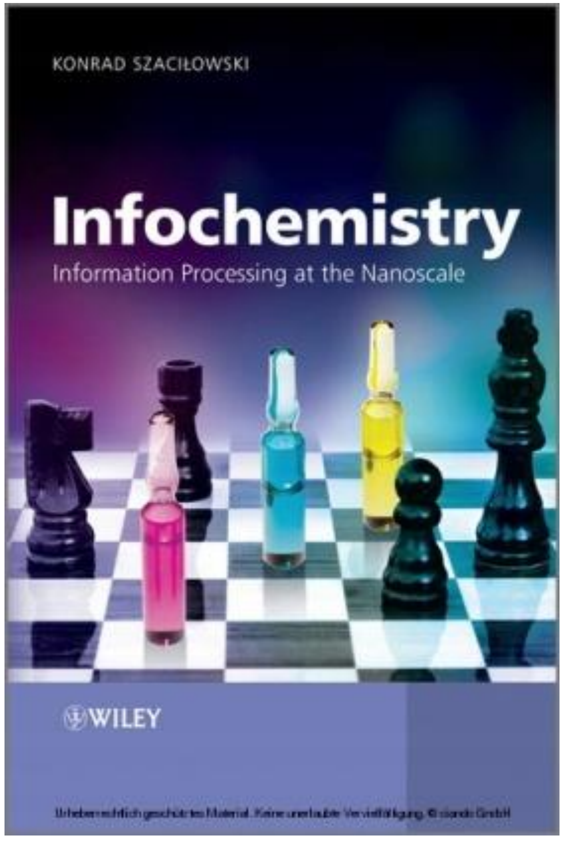

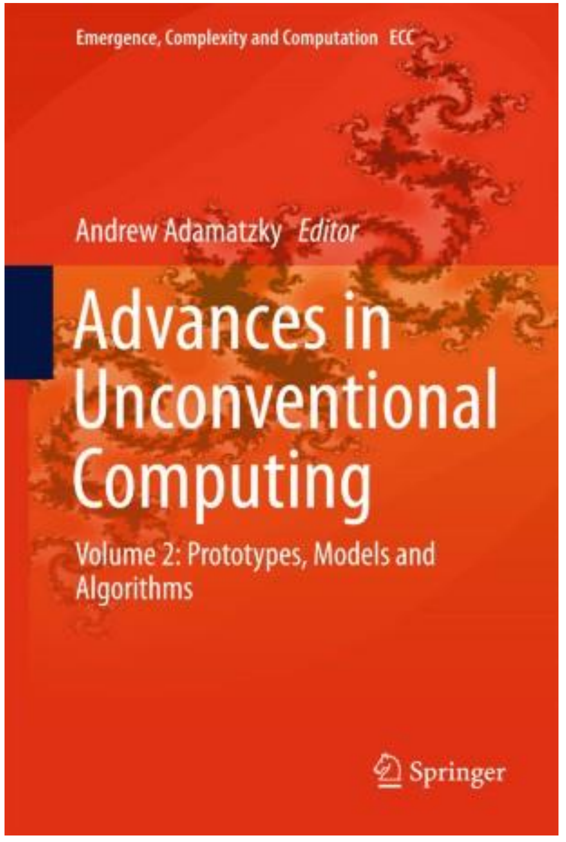

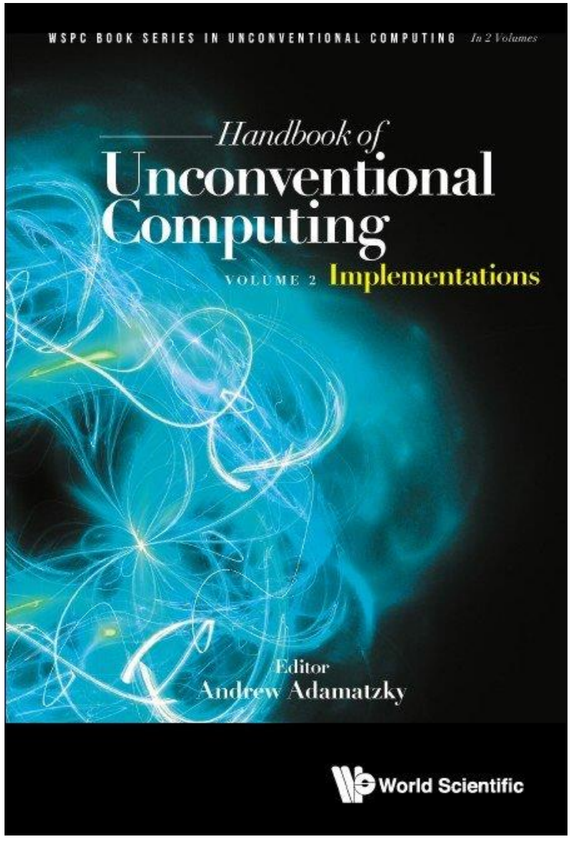

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Review

Molecules, semiconductors, light and inforr sensing and computing paradigms

Kacper Pilarczyk [a,*], Ewelina Wlaźlak [a,b,*], Dawid Przyczy Agnieszka Podborska [a], Vasileios Anathasiou [e], Zoran Kor

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Heavy pnictogen chalcohalides: the synthesis, structure and properties of these rediscovered semiconductors†

Ewelina Wlaźlak,*[ab] Andrzej Blachecki,[ac] Magdalena Bisztyga-Szklarz,[a] Sylwia Klejna,[a] Tomasz Mazur,[a] Krzysztof Mech,*[a] Kacper Pilarczyk,[a] Dawid Przyczyna,[ad] Maciej Suchecki,[ad] Piotr Zawal[ad] and Konrad Szaciłowski *[a]

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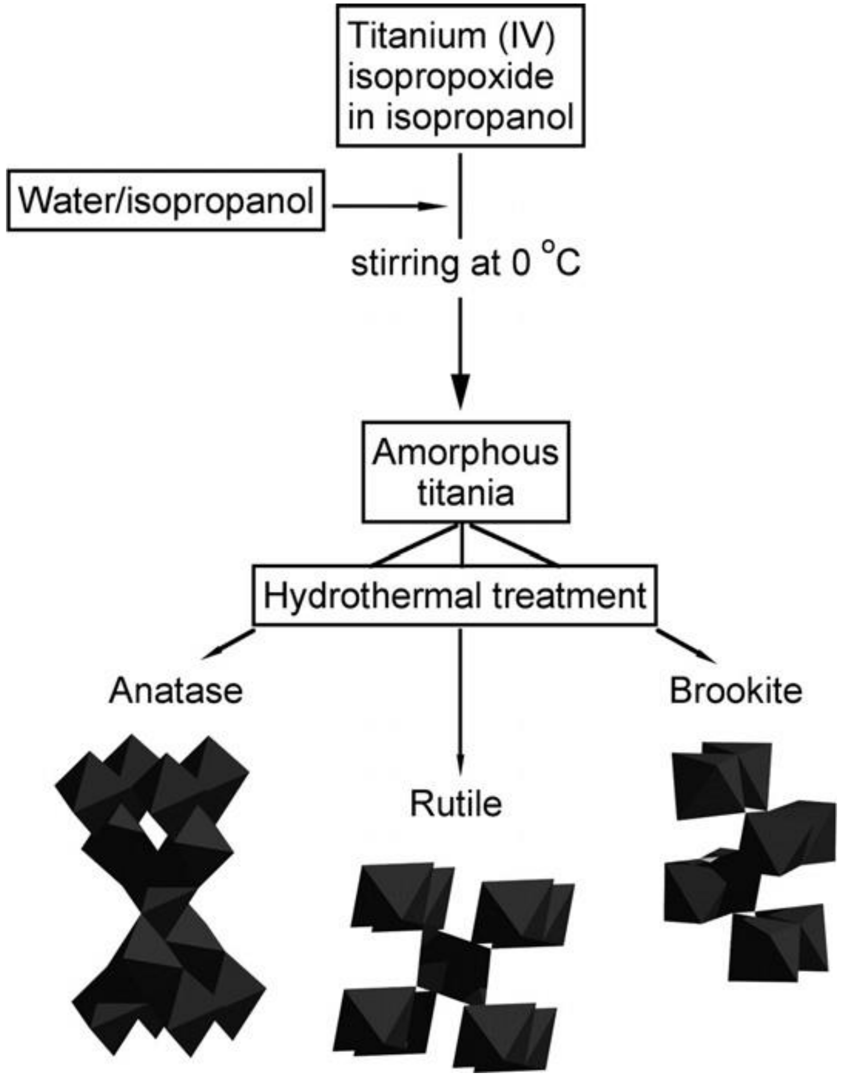
rsc.li/chemcomm

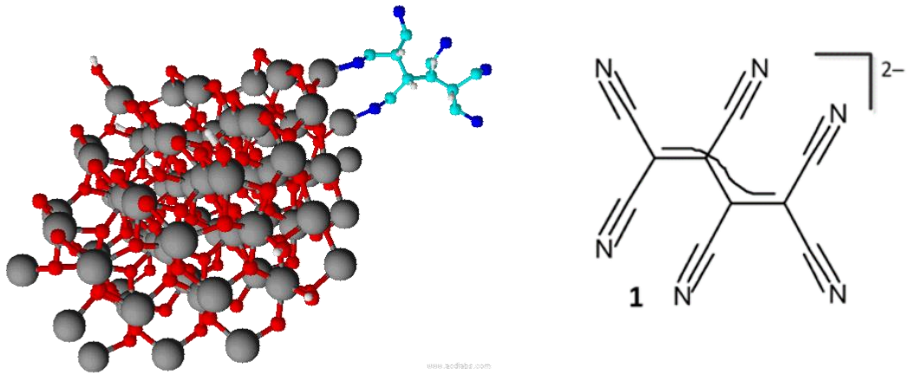
This review focuses on the synthesis, properties and selected applications of heavy pnictogen chalcohalides, *i.e.* compounds of the MQX stoichiometry, where M = As, Sb, and Bi; Q = O, S, Se, and Te; and X = F, Cl, Br and I. The first section focuses on their synthesis and crystal structures, and the second section discusses the electronic structure on the basis of quantum chemical modelling and selected experimental data. Finally, the third section discusses their electrical, photoelectrochemical and photocatalytic properties and applications. In contrast to perovskites, chalcopyrites and kesterites, chalcohalides have attracted relatively less attention, but their structure and properties are well suited for numerous applications.

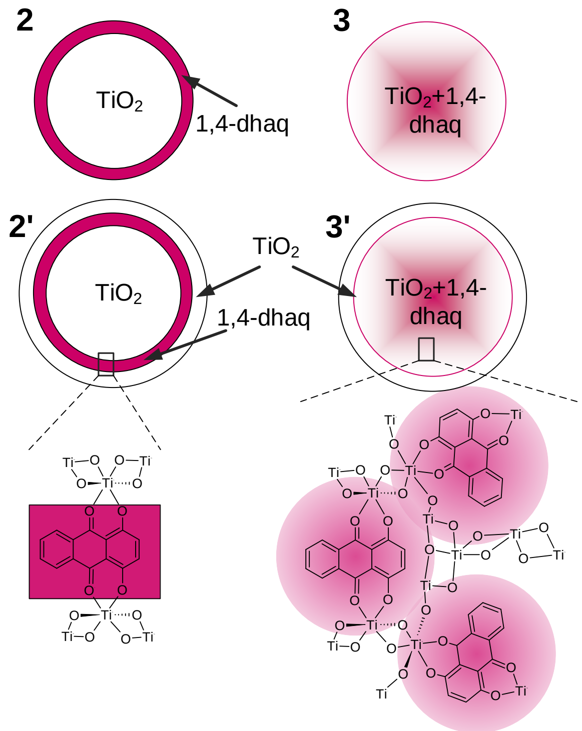
Materiały hybrydowe

Półprzewodniki szerokopasmowe – TiO_2

- P25







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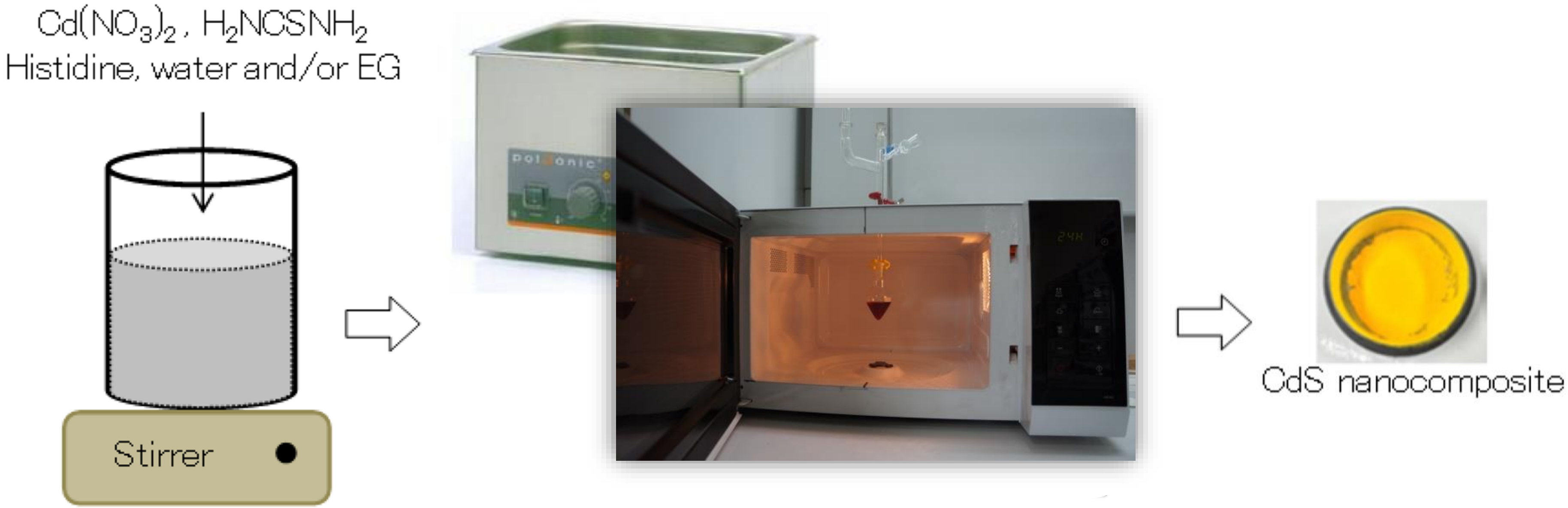
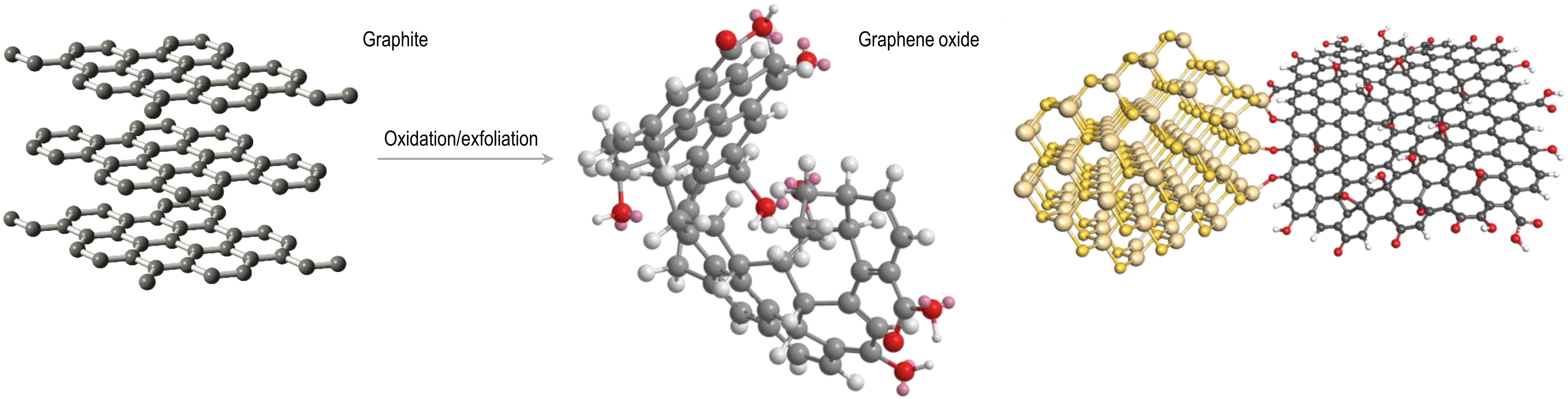
Półprzewodniki szerokopasmowe - CdS





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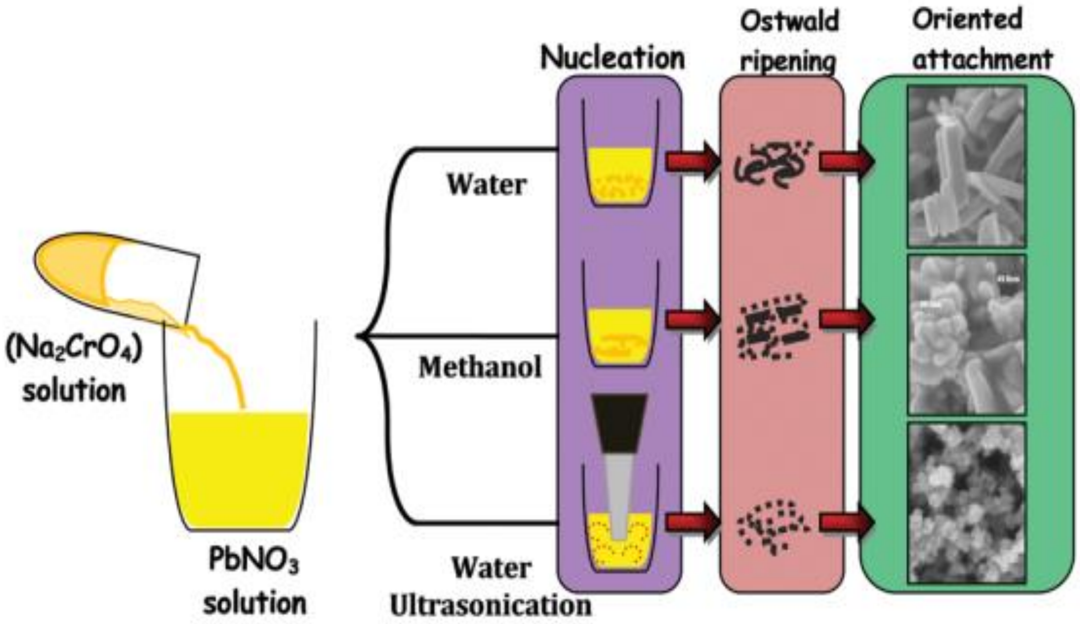
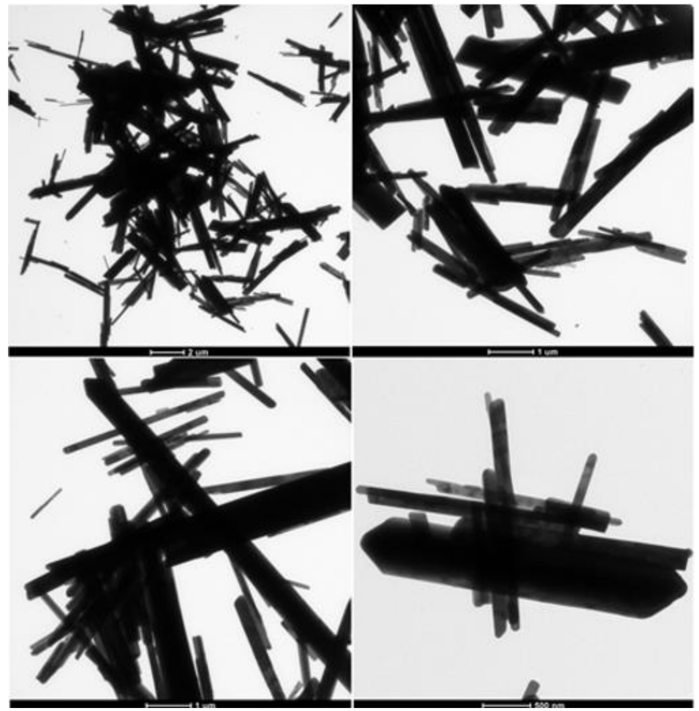
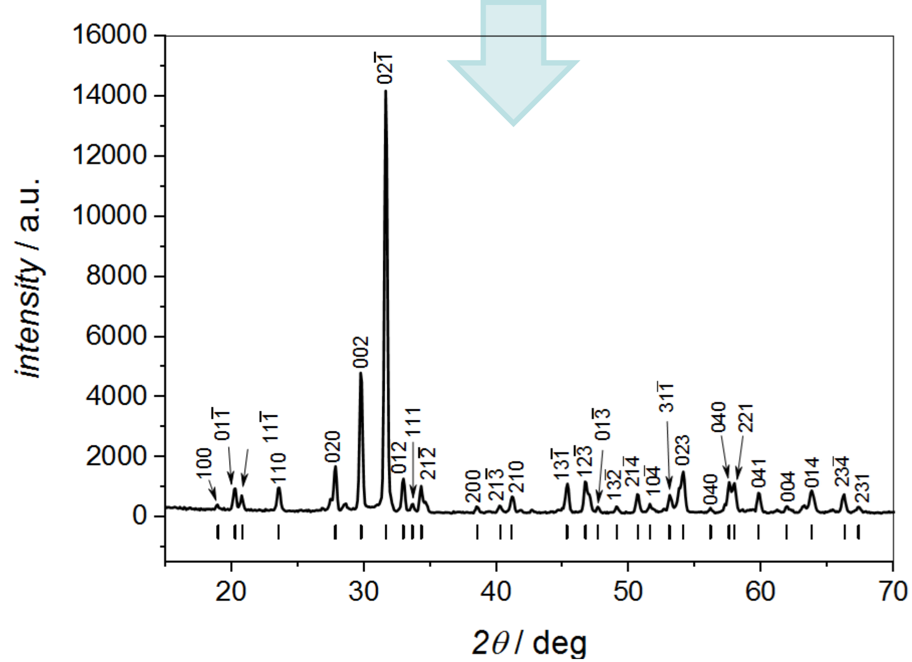
Półprzewodniki szerokopasmowe







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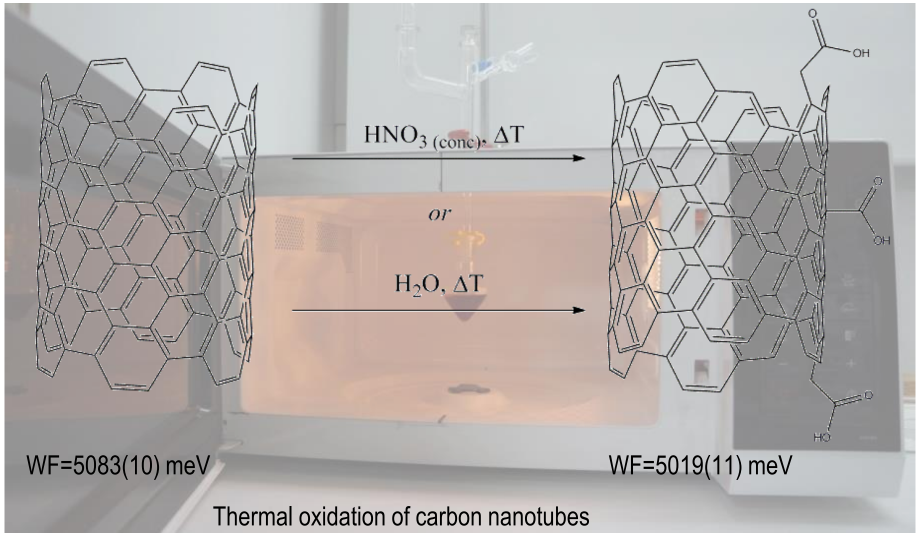
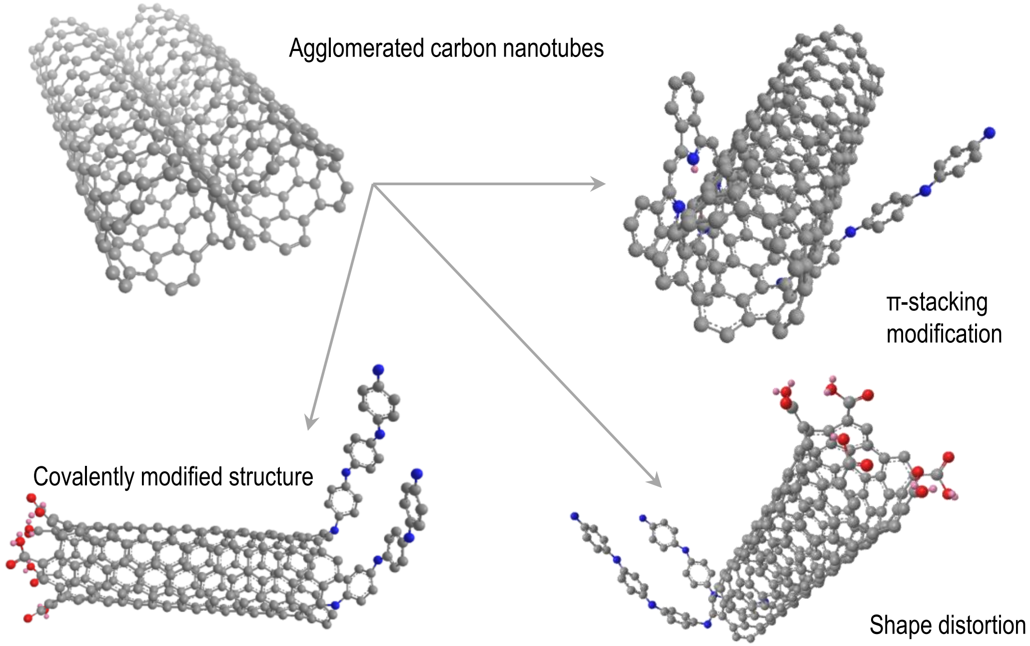
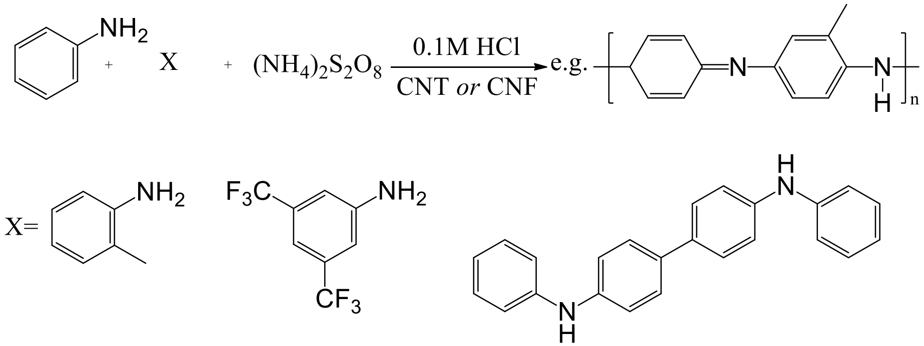
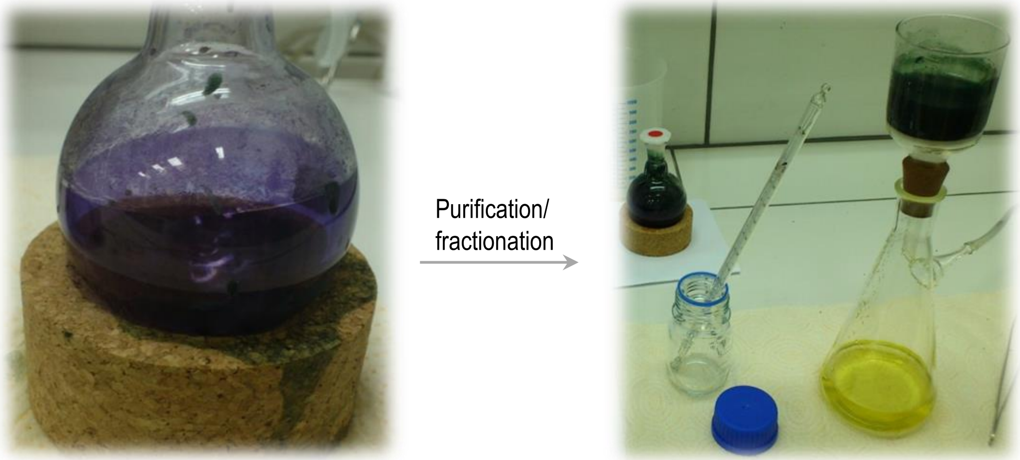
Nanostruktury węglowe jako modyfikatory







o-toluidine   3,5-bis(trifluoromethyl)aniline (BTFMA)   N,N'-Diphenylbenzidine (DPB)



