

**Wybrane wyniki otrzymane w  
Pracowni Mikroskopii  
Elektronowej UMCS**

**Michał Rawski, Grzegorz Słowik**

1. Skaningowy Mikroskop Elektronowy  
FEI Quanta 3D FEG

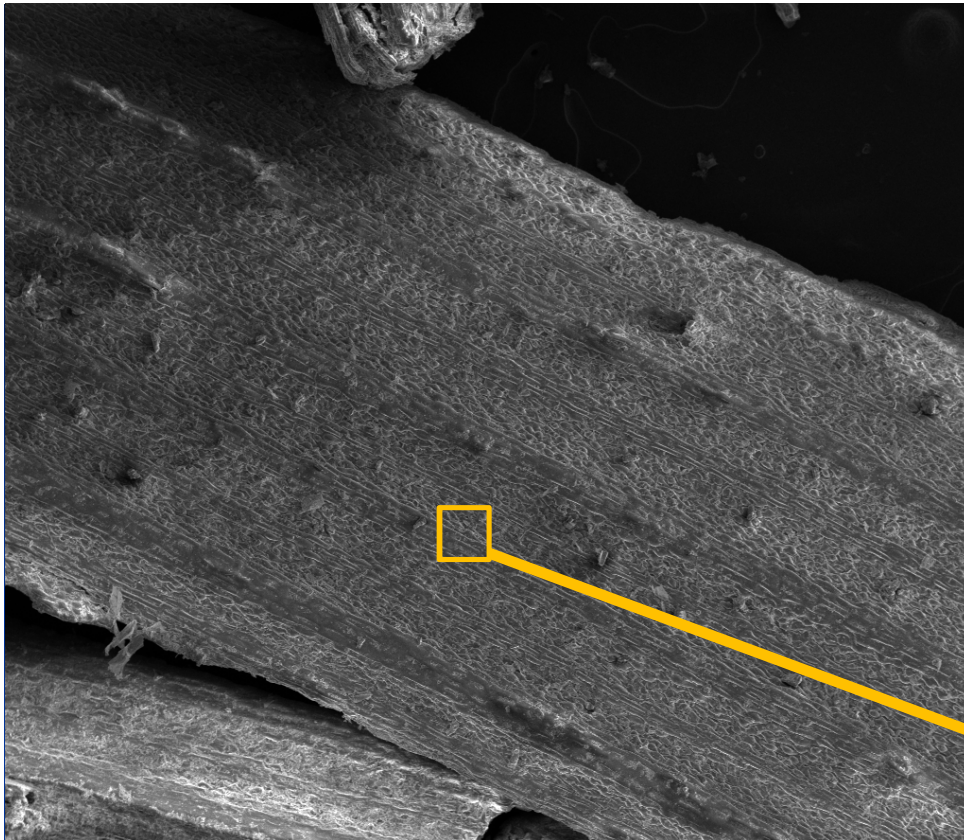
- Obrazowanie
- EDS
- Cięcie FIB

2. Transmisyjny Mikroskop Elektronowy  
FEI Titan G2 60-300

- Obrazowanie TEM
- Obrazowanie STEM
- EDS