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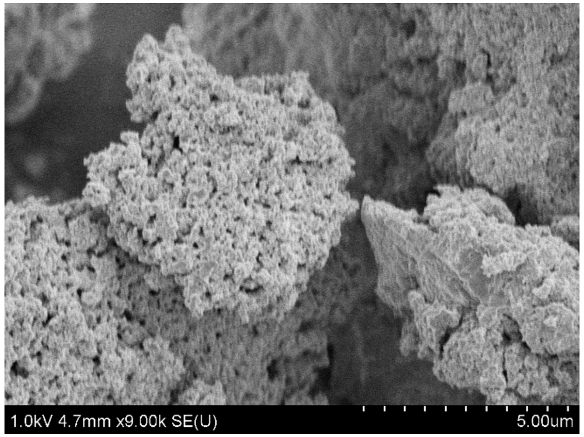
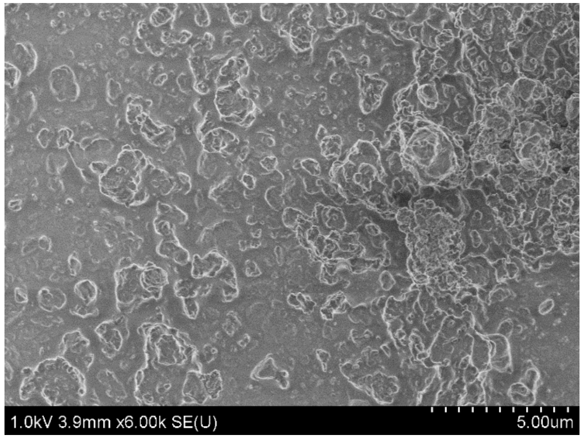
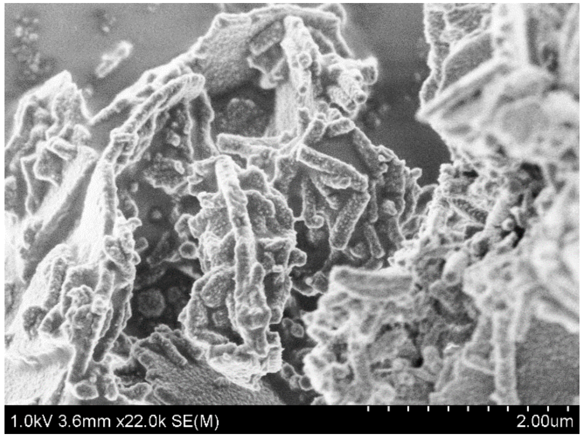
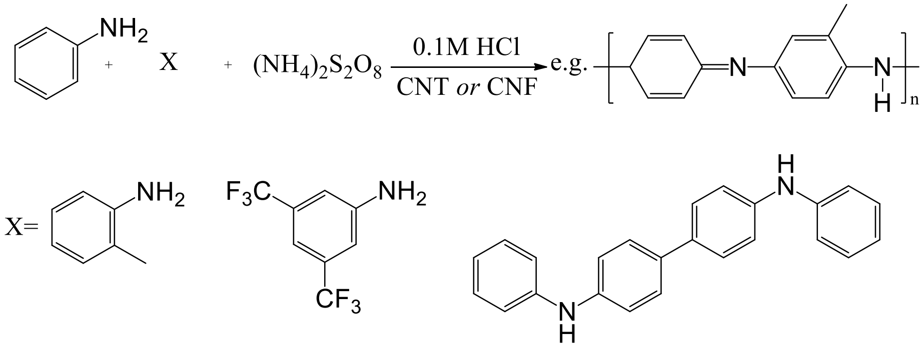






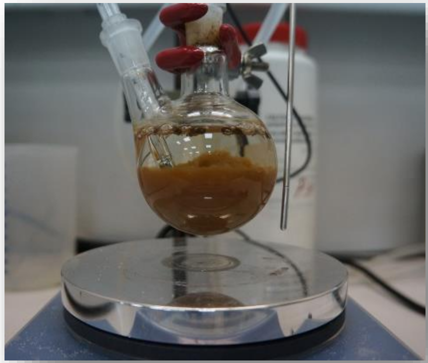


o-toluidine   3,5-bis(trifluoromethyl)aniline (BTFMA)   N,N'-Diphenylbenzidine (DPB)

Purification/
fractionation

Nanostruktury węglowe jako modyfikatory

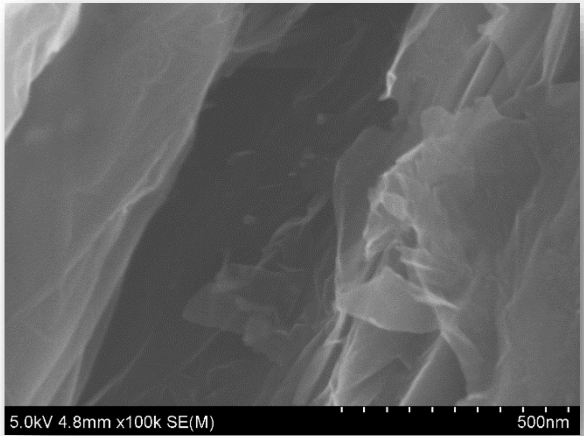
The experimental setup.



Unpurified product.

Purification process.

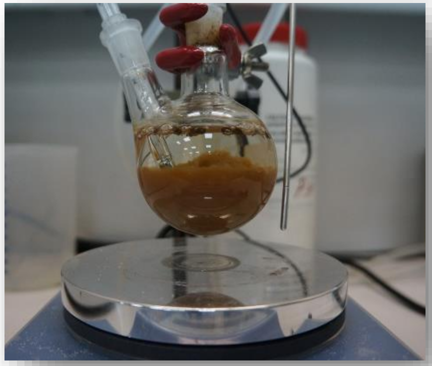
Drying



The final product.

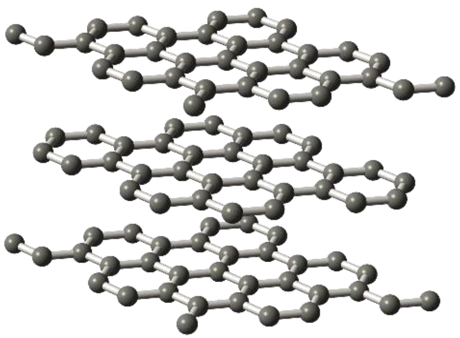
Nanostruktury węglowe jako modyfikatory

The experimental setup.



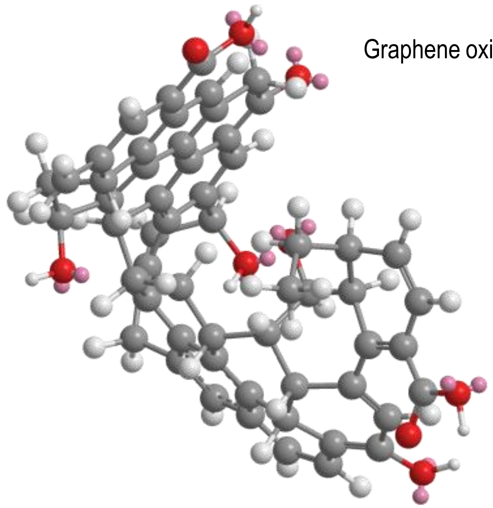
Unpurified product.

Purification process.



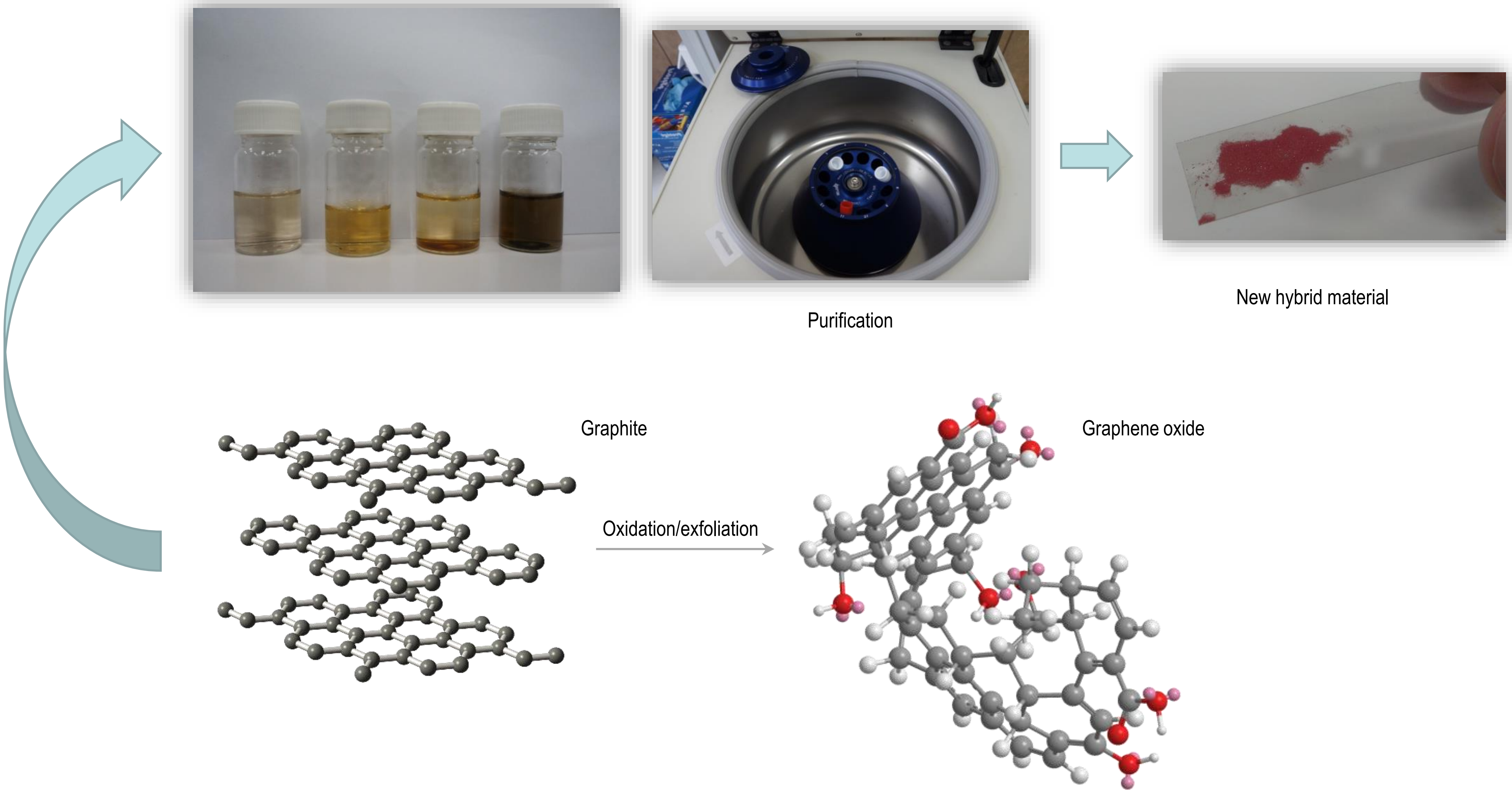
Graphite

Oxidation/exfoliation



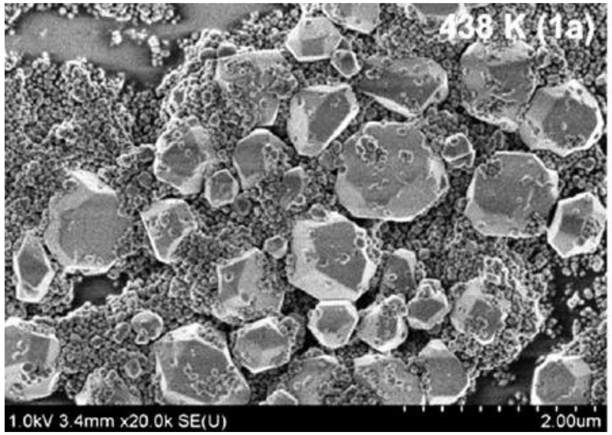
Graphene oxide

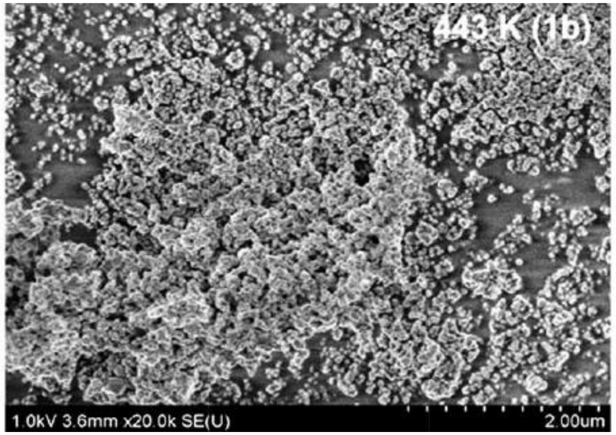
Nanostruktury węglowe jako modyfikatory

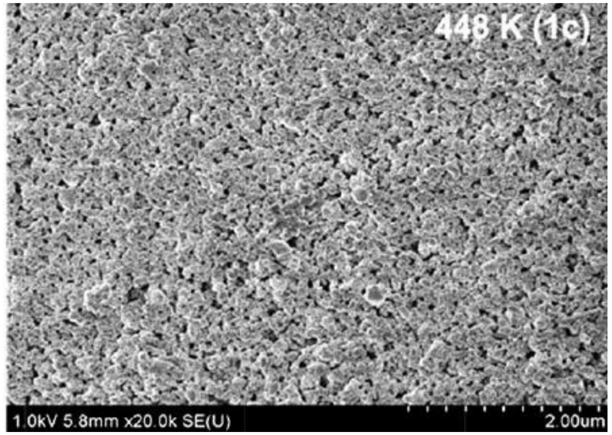


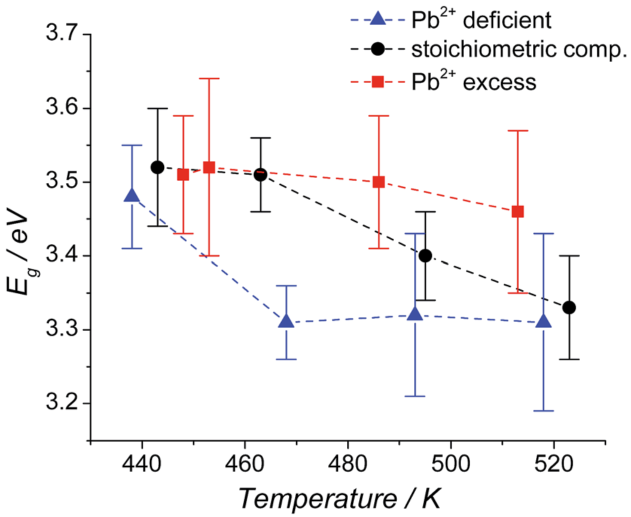
Zastosowanie
Przetwarzanie informacji

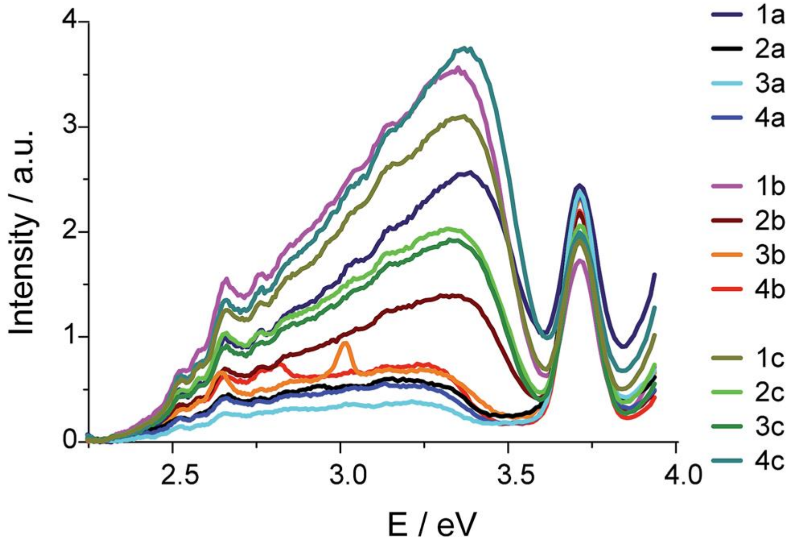
Logika binarna – $PbMoO_4$











- P. Kwolek, K. Pilarczyk, T. Tokarski, M. Łapczyńska, M. Pacia, K. Szaciłowski, J. Mater. Chem. C, 2015, 3, 2614

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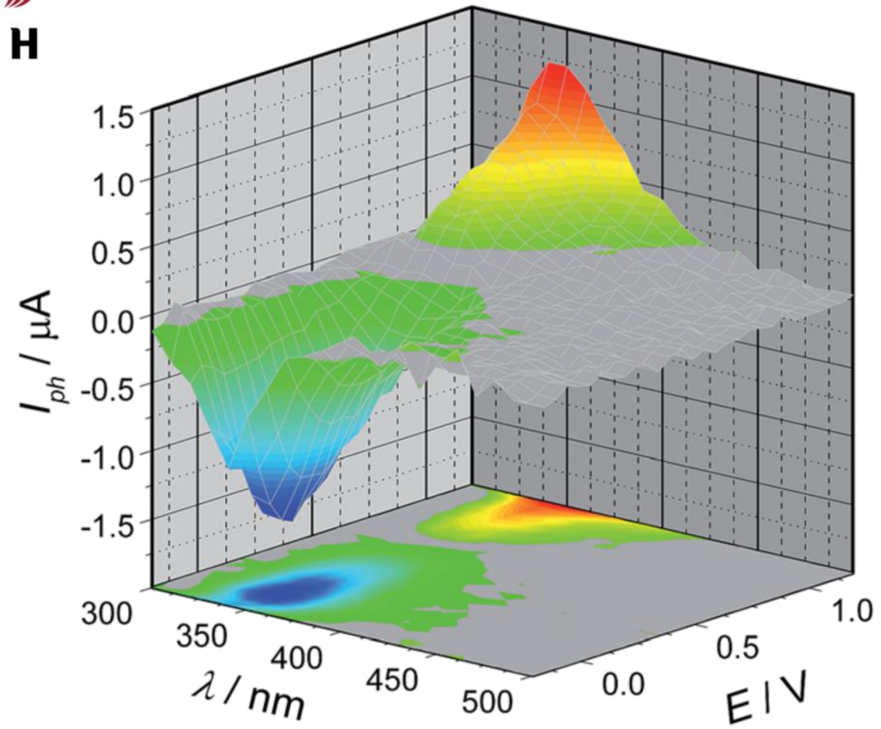

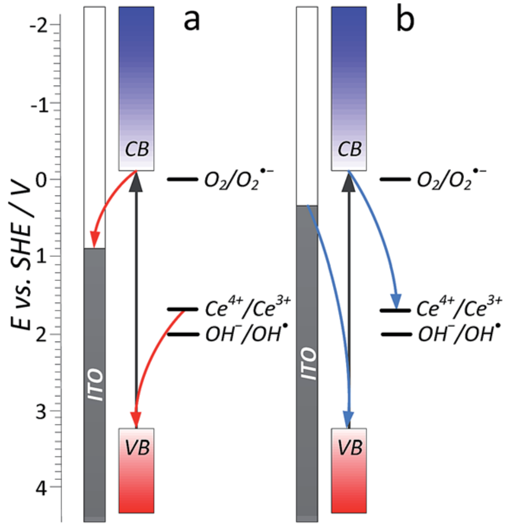

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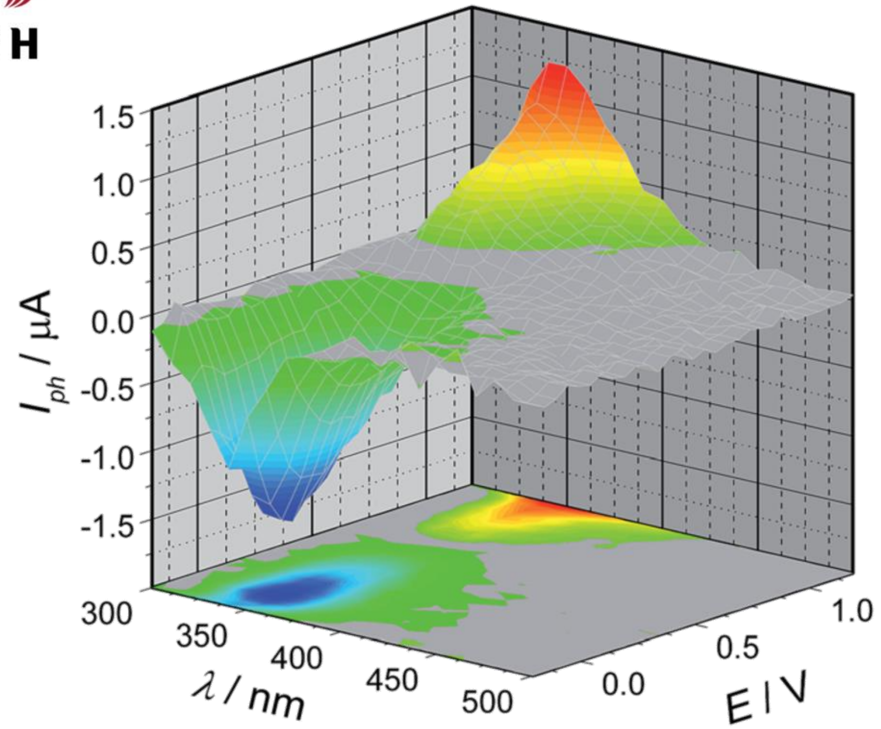

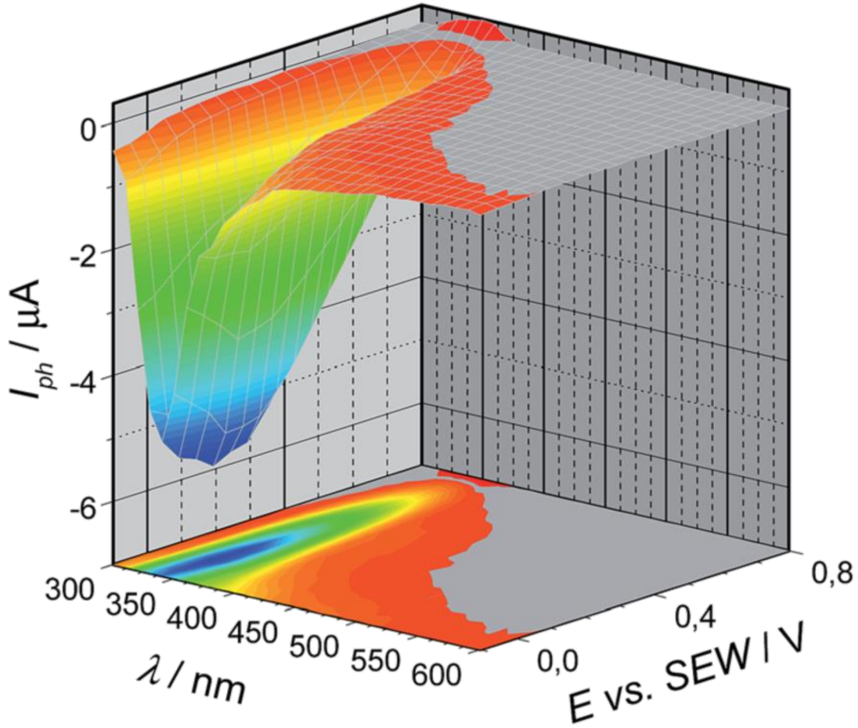

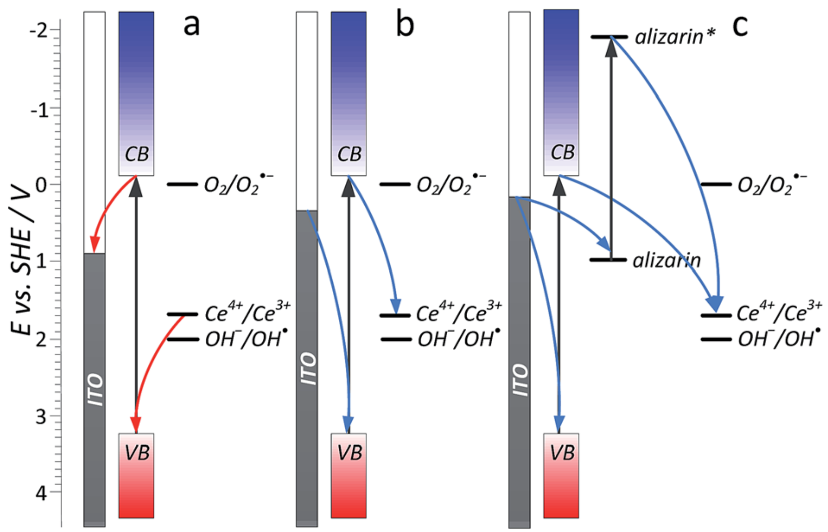

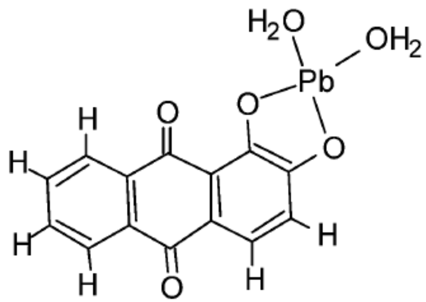

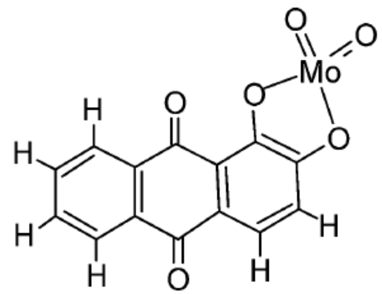

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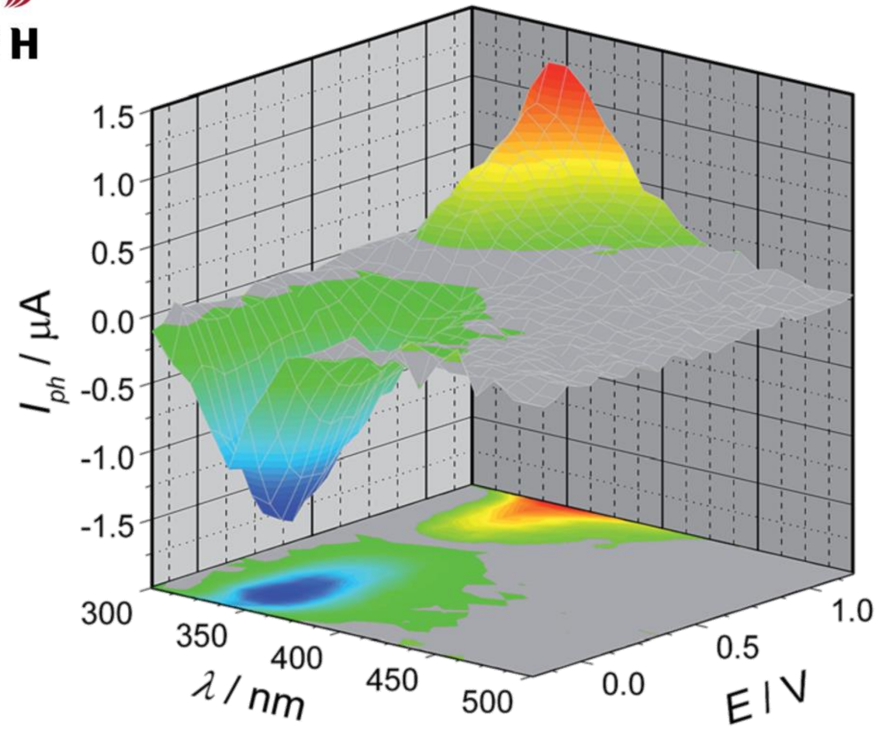
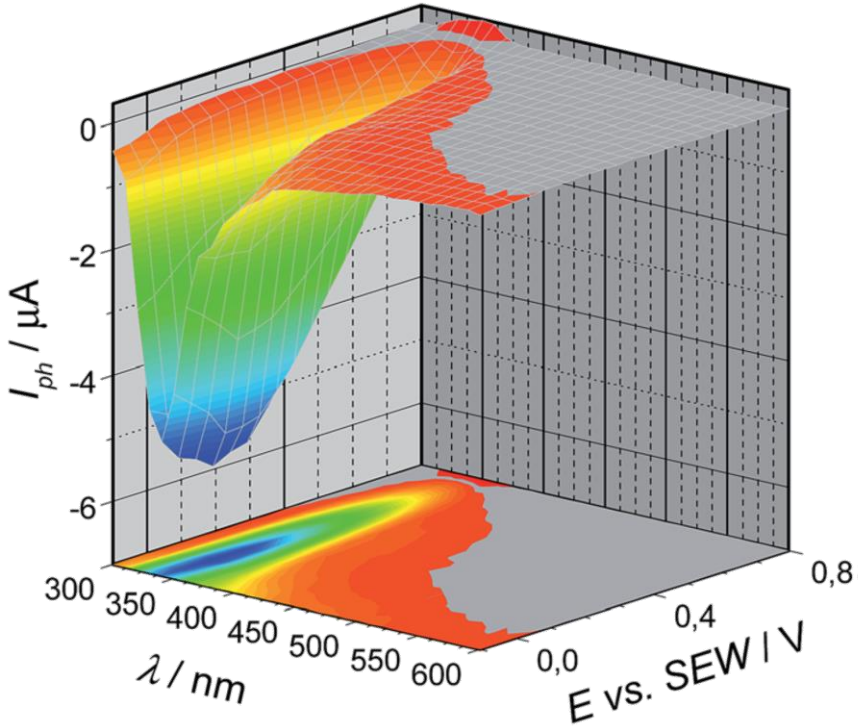
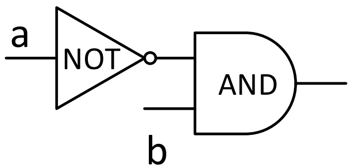
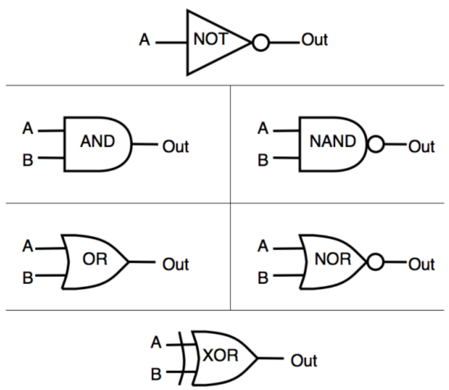


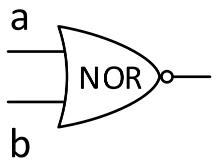


b \ a	+	-
+	-	+
-	-	-





b \ a	+	-
+	-	-
-	-	+



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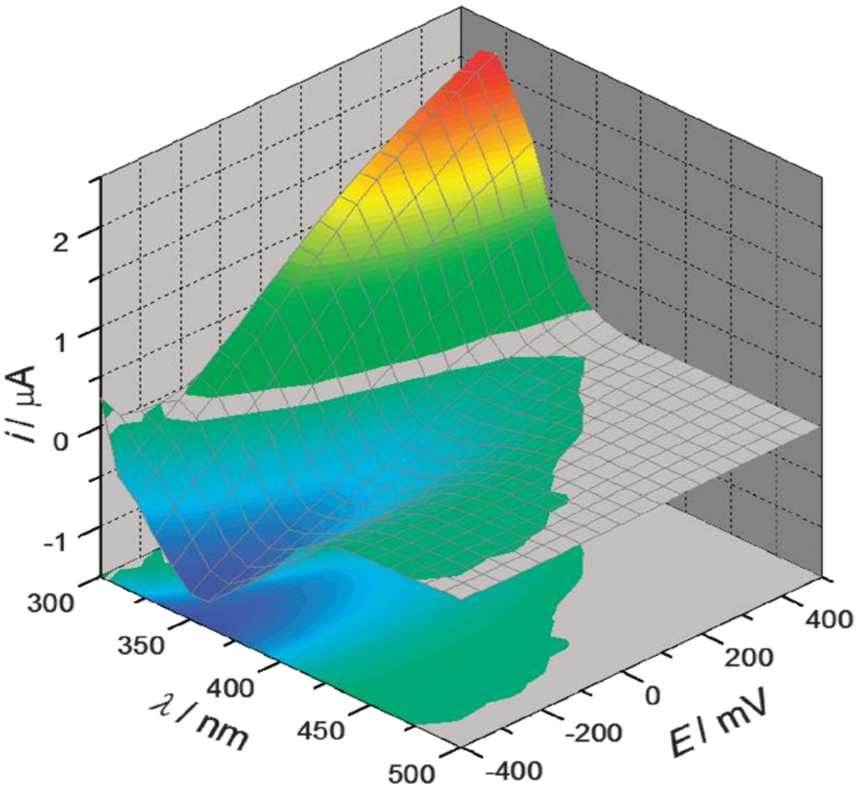
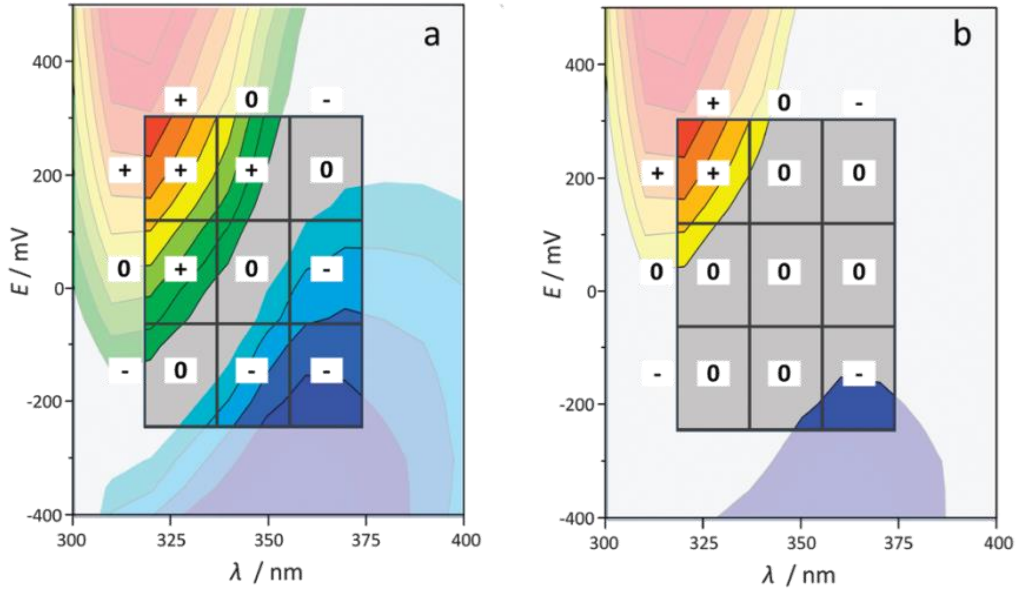
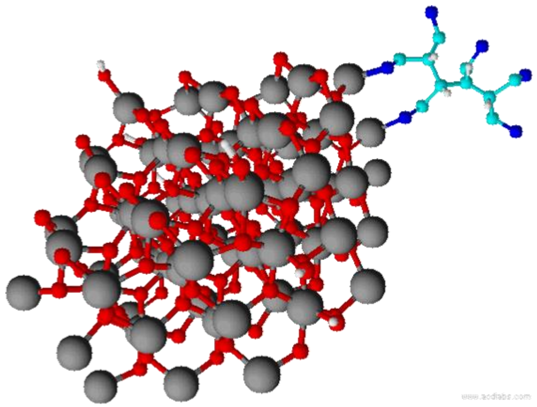
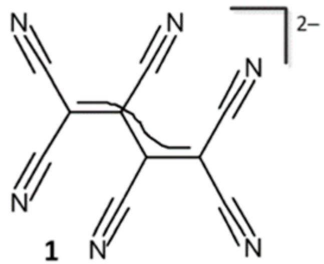
Logika trójwartościowa – TiO_2





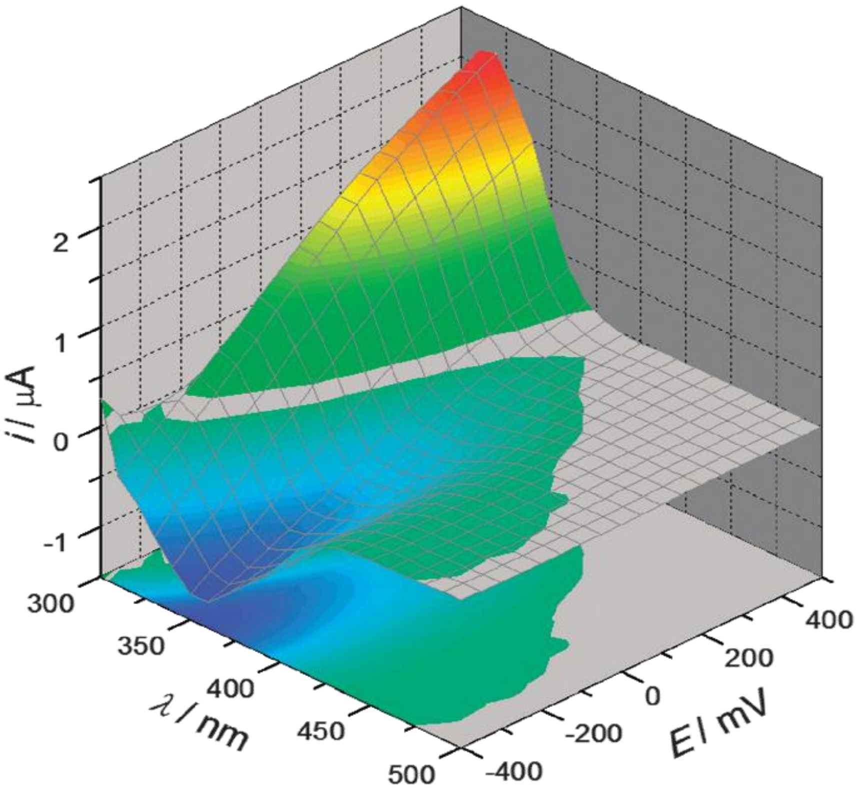


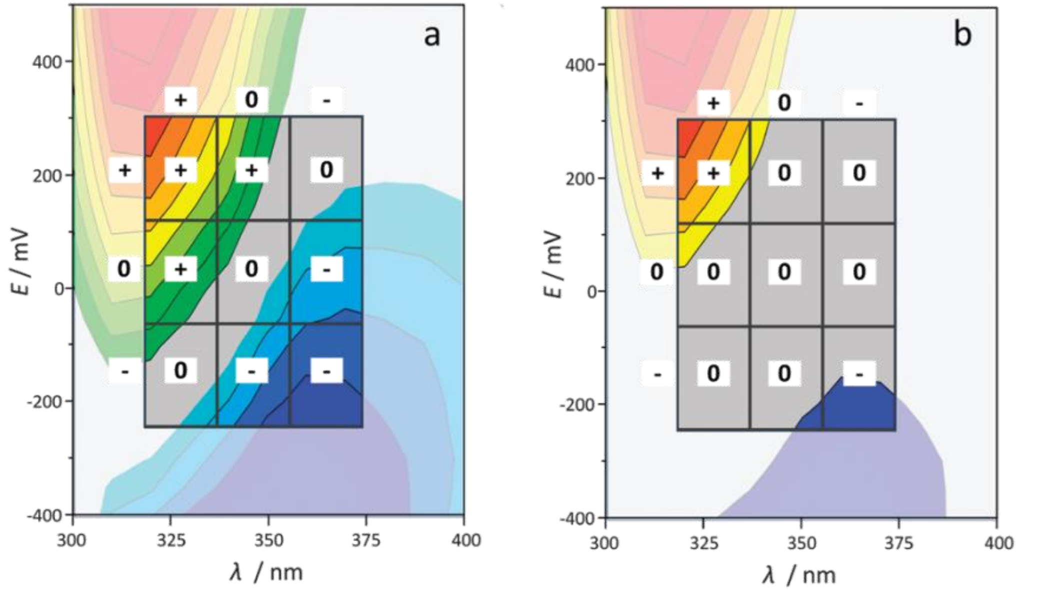


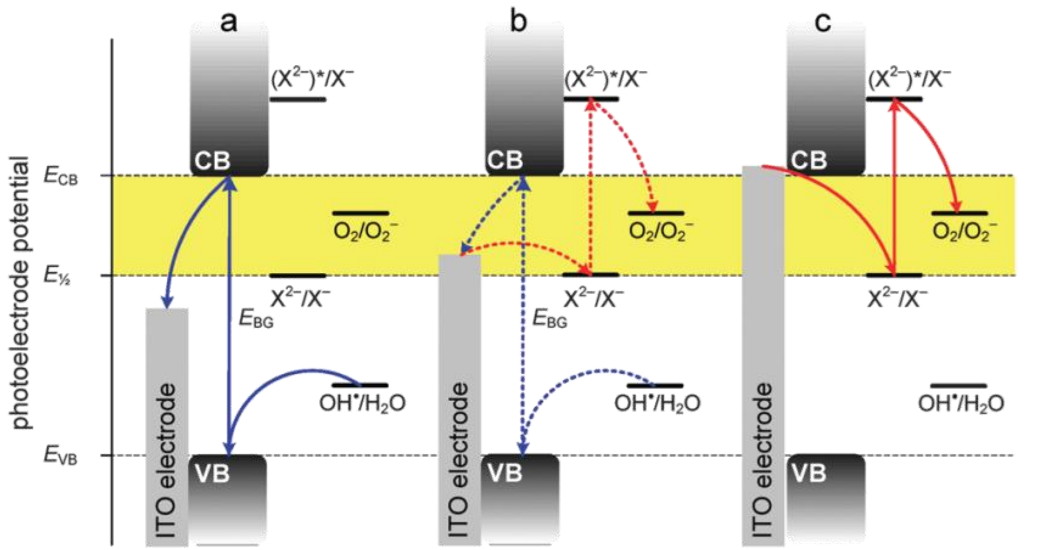
1

- M. Warzecha, M. Oszajca, K. Pilarczyk, K. Szaciłowski, Chem. Commun., 2015, 51, 3529

Logika trójwartościowa – TiO_2







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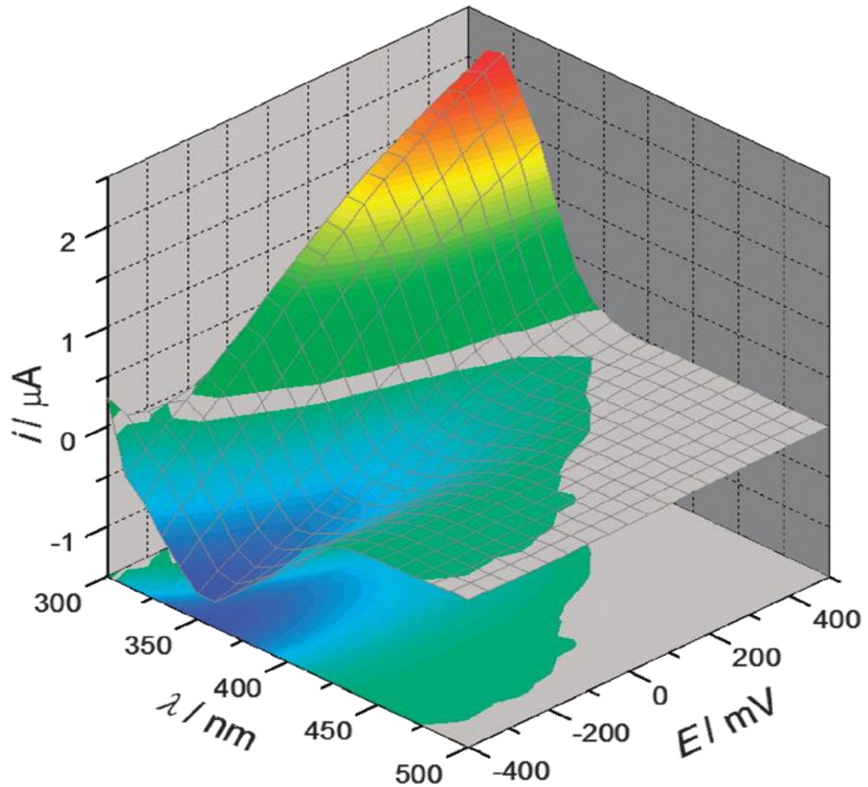
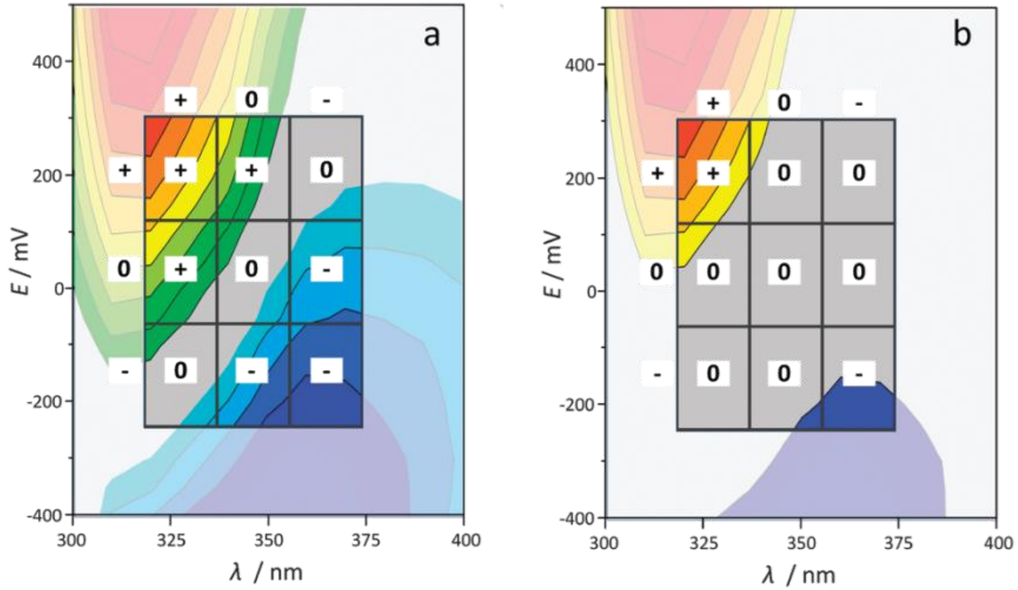
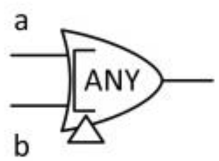




Input b \ Input a	+	0	-
+	+	+	0
0	+	0	-
-	0	-	-



Input b \ Input a	+	0	-
+	+	0	0
0	0	0	0
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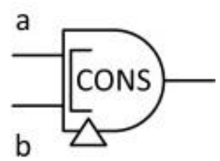

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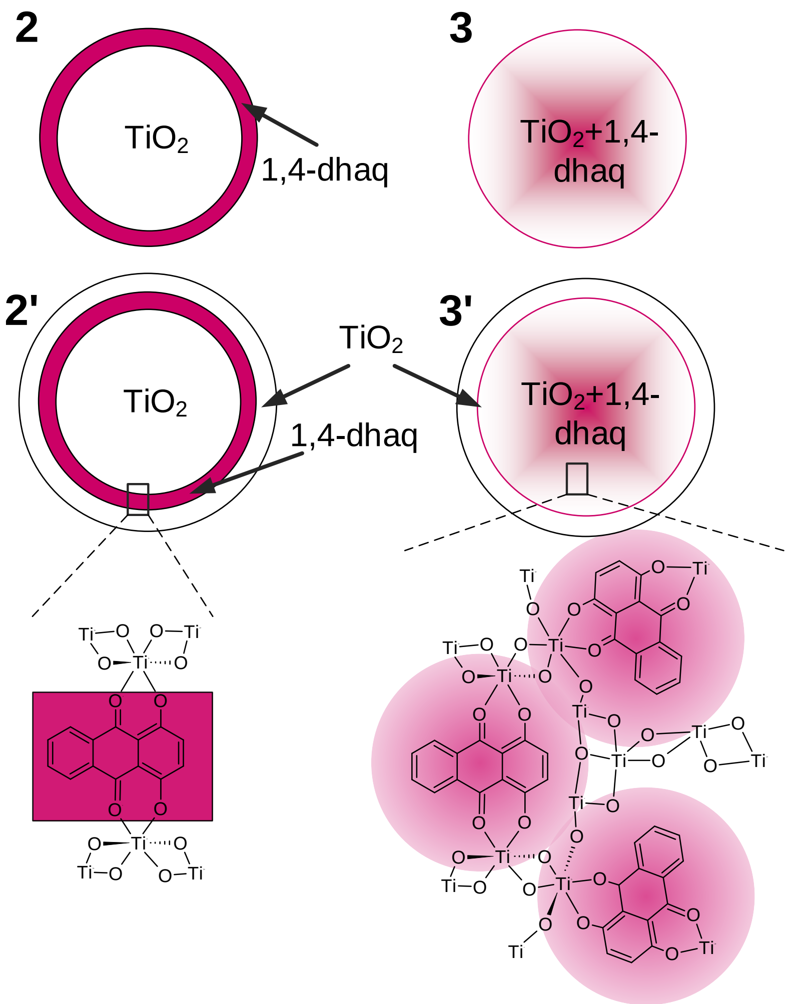
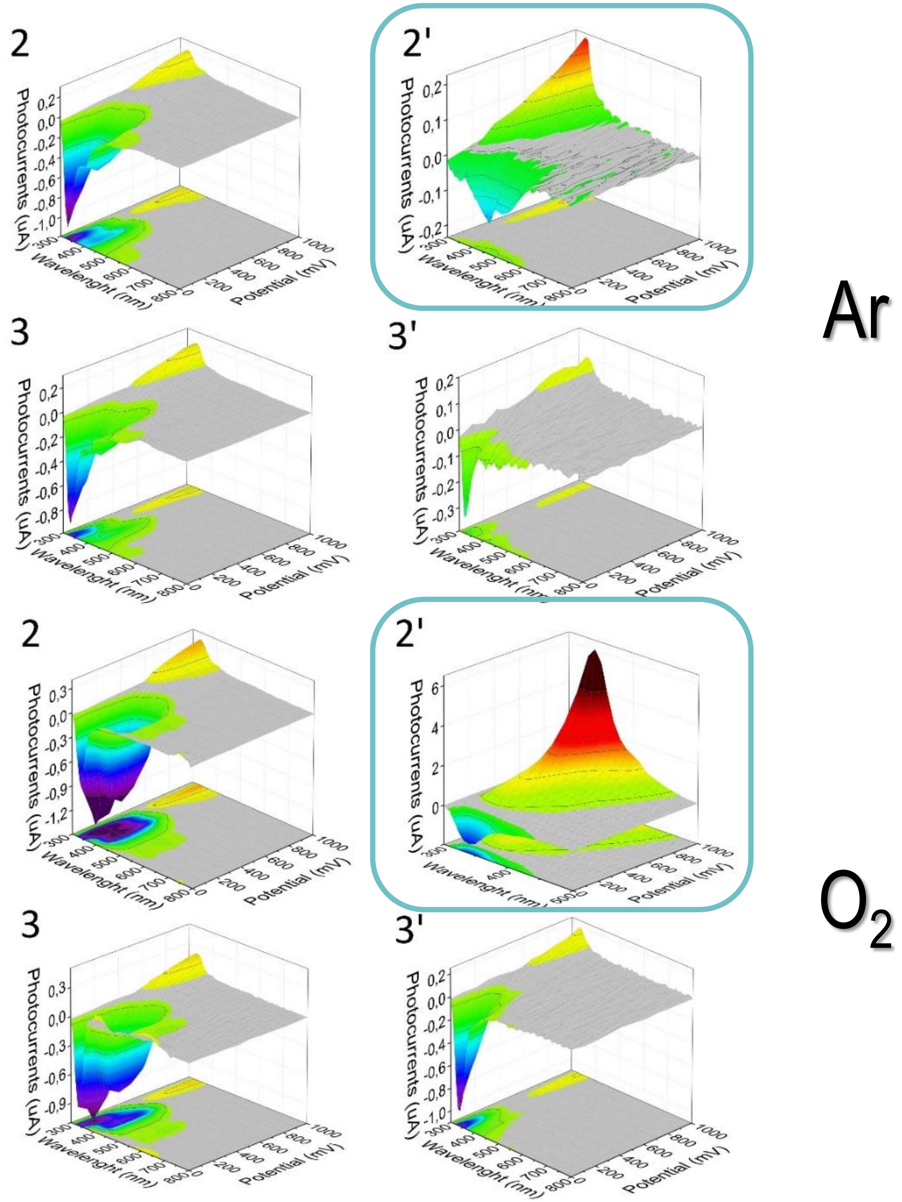
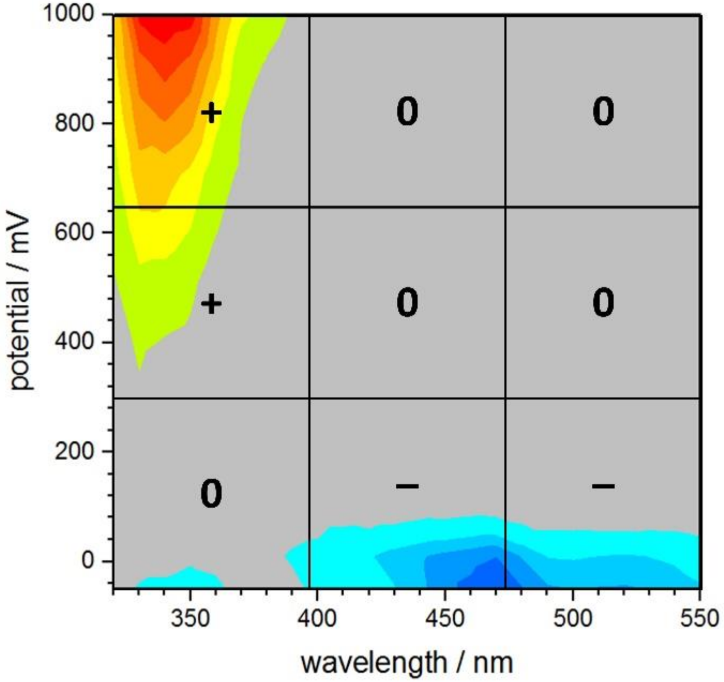
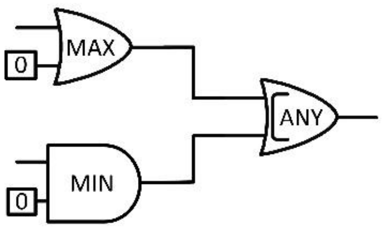




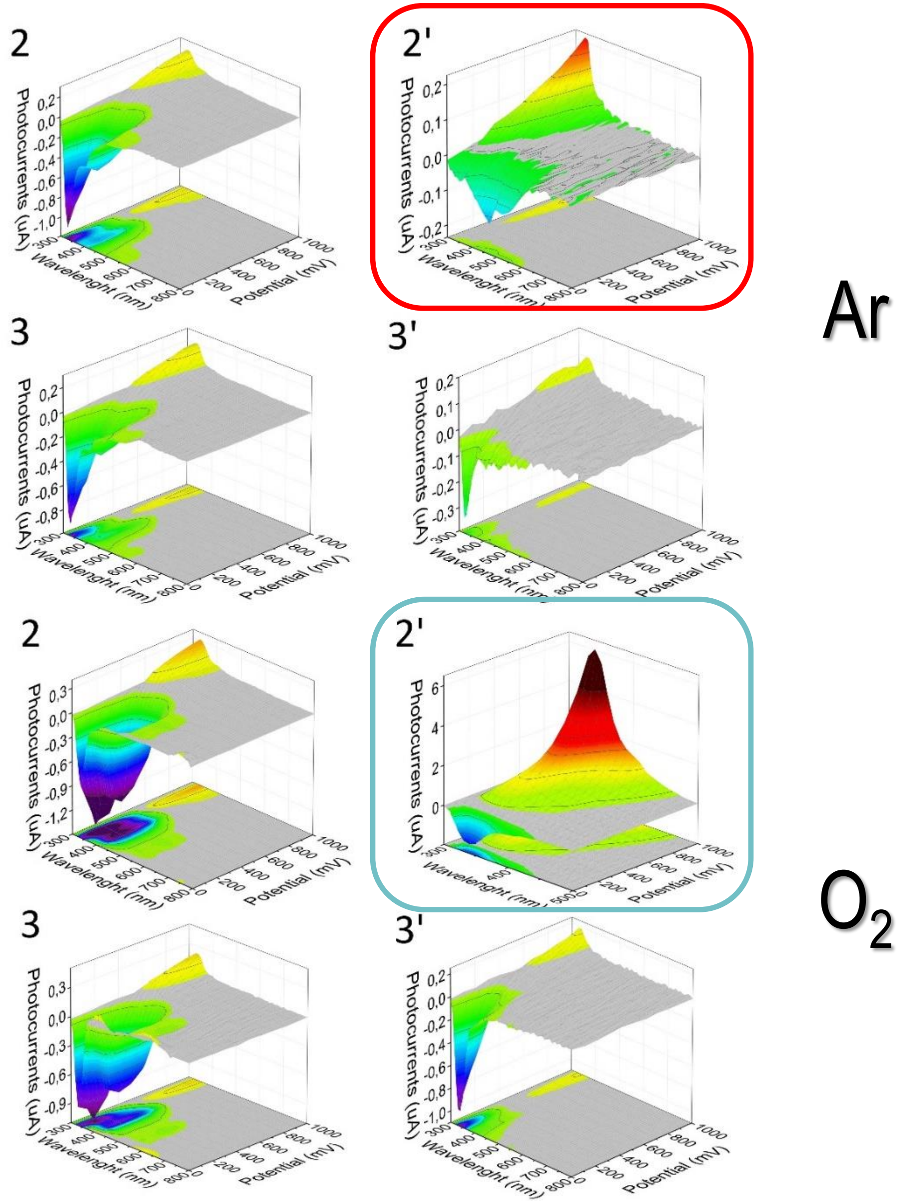
- A. Blachecki, J. Mech-Piskorz, M. Gajewska, K. Mech, K. Pilarczyk, K. Szacilowski, ChemPhysChem, 2017, 18, 1798

Logika trójwartościowa – TiO_2





		Energy		
Potential		1	0	-1
	1	1	0	0
	0	1	0	0
	-1	0	-1	-1



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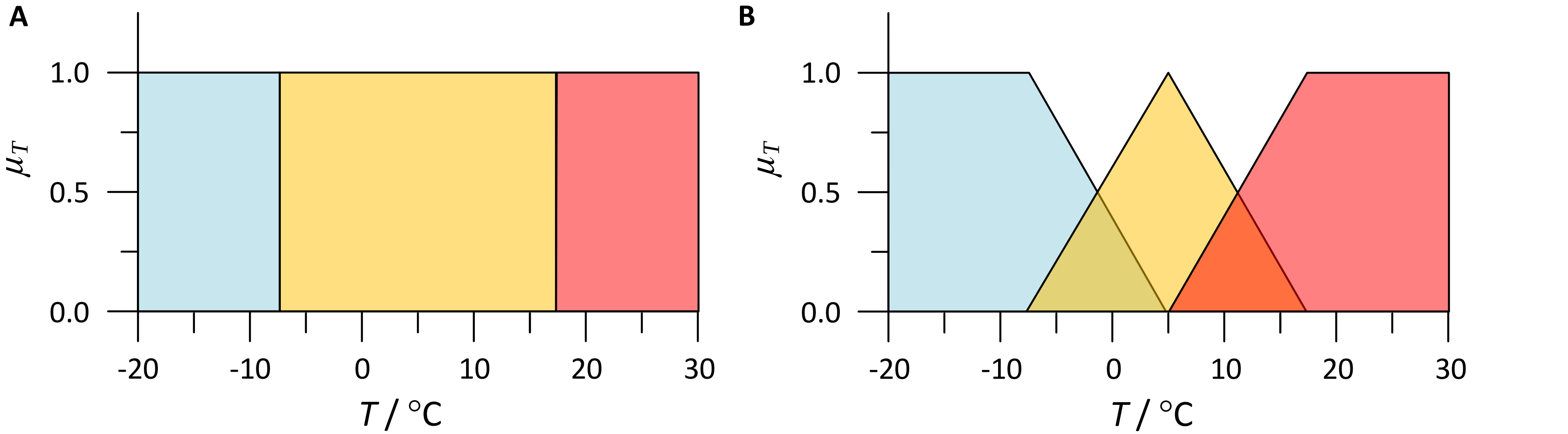
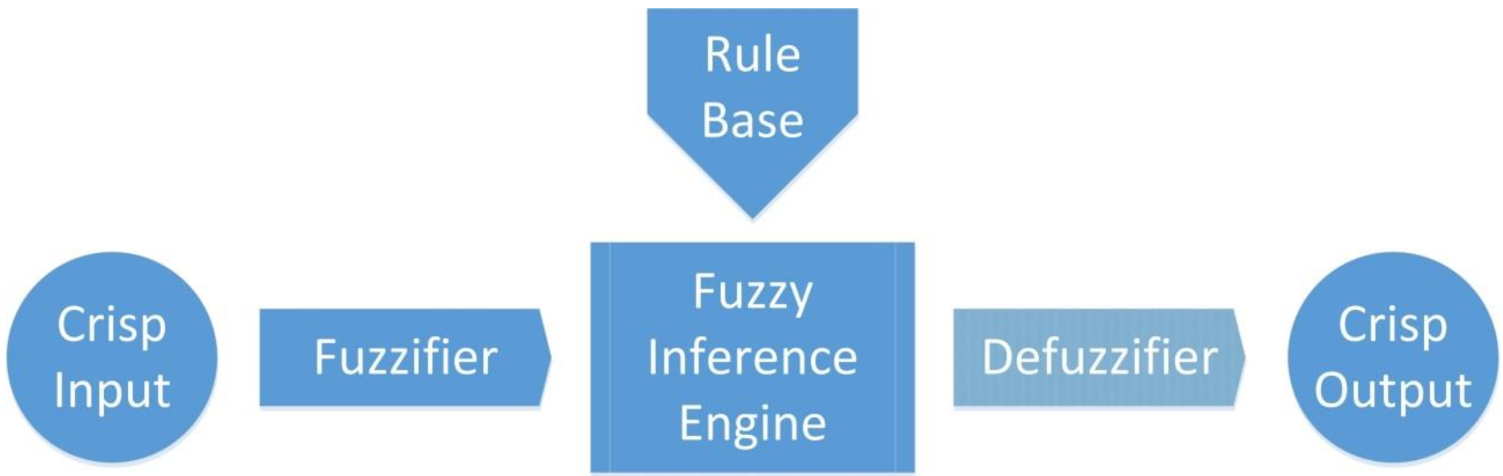
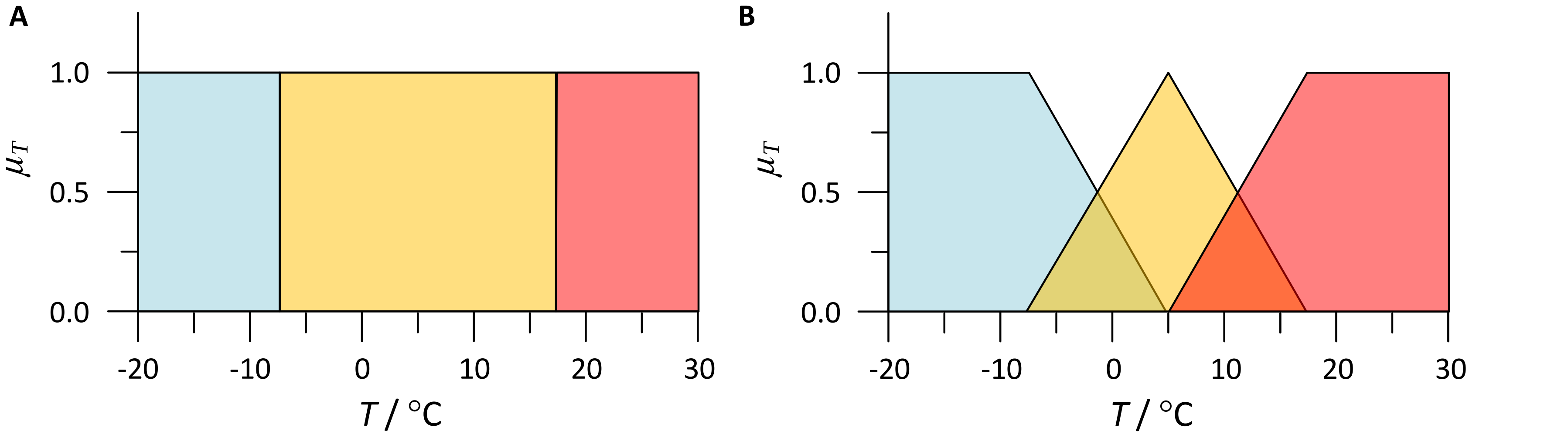
Implementacja logiki rozmytej





- K. Pilarczyk, B. Daly, A. Podborska, P. Kwolek, V. Silverson, A. de Silva, K. Szaciłowski, Coordination Chemistry Reviews, 2016, 325, 1798

Implementacja logiki rozmytej



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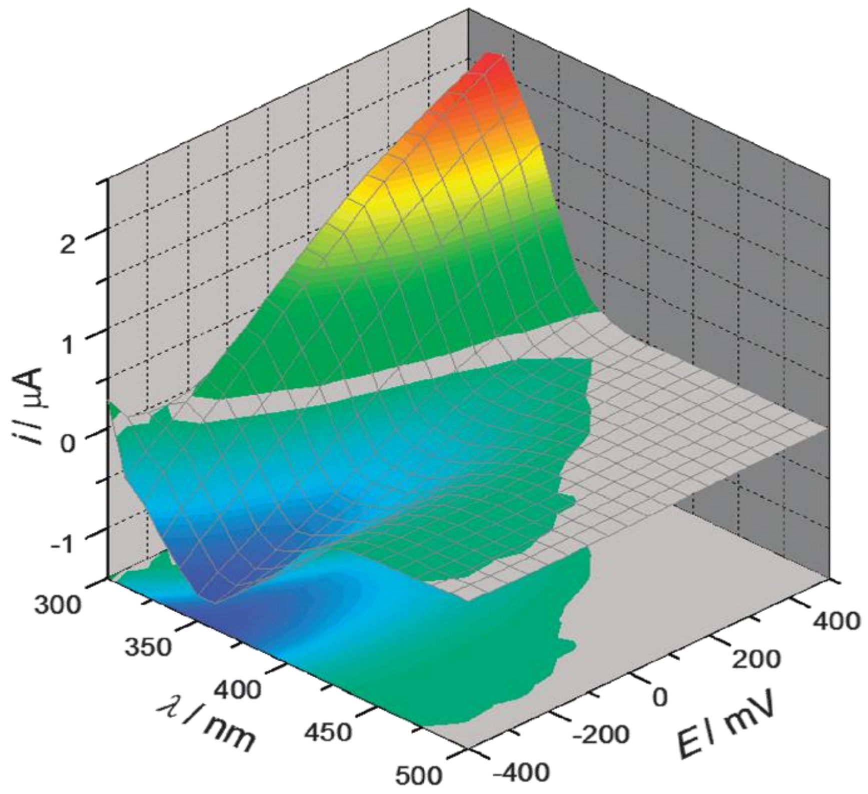
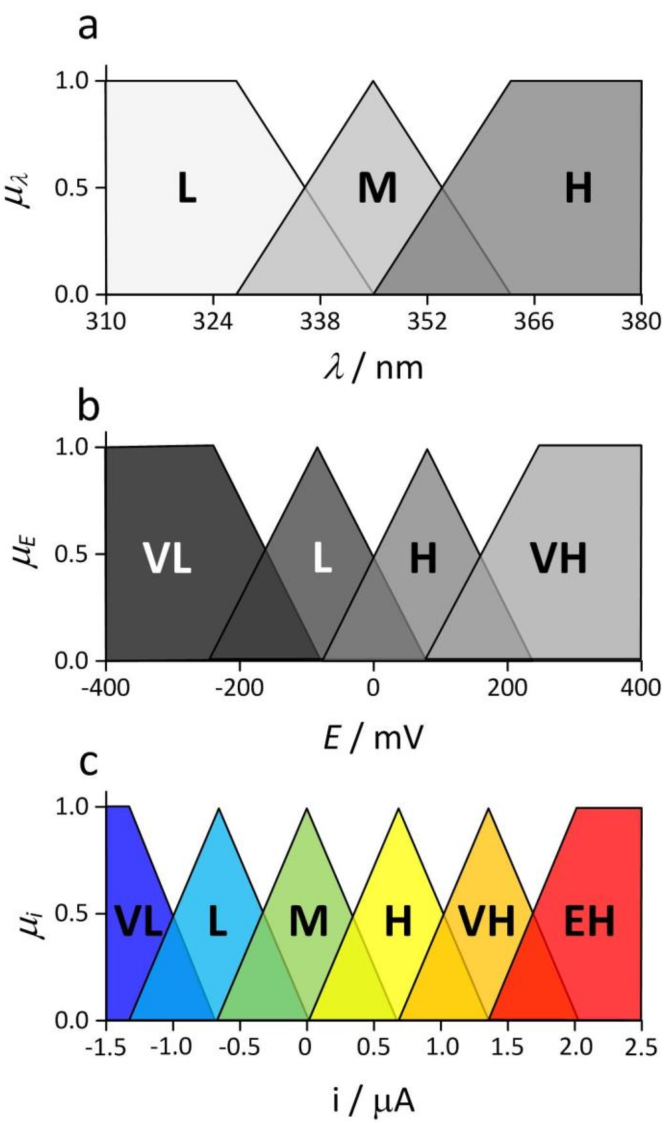
Implementacja logiki rozmytej





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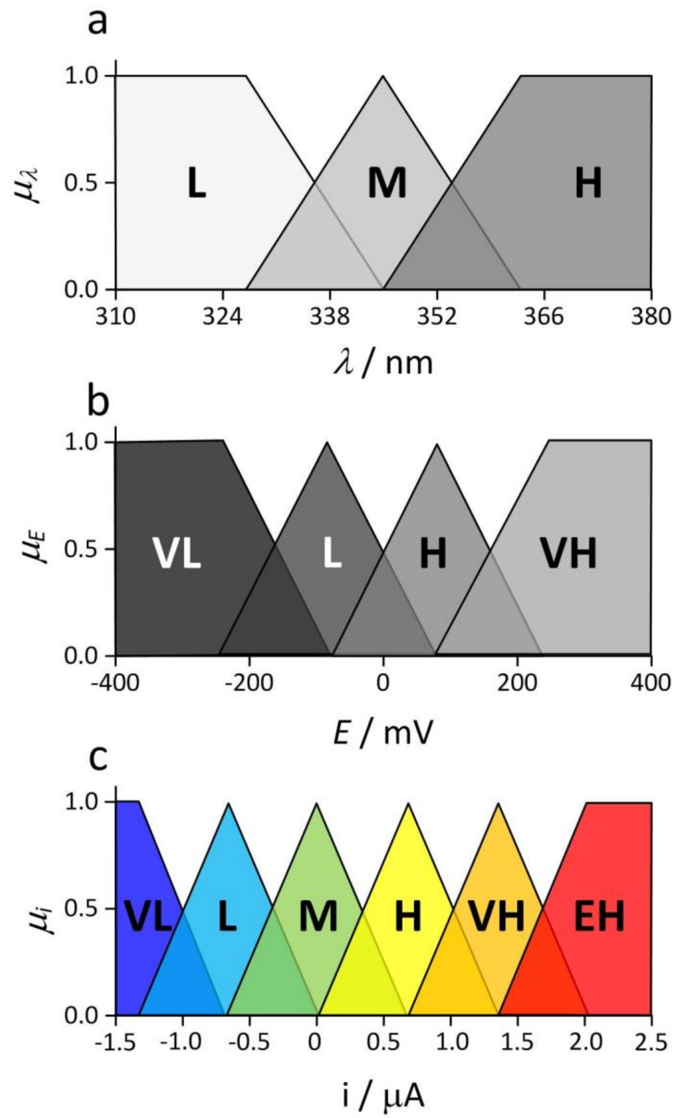
Implementacja logiki rozmytej

	potential			
wavelength		**VL**	**L**	**H**	**VH**

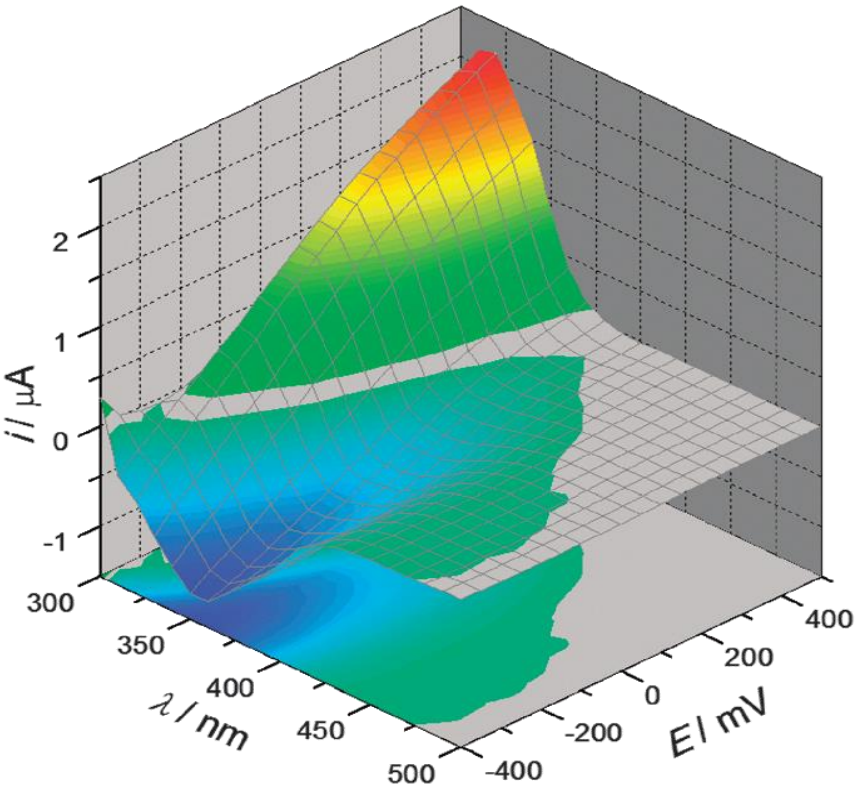


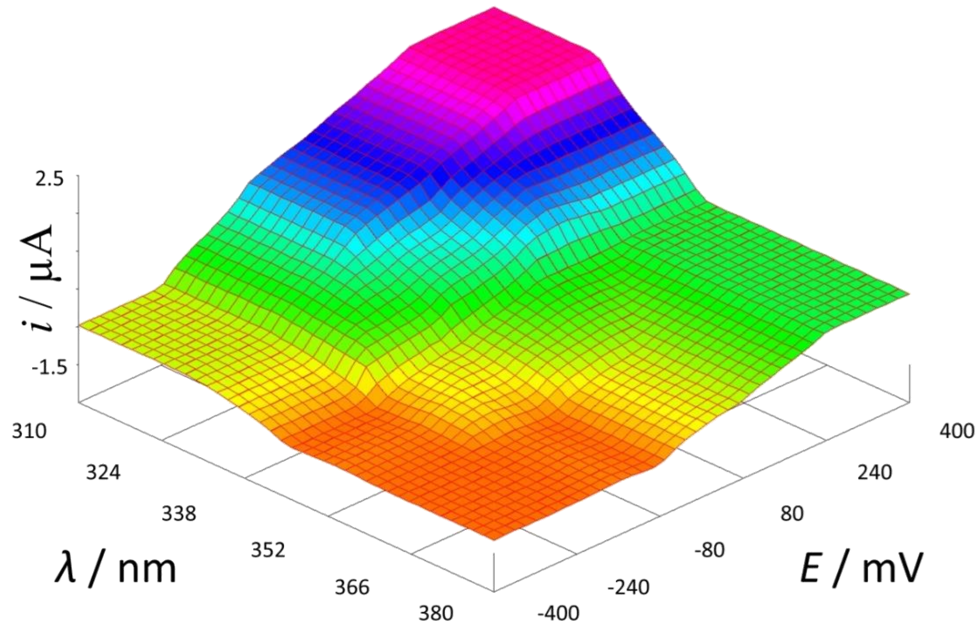
Zdania języka naturalnego:

IF λ=L **AND** E=L **THEN** I=H

- K. Pilarczyk, B. Daly, A. Podborska, P. Kwolek, V. Silverson, A. de Silva, K. Szaciłowski, Coordination Chemistry Reviews, 2016, 325, 1798

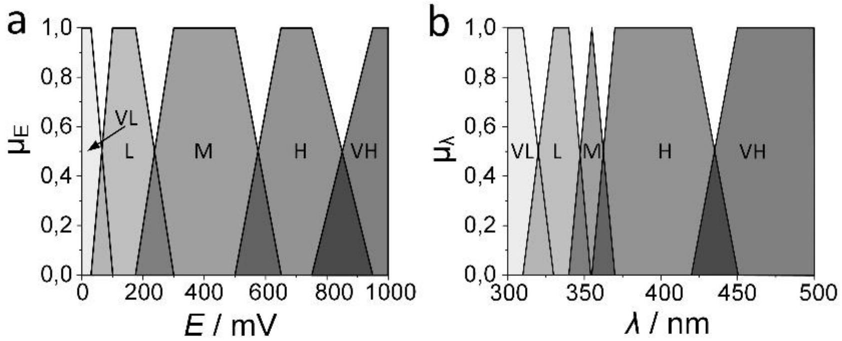
Implementacja logiki rozmytej

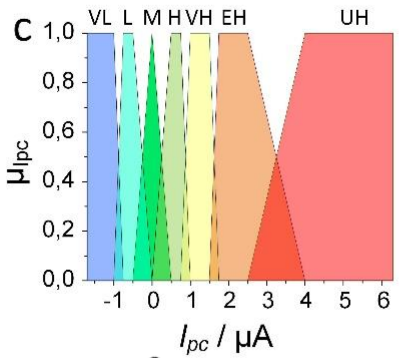




• K. Pilarczyk, B. Daly, A. Podborska, P. Kwolek, V. Silverson, A. de Silva, K. Szaciłowski, Coordination Chemistry Reviews, 2016, 325, 1798

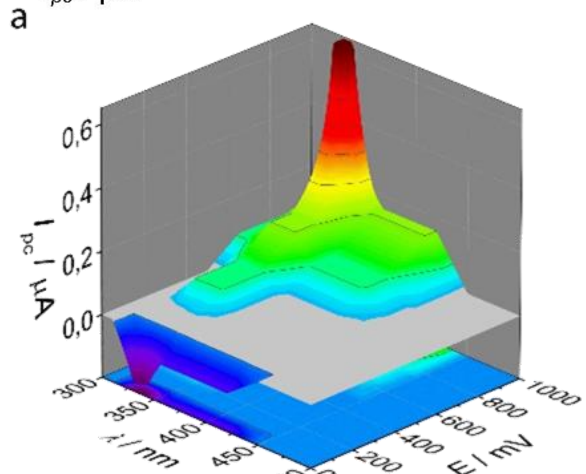
Implementacja logiki rozmytej – bardziej złożony przykład

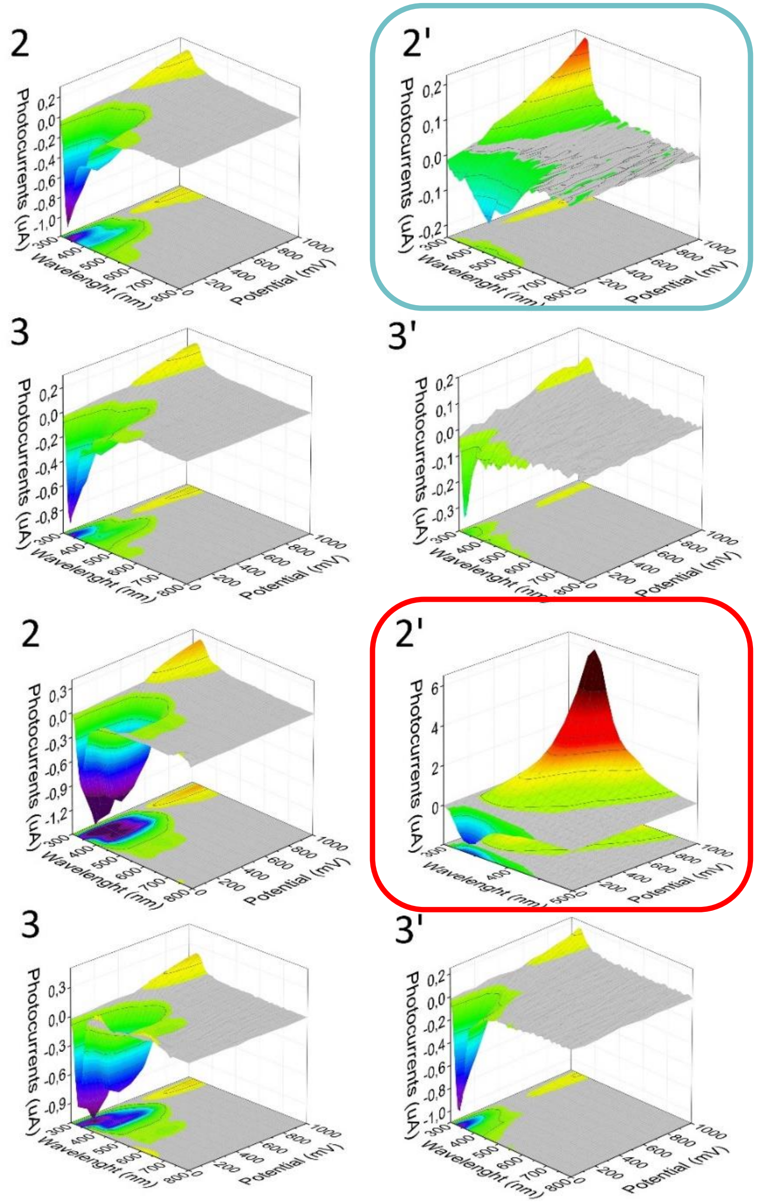




d

		Potential				
		VL	L	M	H	VH
Wavelength	VL	M	M	M	H	H
	L	VL	M	H	VH	UH
	M	L	M	H	VH	EH
	H	L	M	M	H	VH
	VH	M	M	M	M	M



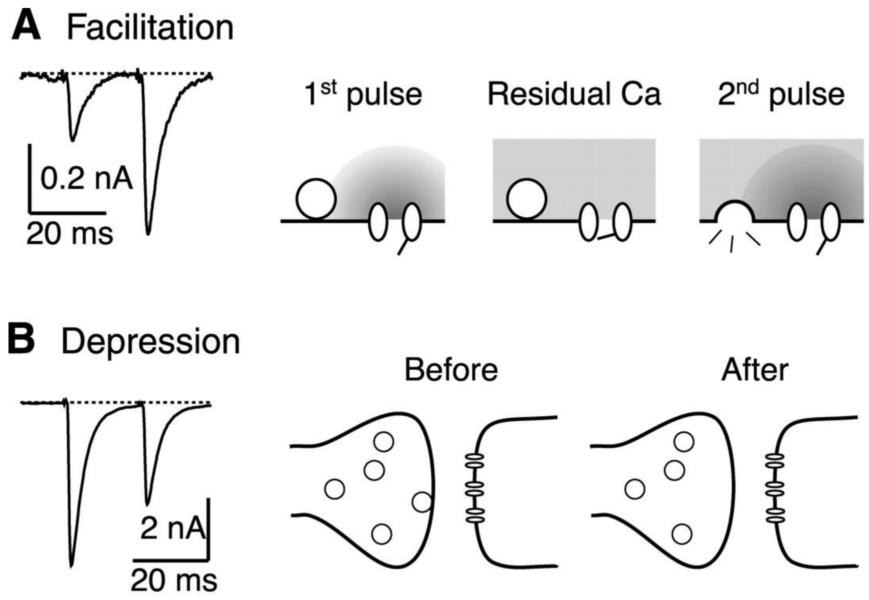


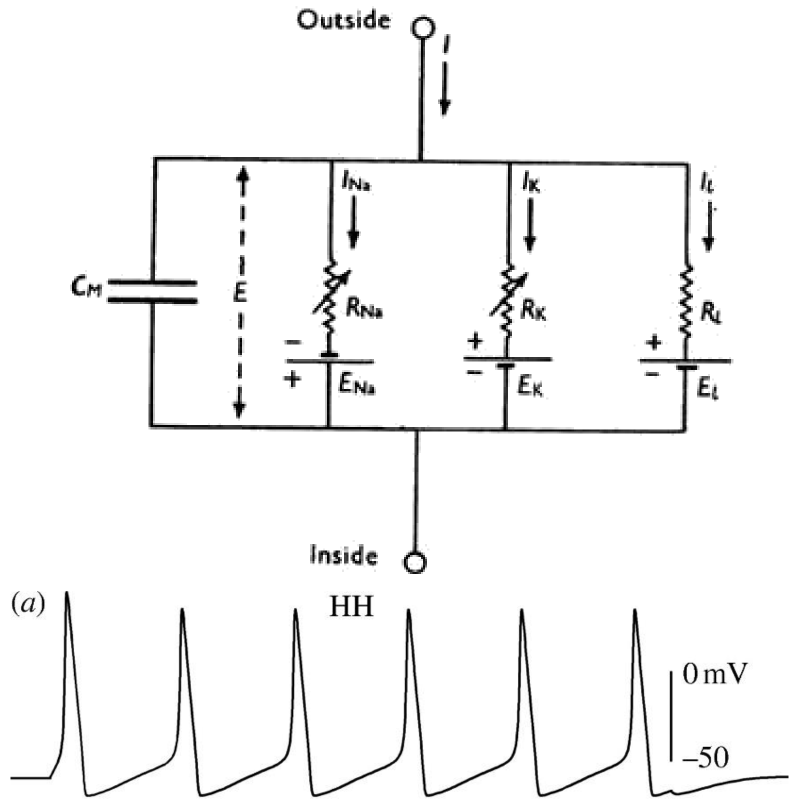
Ar

O_2

- A. Blachecki, J. Mech-Piskorz, M. Gajewska, K. Mech, K. Pilarczyk, K. Szacilowski, ChemPhysChem, 2017, 18, 1798

W stronę elementów neuromimetycznych

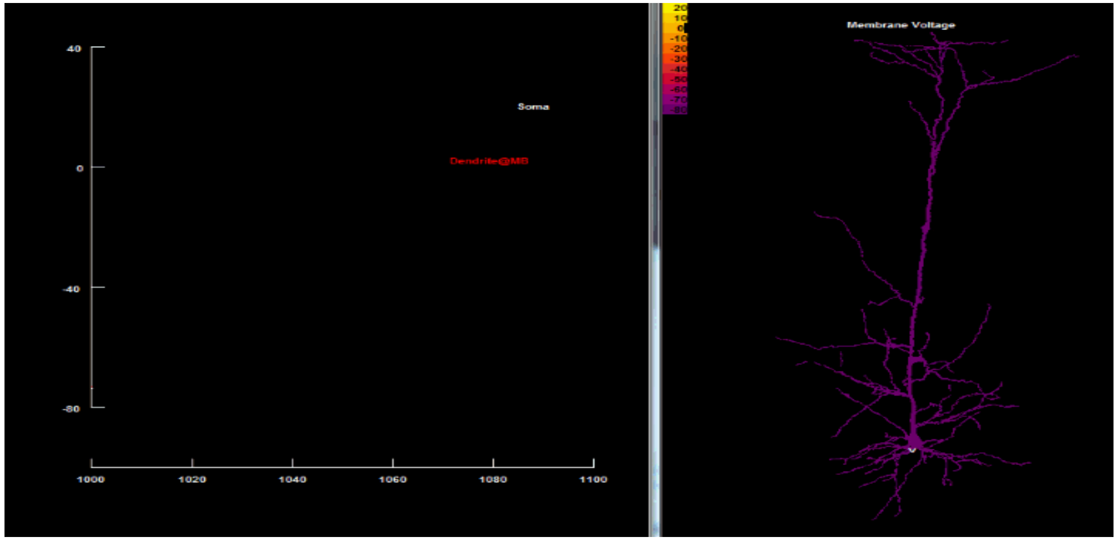


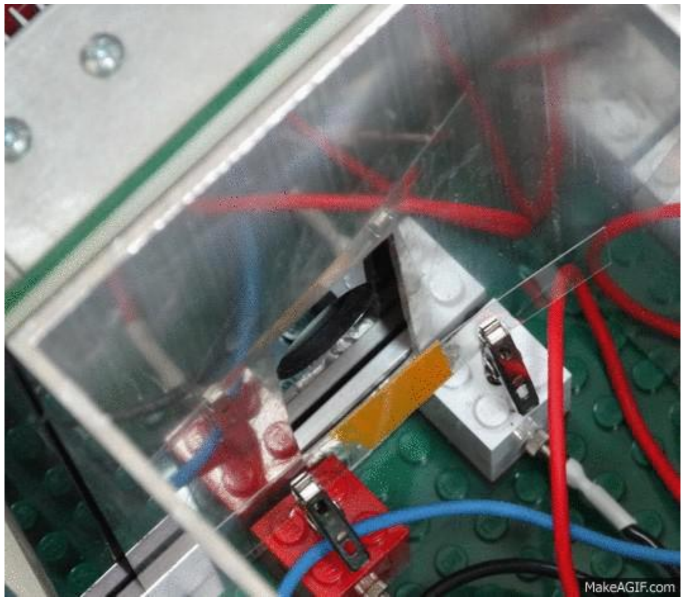


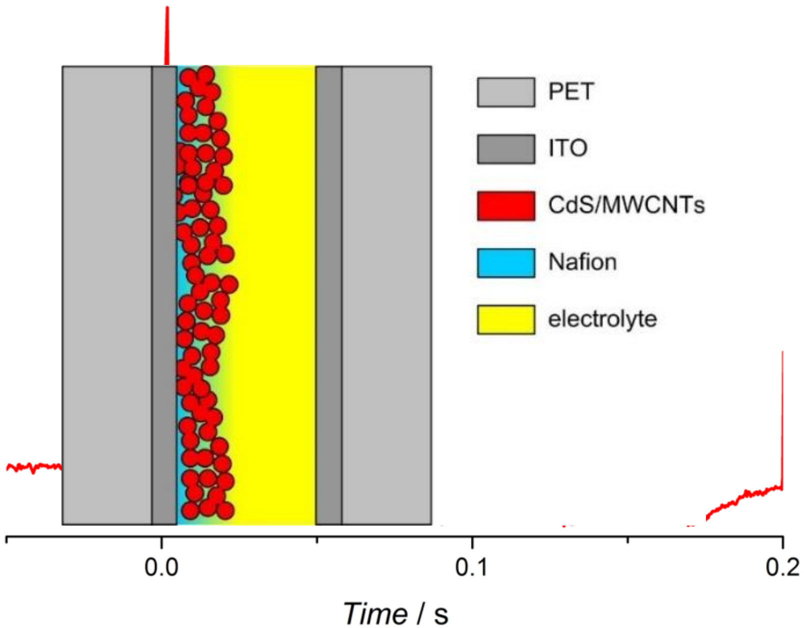
- A. L. Hodgkin, A. F. Huxley, J. Physiol., 1952, 117, 500.
- J. R. Clay, D. Paydarfar, D. B. Forger, J. R. Soc. Interface, 2008, 5, 1421.
- M. A. Xu-Friedman, W. G. Regehr, Physiol. Rev., 2004, 84, 69.

AGH

W stronę elementów neuromimetycznych







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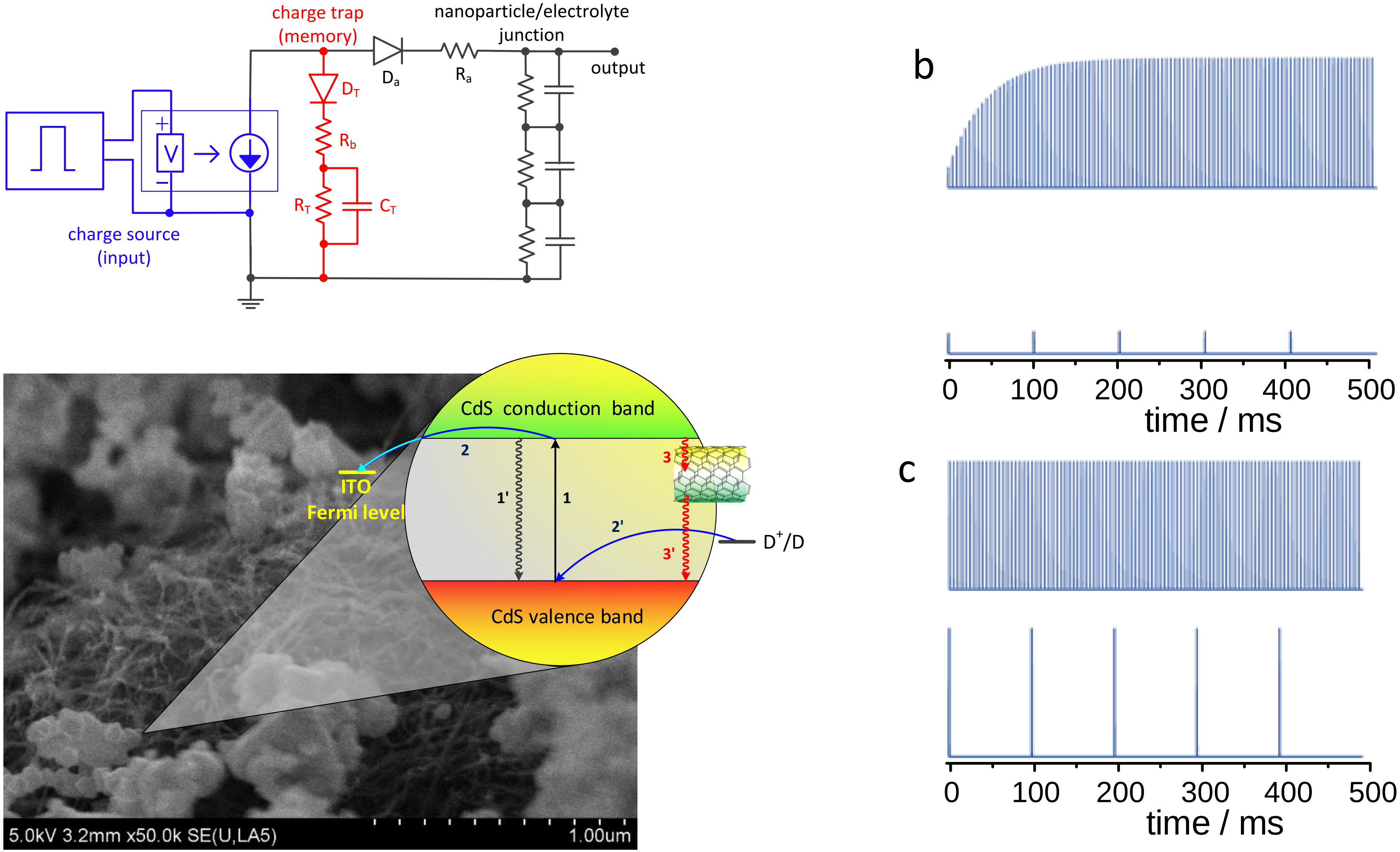

- K. Pilarczyk, A. Podborska, M. Lis, M. Kawa, D. Migdal, K. Szaciłowski, Adv. Electron. Mater., 2016, 1500471

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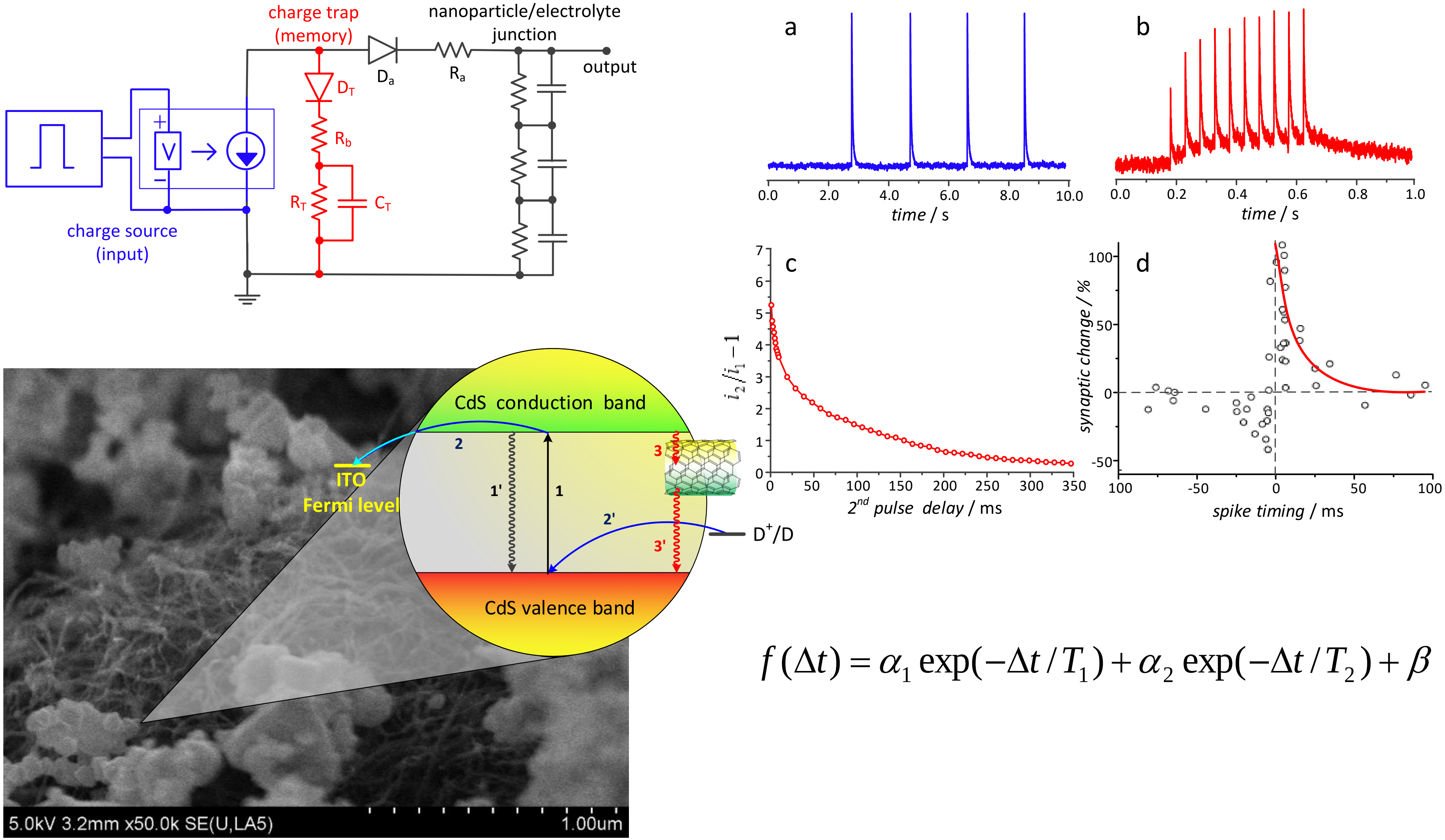
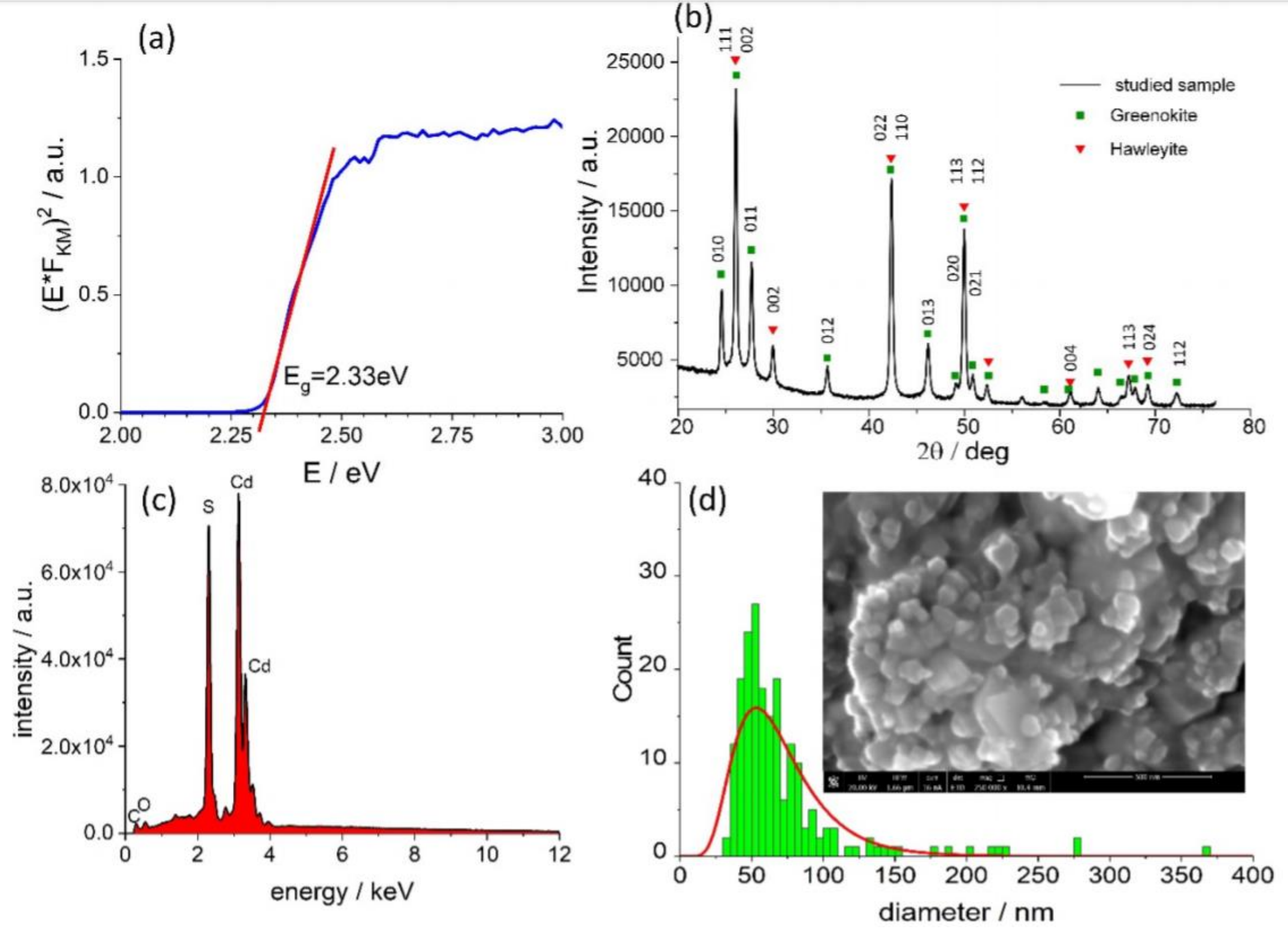


$$f(\Delta t) = \alpha_1 \exp(-\Delta t / T_1) + \alpha_2 \exp(-\Delta t / T_2) + \beta$$

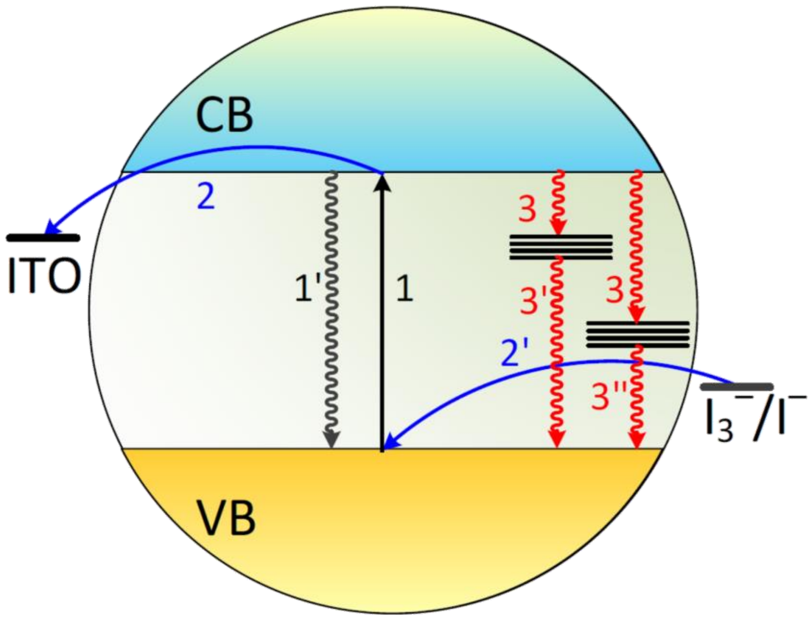
- K. Pilarczyk, A. Podborska, M. Lis, M. Kawa, D. Migdal, K. Szaciłowski, Adv. Electron. Mater., 2016, 1500471

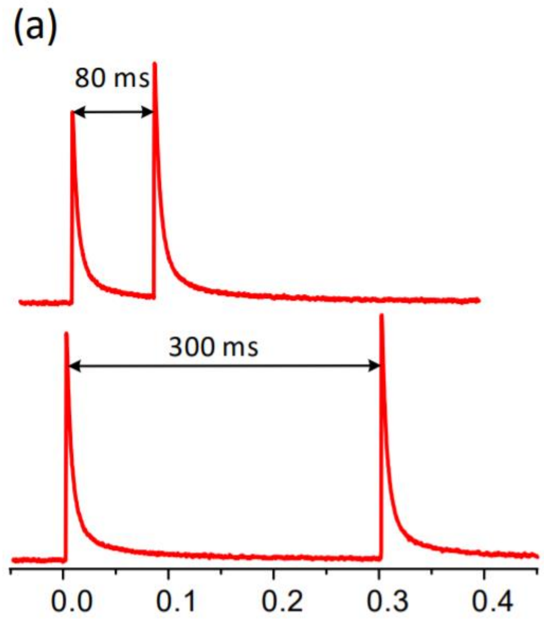
Wykorzystanie pamięci tymczasowej

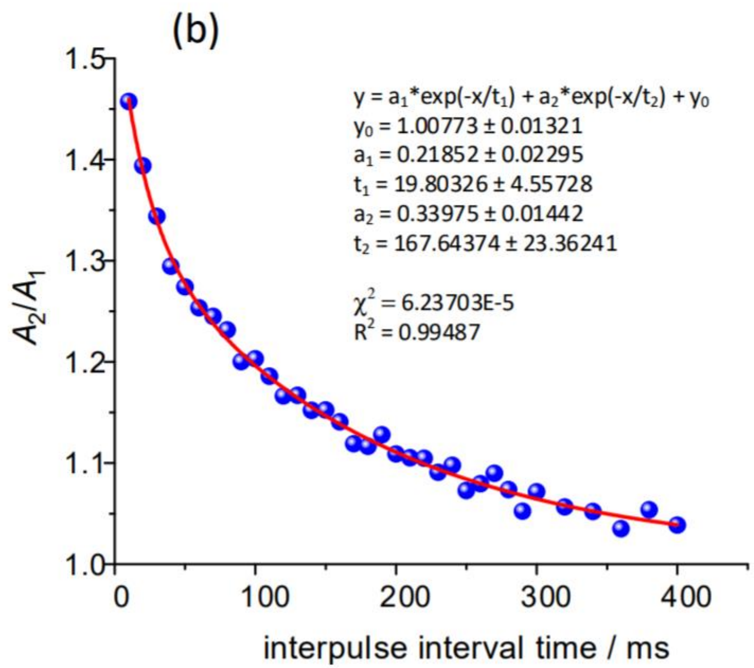


- D. Przyczyna, M. Lis, K. Pilarczyk, K. Szaciłowski, Molecules 2019, 24, 2738.

Wykorzystanie pamięci tymczasowej







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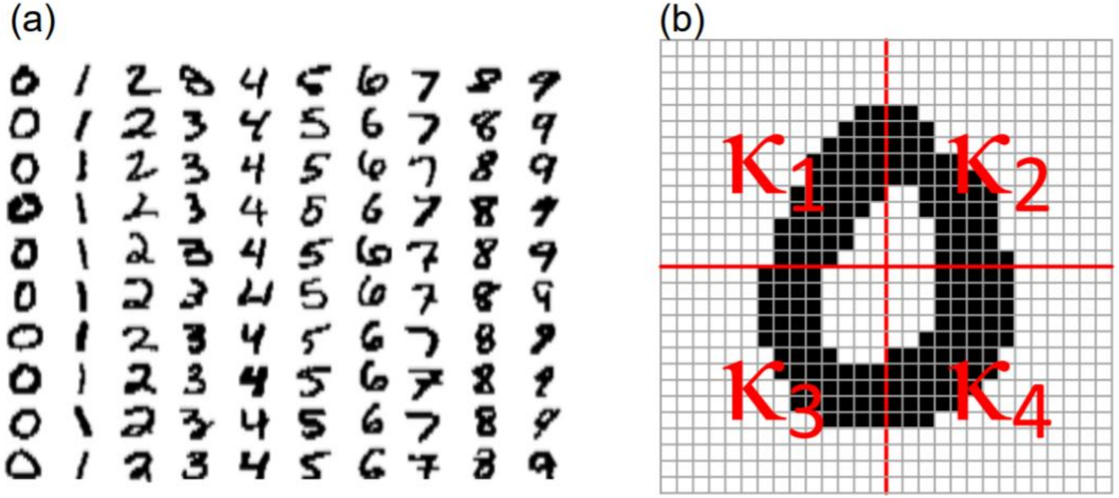

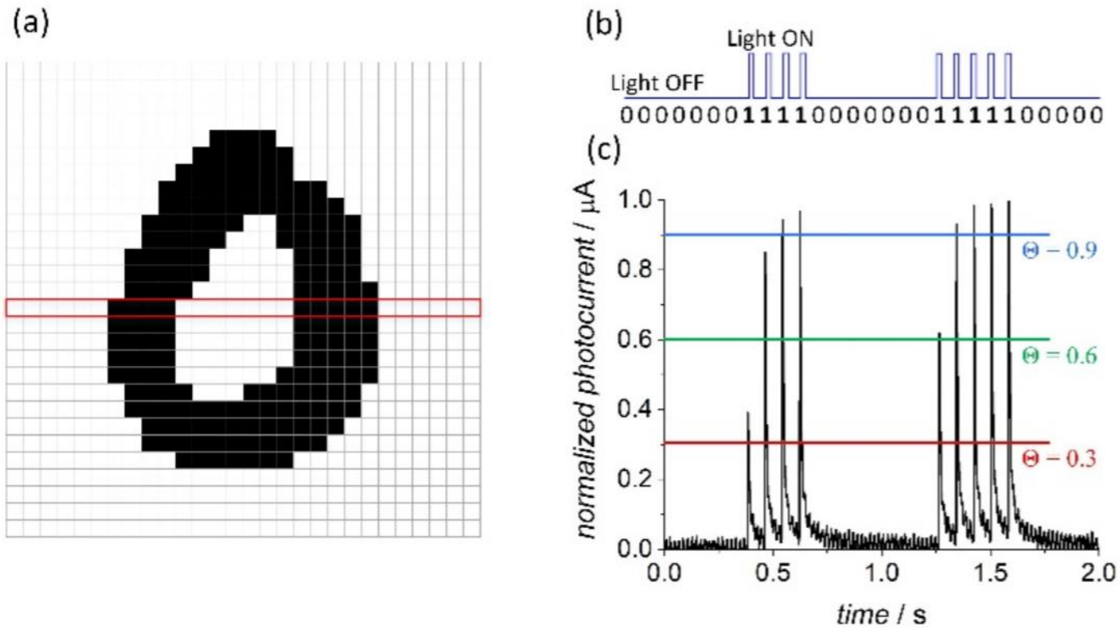

• D. Przyczyna, M. Lis, K. Pilarczyk, K. Szaciłowski, Molecules 2019, 24, 2738.

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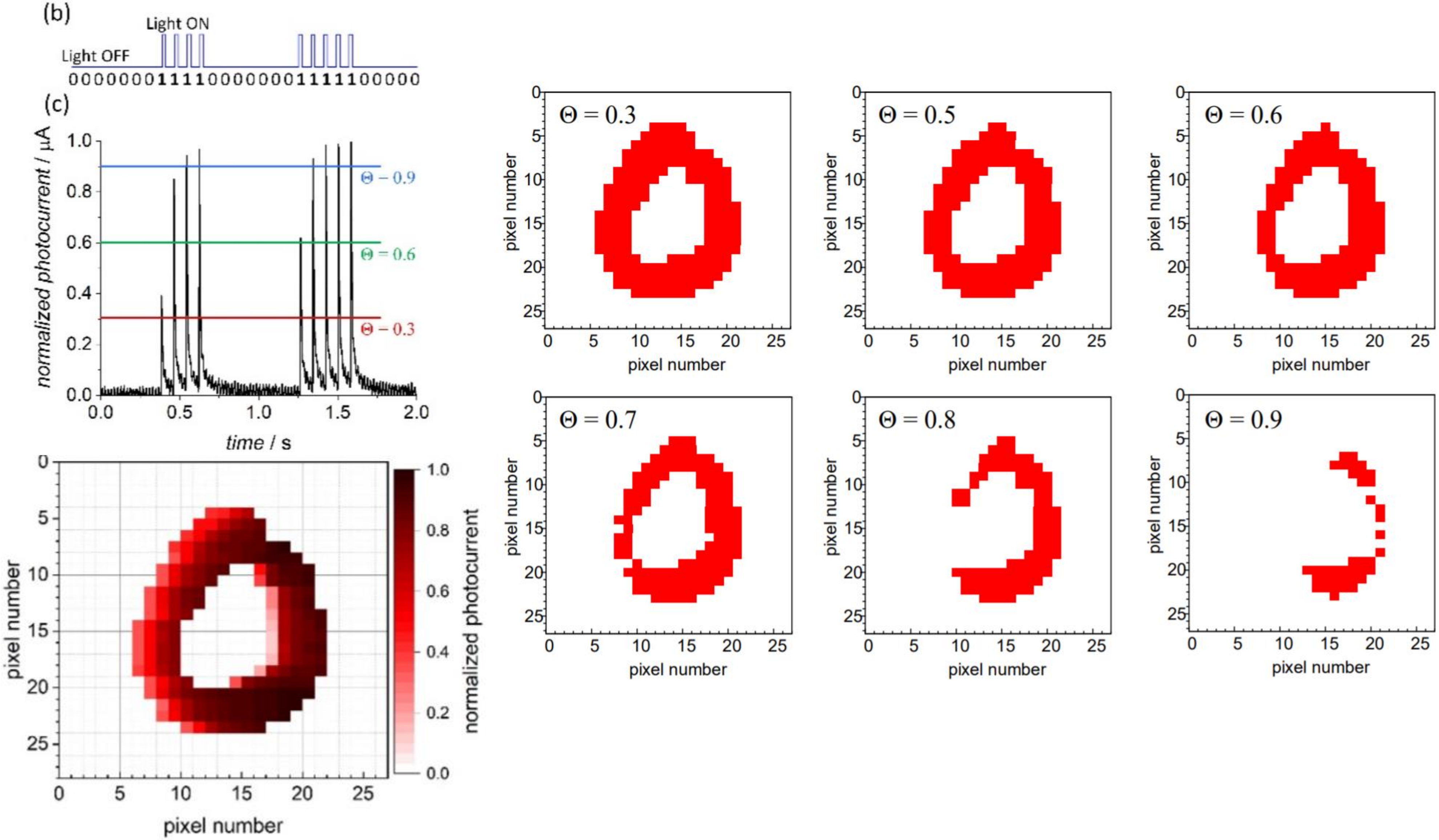
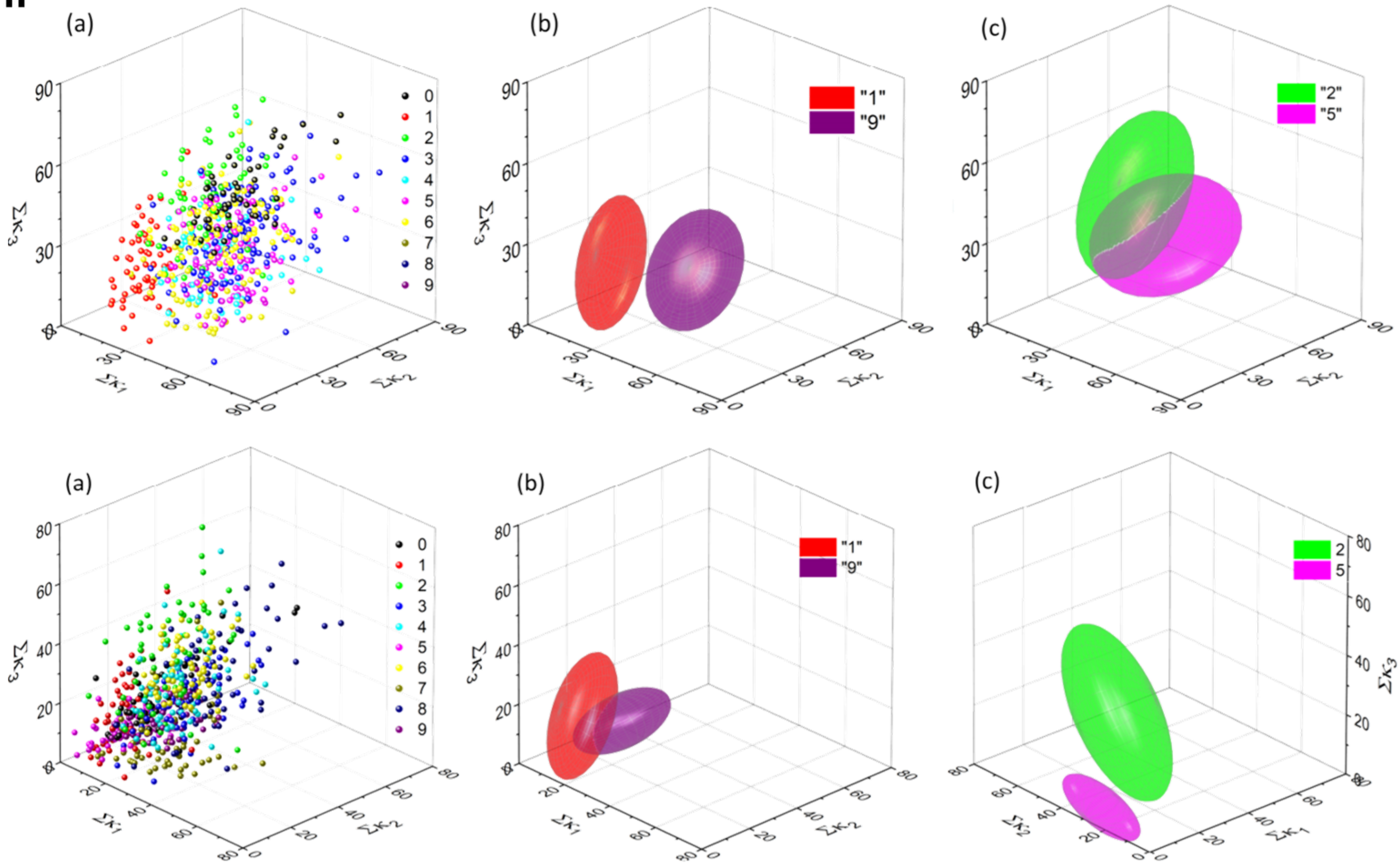


• D. Przyczyna, M. Lis, K. Pilarczyk, K. Szaciłowski, Molecules 2019, 24, 2738.

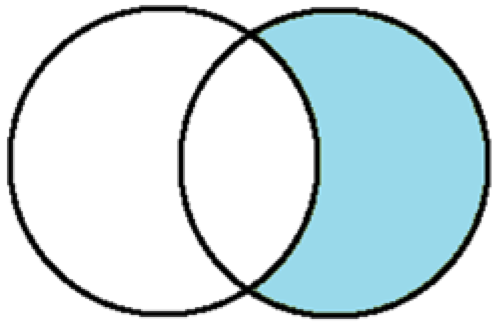
Wykorzystanie pamięci tymczasowej



• D. Przyczyna, M. Lis, K. Pilarczyk, K. Szaciłowski, Molecules 2019, 24, 2738.

Wykorzystanie pamięci tymczasowej

$$\xi_{m/n} = \frac{V\left(\mathrm{m}\left(\kappa_i, \kappa_j, \kappa_k\right) \backslash \mathrm{n}\left(\kappa_i, \kappa_j, \kappa_k\right)\right)}{V\left(\mathrm{m}\left(\kappa_i, \kappa_j, \kappa_k\right)\right)}$$



$$\Xi_{m/n} = \frac{\xi_{m/n}^{output}}{\xi_{m/n}^{input}}$$

Stosunek separacji

$$\Omega\left(\kappa_i, \kappa_j, \kappa_k, \Theta\right) = \frac{\sum_m \sum_n \xi_{m/n}^{output}}{\sum_m \sum_n \xi_{m/n}^{input}}, m \neq n$$

Całkowity indeks separacji

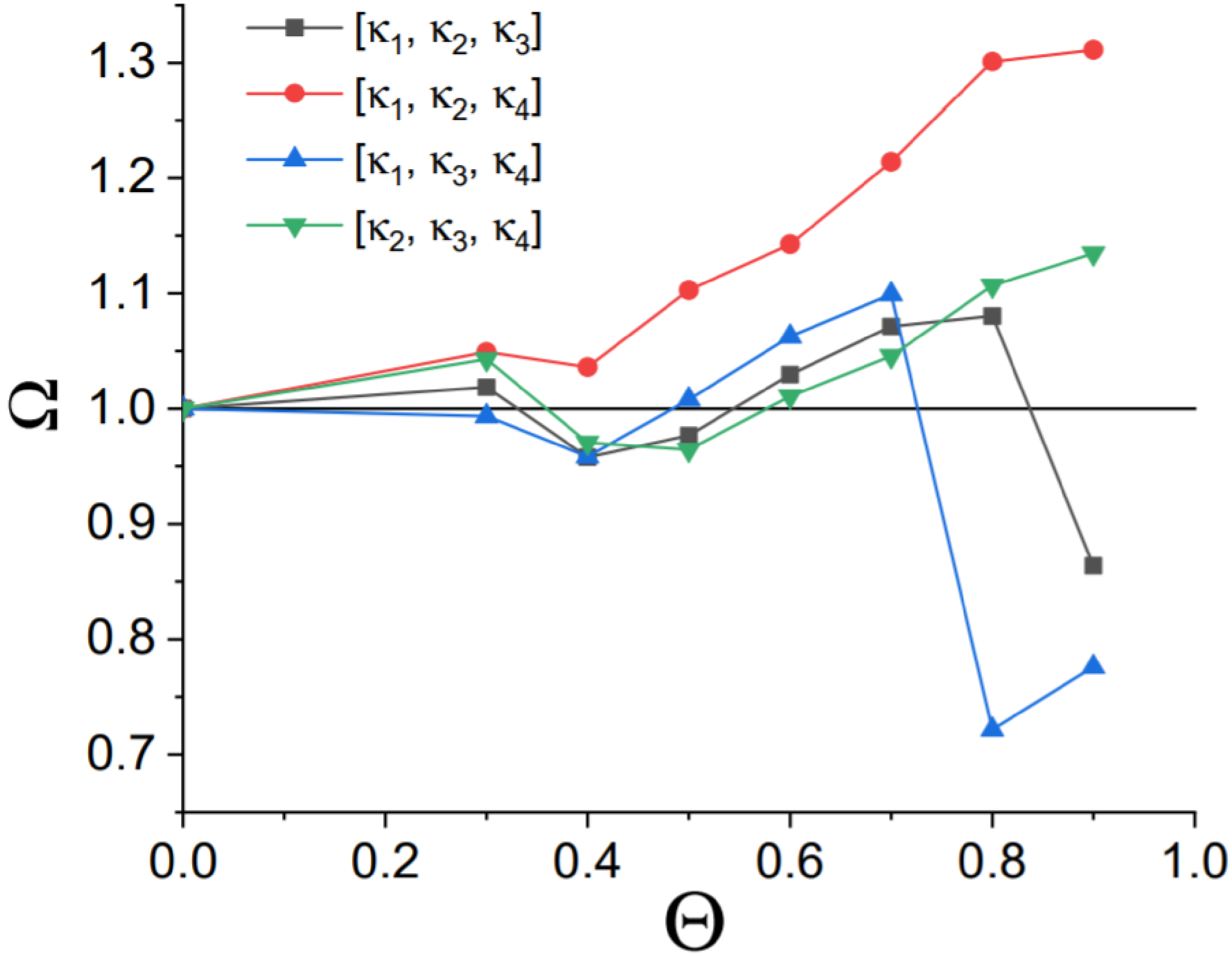
- D. Przyczyna, M. Lis, K. Pilarczyk, K. Szaciłowski, Molecules 2019, 24, 2738.

Wykorzystanie pamięci tymczasowej

	0	1	2	3	4	5	6	7	8	9
0	0.000	0.482	1.040	0.564	0.913	0.556	1.363	0.705	0.933	0.372
1	0.608	0.000	0.971	0.919	1.011	0.377	1.019	0.903	0.984	0.710
2	1.468	0.897	0.000	0.715	0.475	1.777	0.974	1.183	1.147	0.787
3	0.485	0.881	0.954	0.000	1.369	2.682	1.219	1.019	1.167	0.945
4	0.926	1.026	0.781	1.074	0.000	1.979	0.642	2.203	1.205	9.127
5	1.398	0.766	1.542	3.055	2.134	0.000	2.198	1.393	2.818	1.438
6	2.267	1.037	1.070	1.166	0.694	1.923	0.000	1.239	1.233	1.204
7	0.652	0.877	1.235	1.021	2.770	1.202	1.291	0.000	1.135	0.742
8	0.788	0.949	1.061	0.515	1.044	4.229	1.253	0.931	0.000	0.947
9	0.682	0.801	1.016	1.097	1.877	0.947	1.112	1.125	1.125	0.000

• D. Przyczyna, M. Lis, K. Pilarczyk, K. Szaciłowski, Molecules 2019, 24, 2738.

Wykorzystanie pamięci tymczasowej

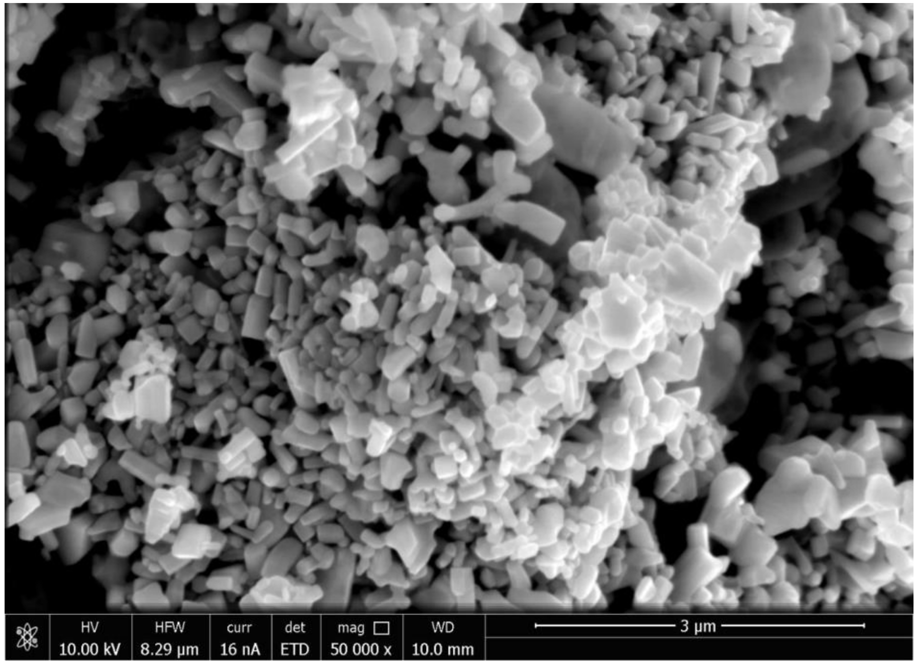


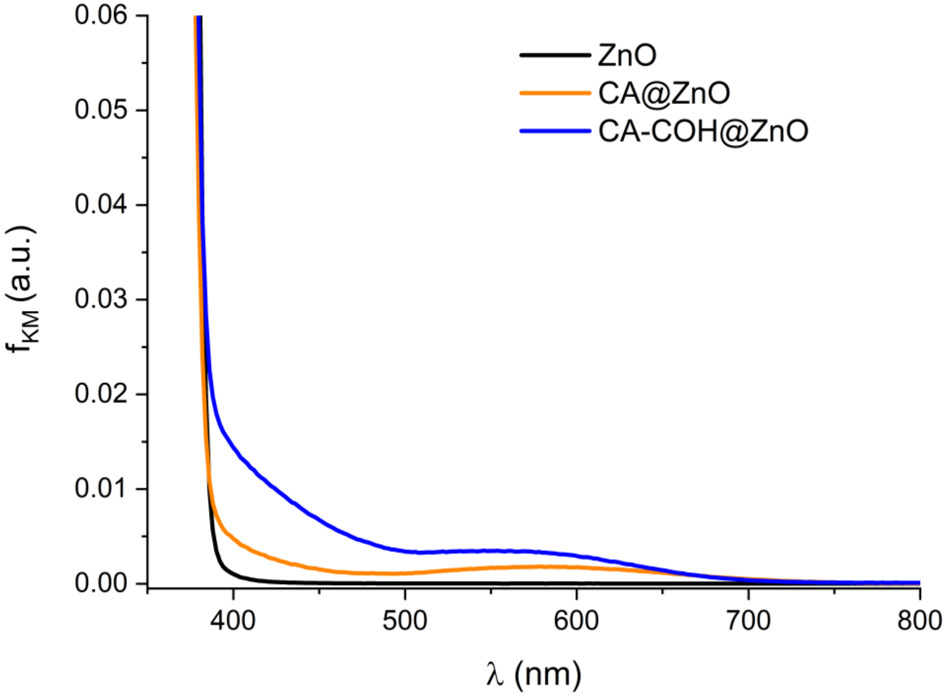
$$\Omega(\kappa_i, \kappa_j, \kappa_k, \Theta) = \frac{\sum_m \sum_n \xi_{m/n}^{output}}{\sum_m \sum_n \xi_{m/n}^{input}}, m \neq n$$

- D. Przyczyna, M. Lis, K. Pilarczyk, K. Szaciłowski, Molecules 2019, 24, 2738.

Efekt LIIPS

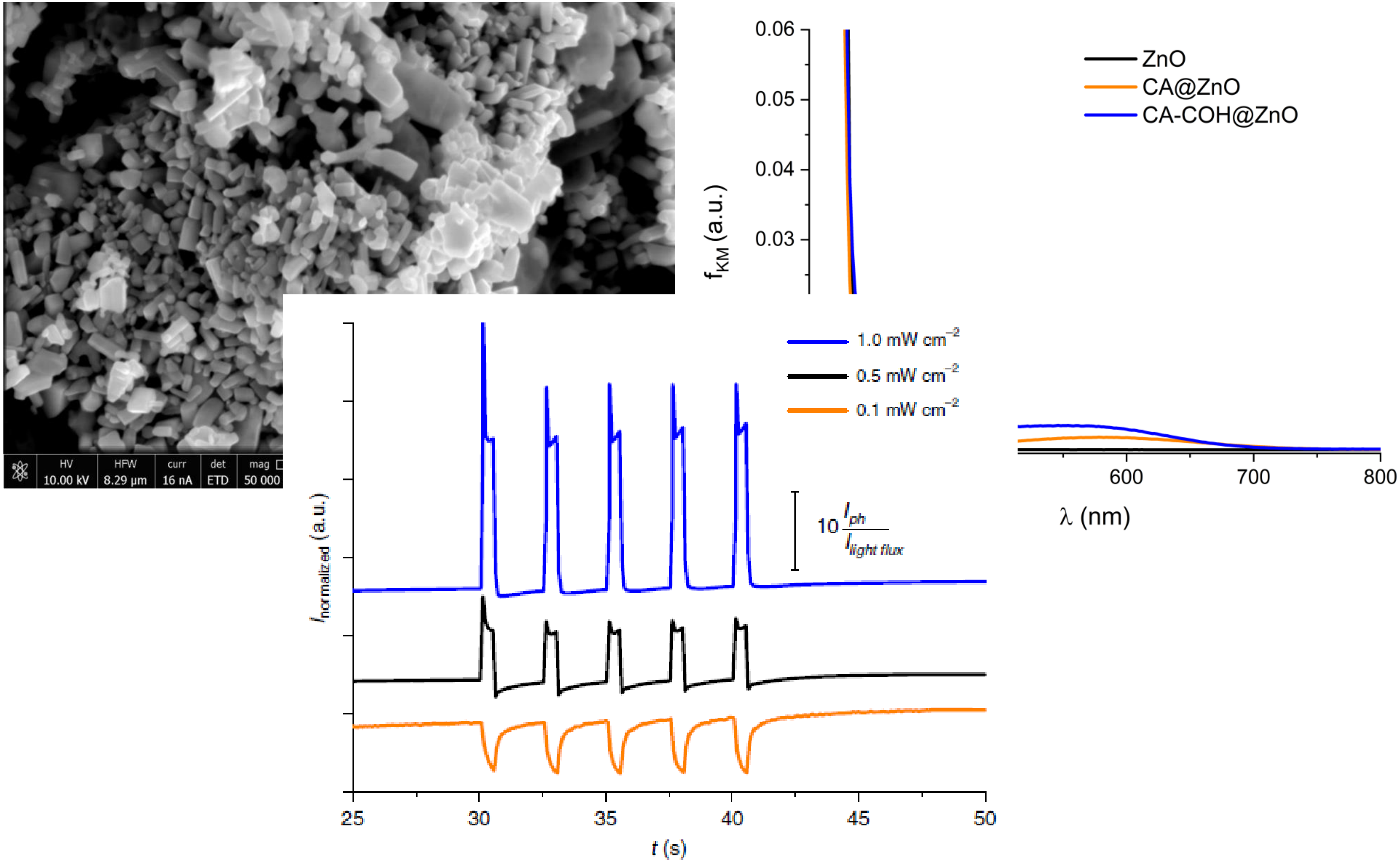
Ciekawy przypadek hybrydy CA-COH@ZnO





- A. Podborska, M. Suchecki, K. Mech, M. Marzec, K. Pilarczyk, K. Szaciłowski, Nature Communications, 2020, 11, 854.

Ciekawy przypadek hybrydy CA-COH@ZnO



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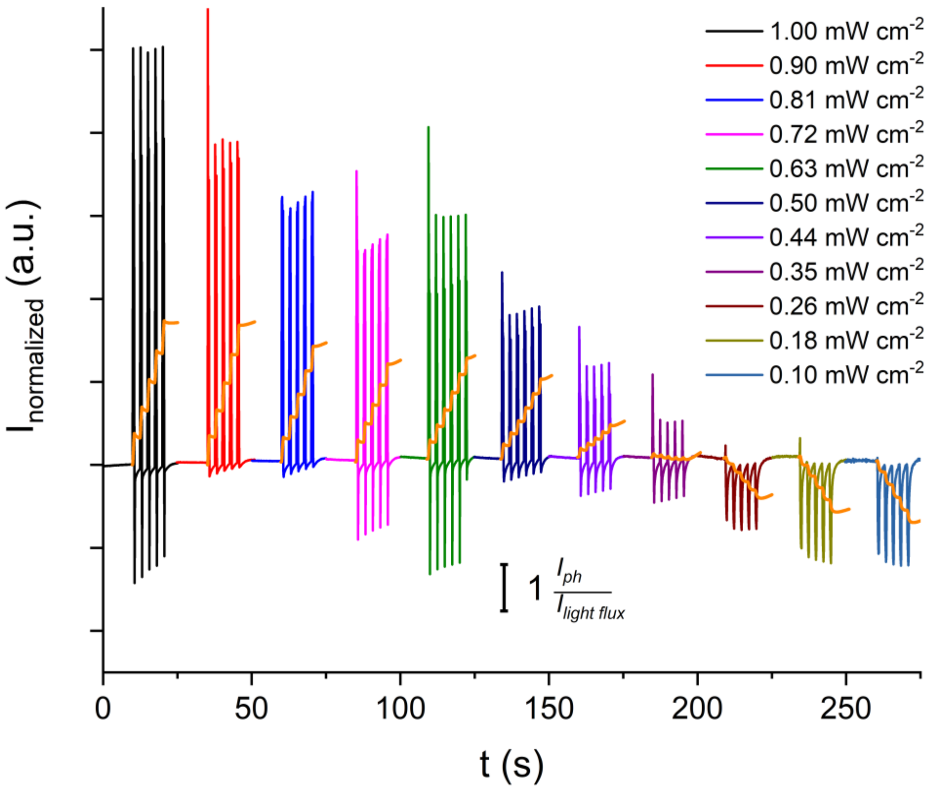

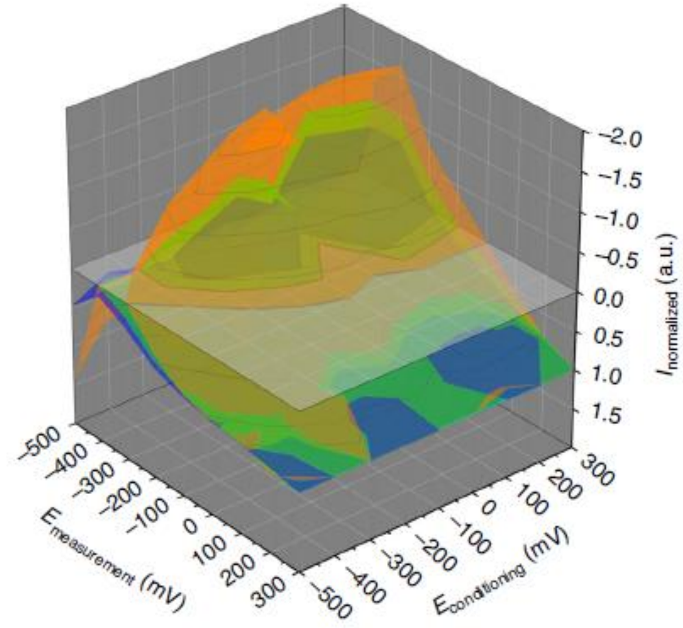

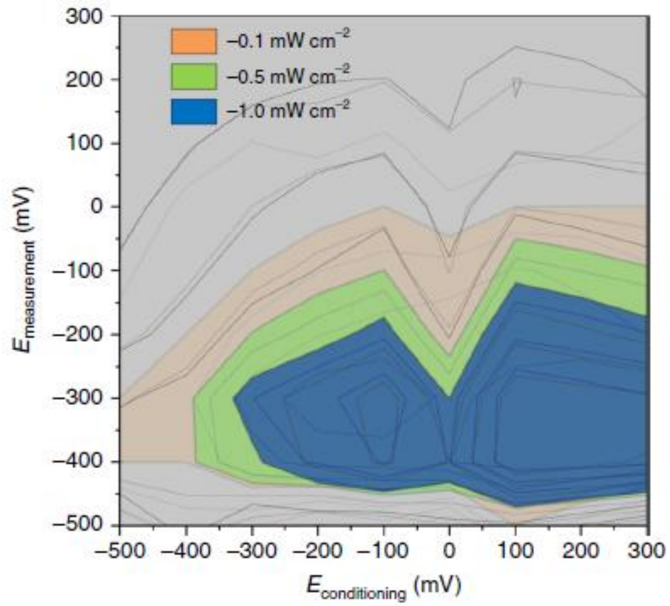

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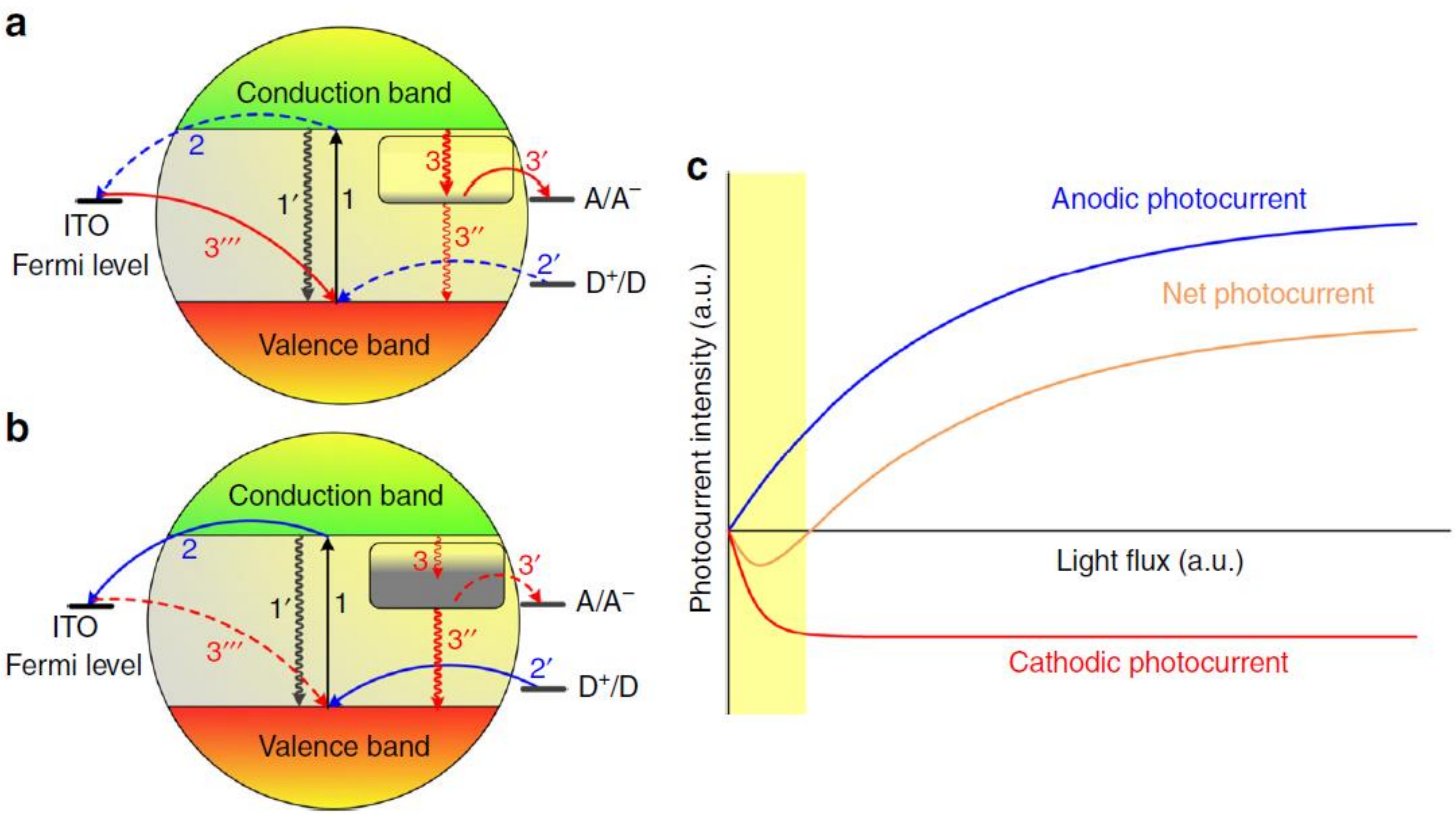
Light intensity-induced photocurrentswitching effect



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Light intensity-induced photocurrentswitching effect

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Light intensity-induced photocurrent switching effect

Agnieszka Podborska[1], Maciej Suchecki[1,2], Krzysztof Mech[1], Mateusz Marzec[1], Kacper Pilarczyk[1] ✉ & Konrad Szaciłowski[1]

- A. Podborska, M. Suchecki, K. Mech, M. Marzec, K. Pilarczyk, K. Szaciłowski, Nature Communications, 2020, 11, 854.

AGH

Teraźniejszość
Współpraca z SGPR.TECH

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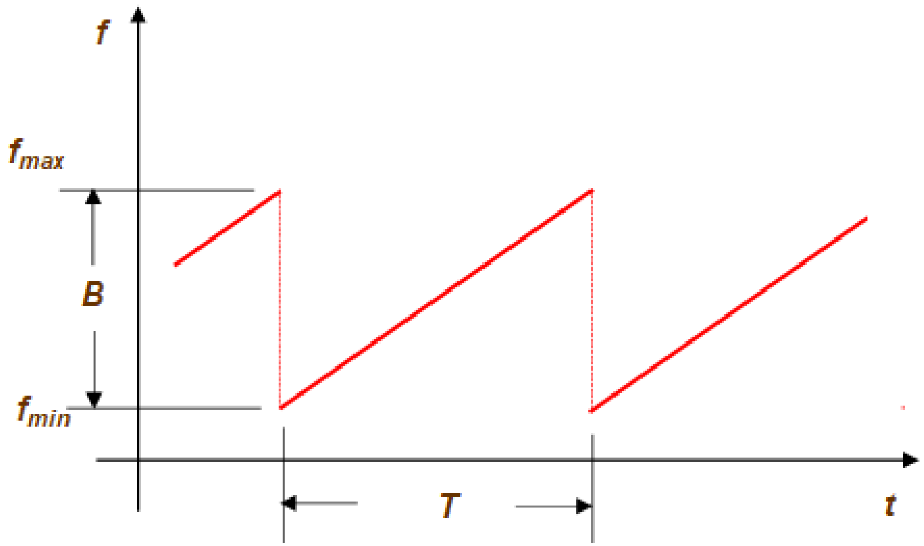
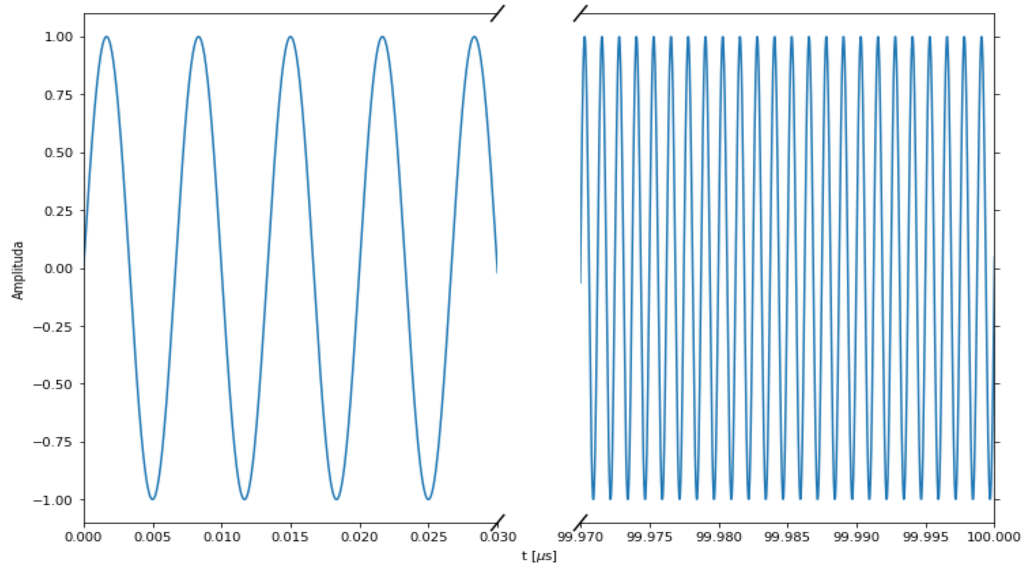




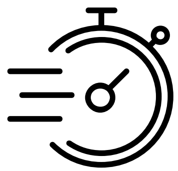
f_{min} | f_{max}

150 MHz | **800 MHz**

Umożliwia szerokopasmową analizę parametrów podłoża

WIDZENIE KOLOROWE VS MONOCHROMATYCZNE

Zapewnia wyjątkowo szybkie pozyskiwanie informacji o podłożu



PONAD 100X LEPSZY STOSUNEK SYGNAŁ/SZUM W PORÓWNANIU Z ROZWIĄZANIAMI TRADYCYJNYMI

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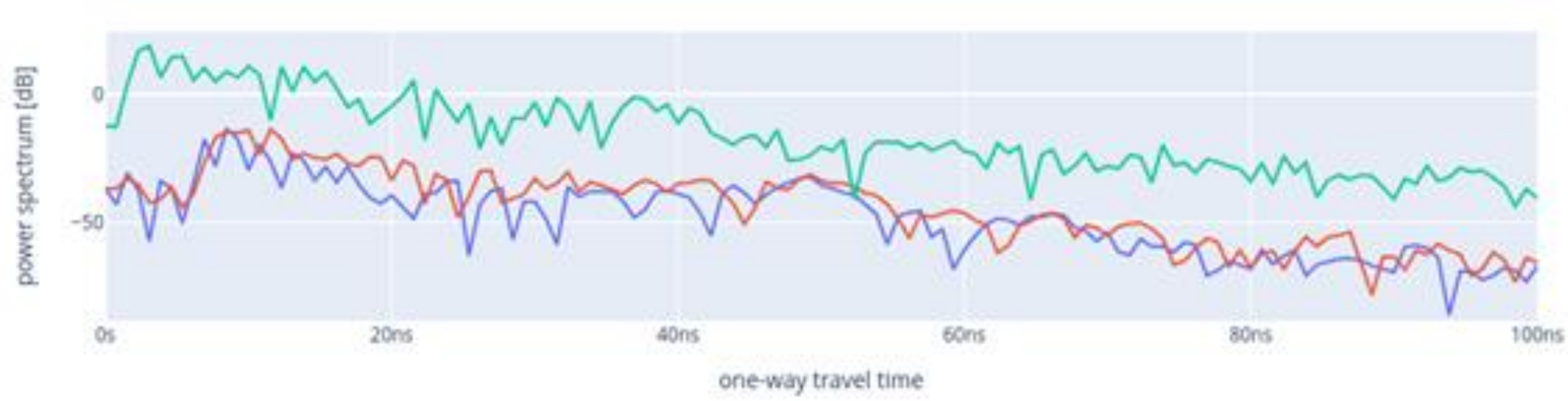
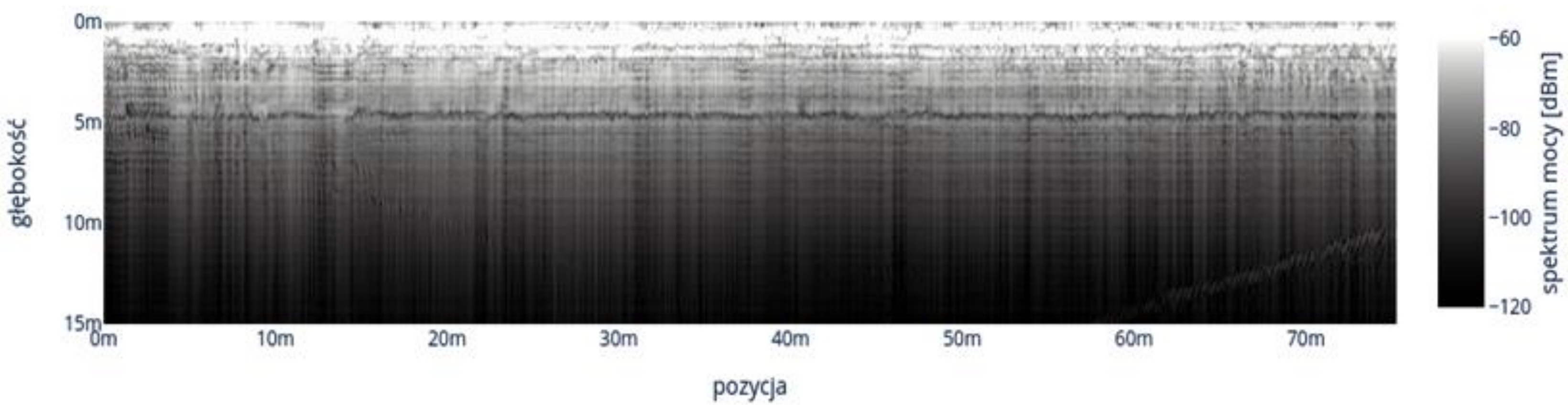
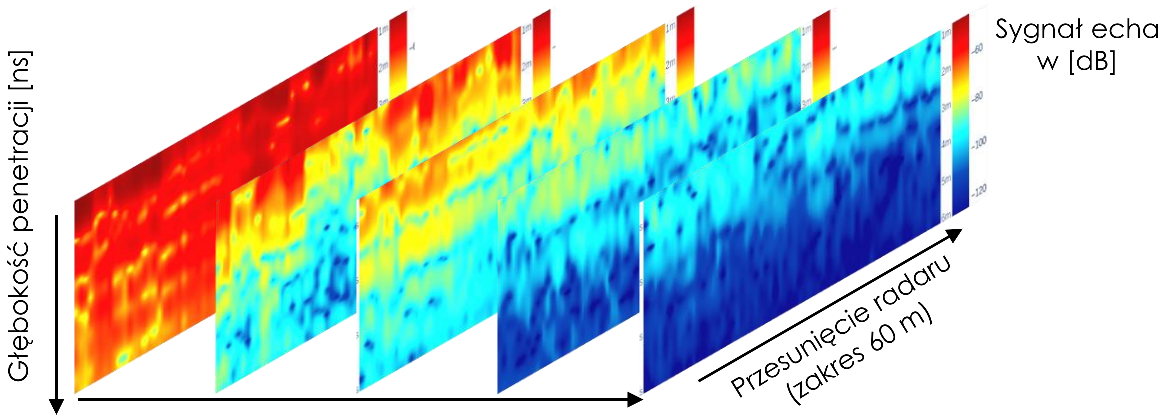
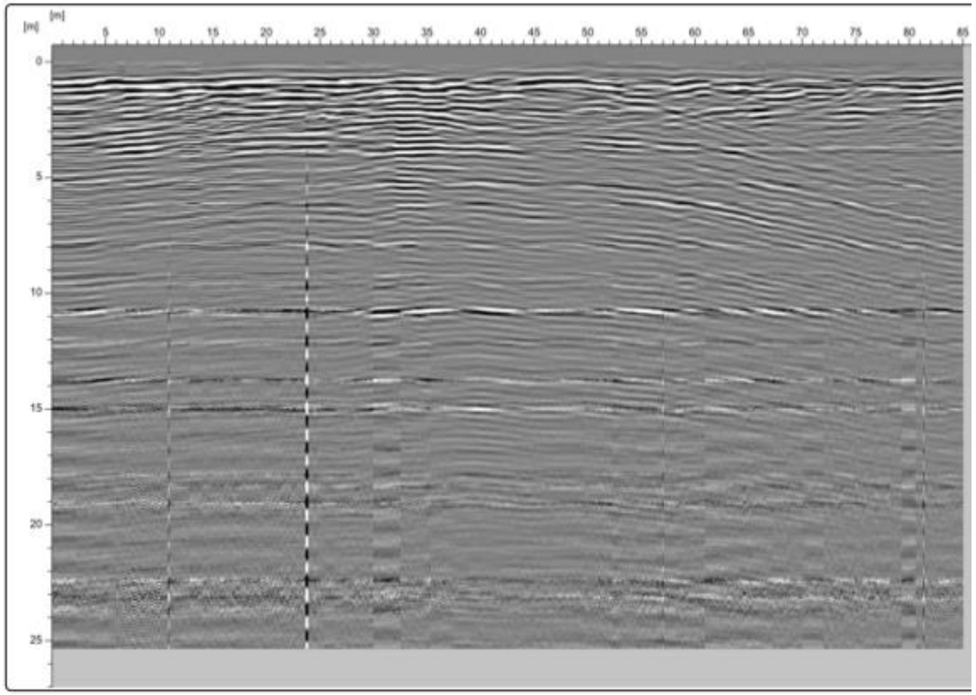


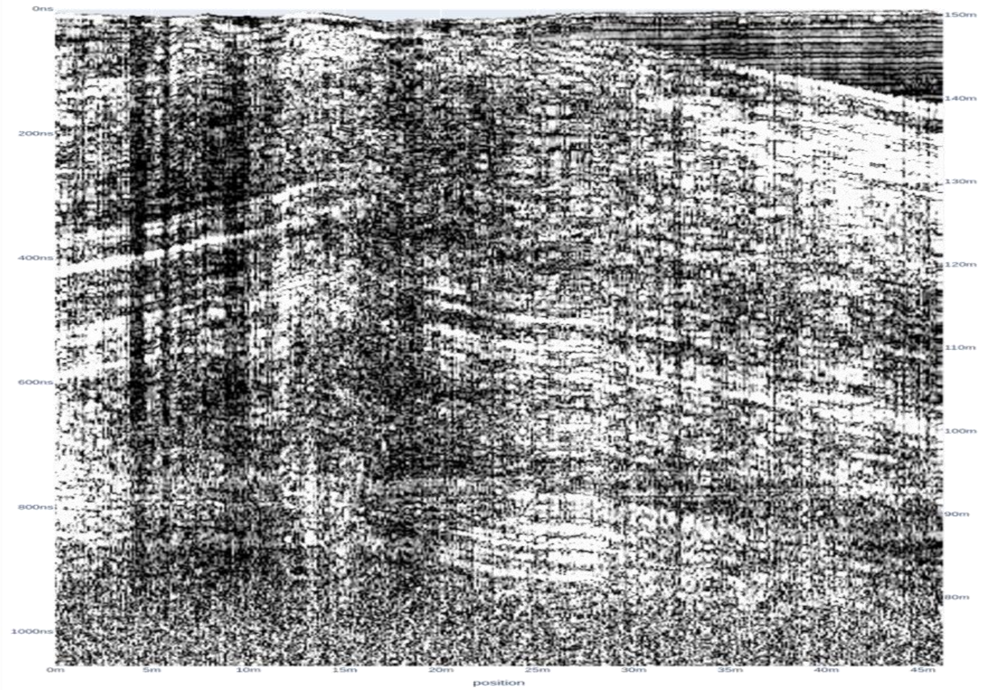




Współpraca z SGPR.TECH



Georadar impulsowy Malå



Georadar SGPR.TECH

Niedaleka przyszłość
Projekt z KU Leuven

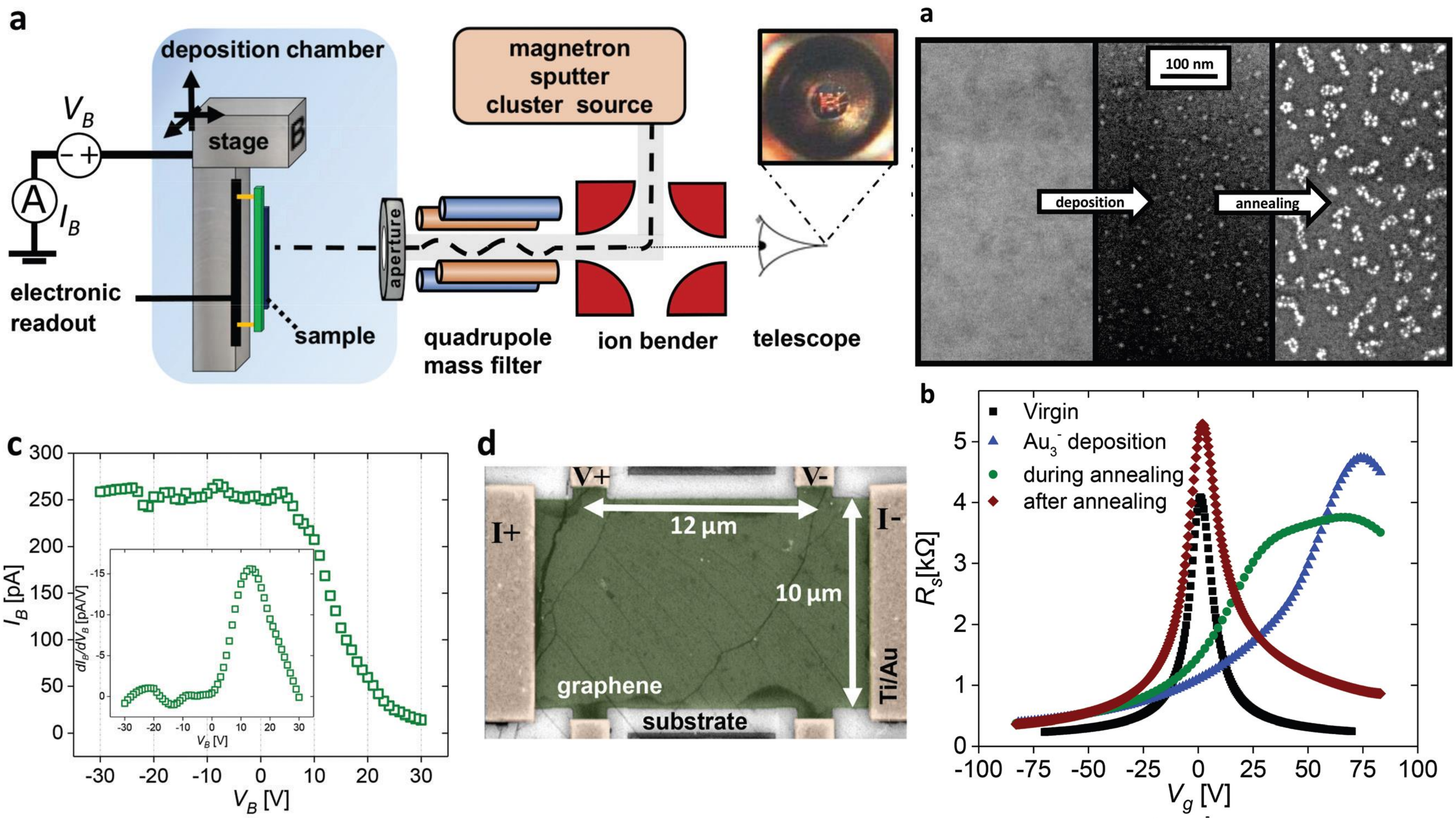
AGH

Współpraca z KU Leuven

prof. Ewald Janssens
prof. Joris Van de Vondel

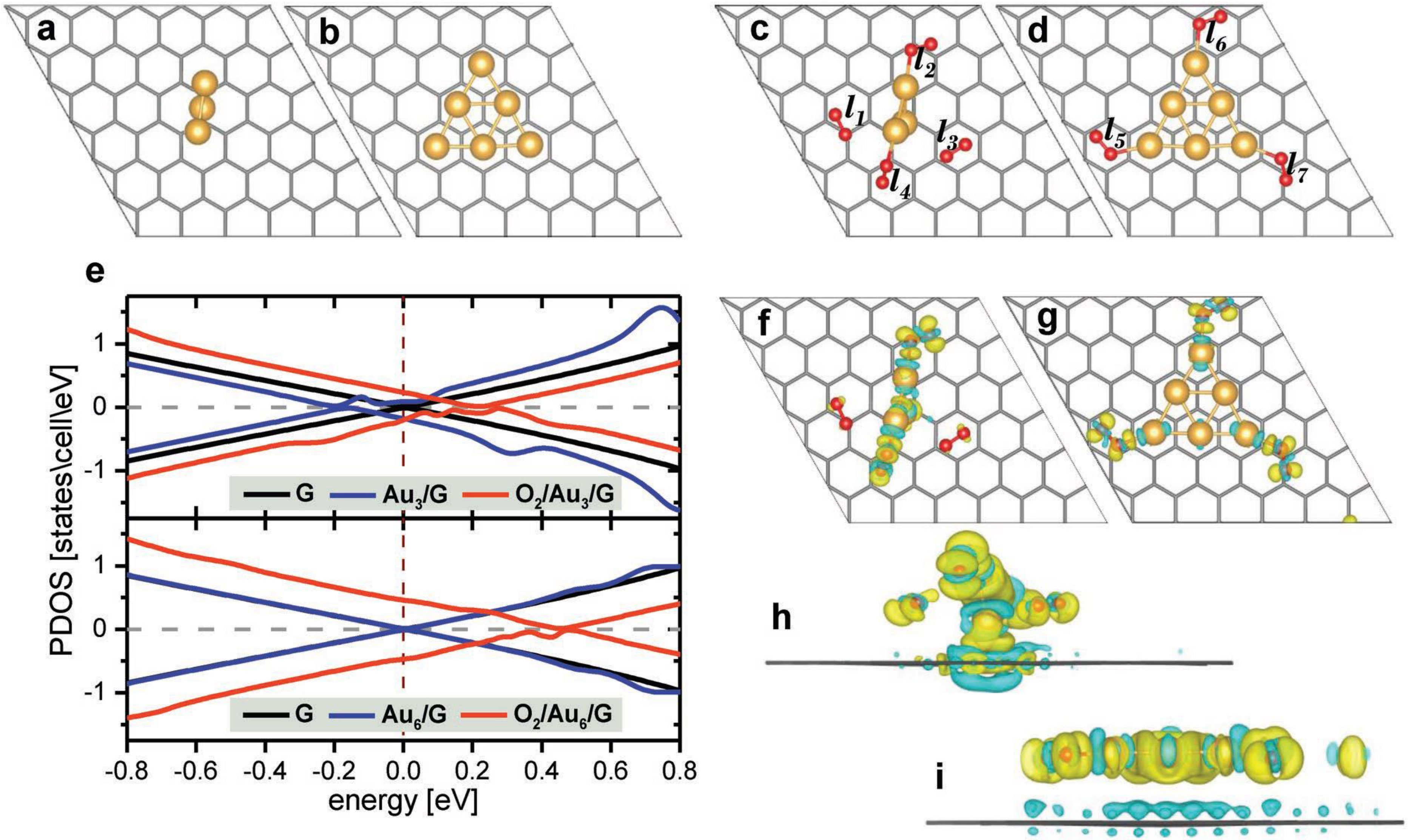
NAWA NARODOWA AGENCJA WYMIANY AKADEMICKIEJ

Współpraca z KU Leuven



• J. E. Scheerder, et al., Nanoscale, 2017, 9, 10494.

Współpraca z KU Leuven



- J. E. Scheerder, et al., Adv. Mater. Interfaces, 2018, 5, 1801274.

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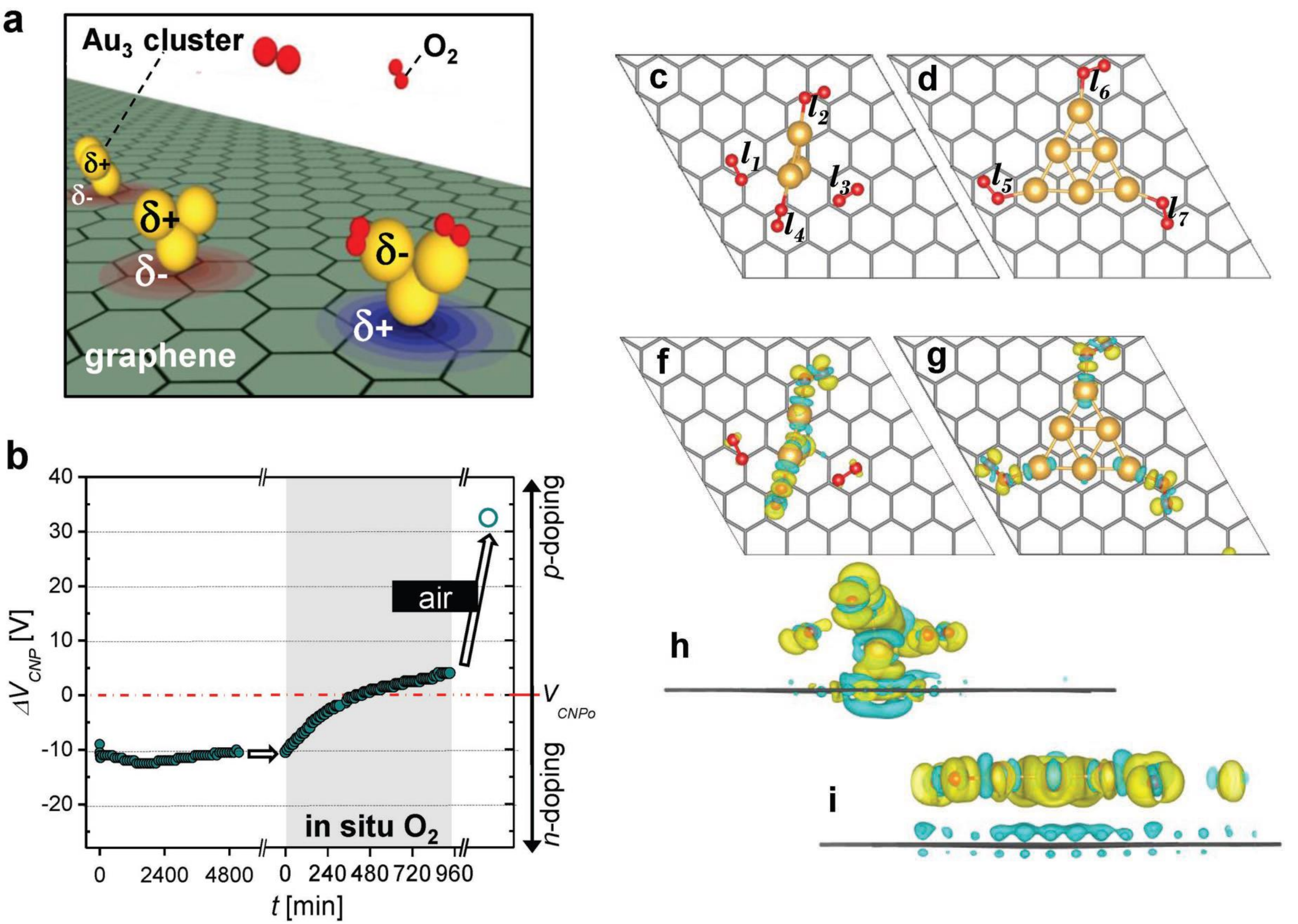

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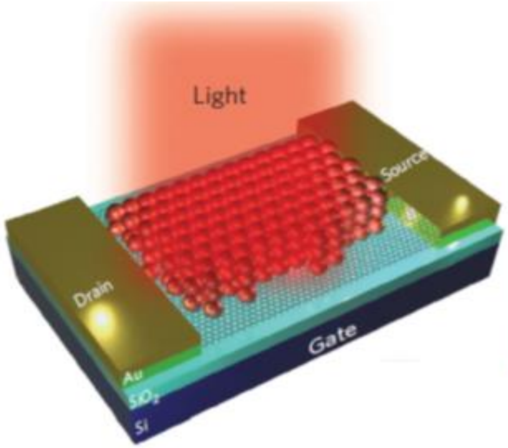

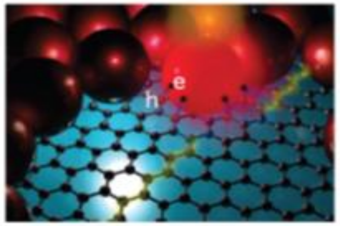

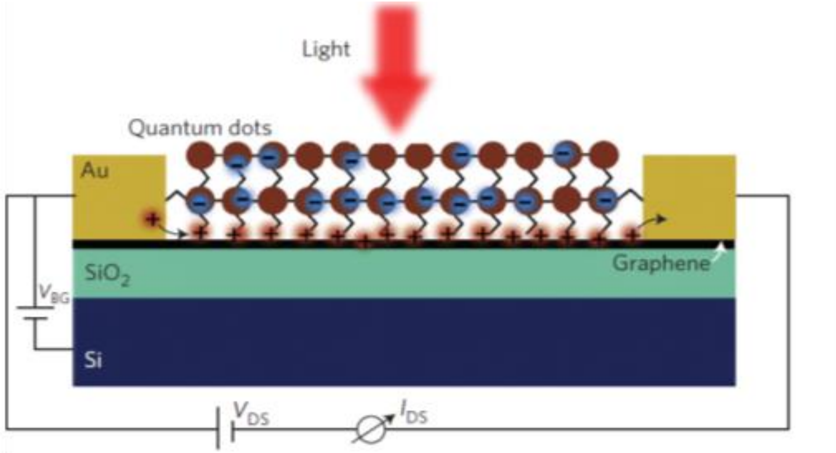

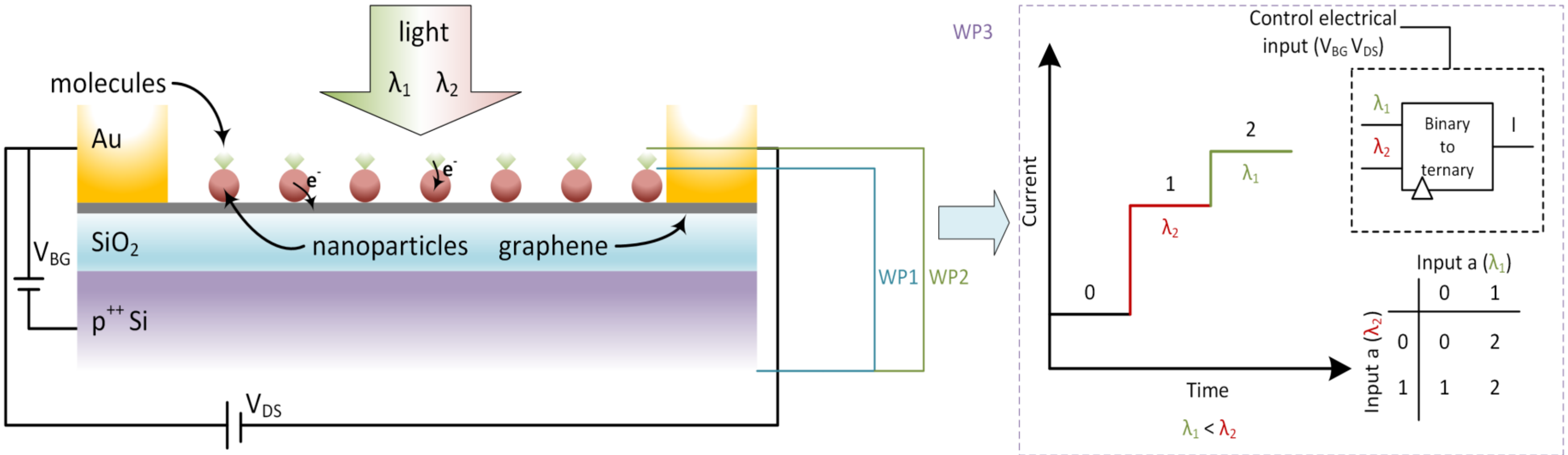

- G. Konstantatos, et al., Nature Nanotechnology, 2012, 7, 363.

Dziękuję za uwagę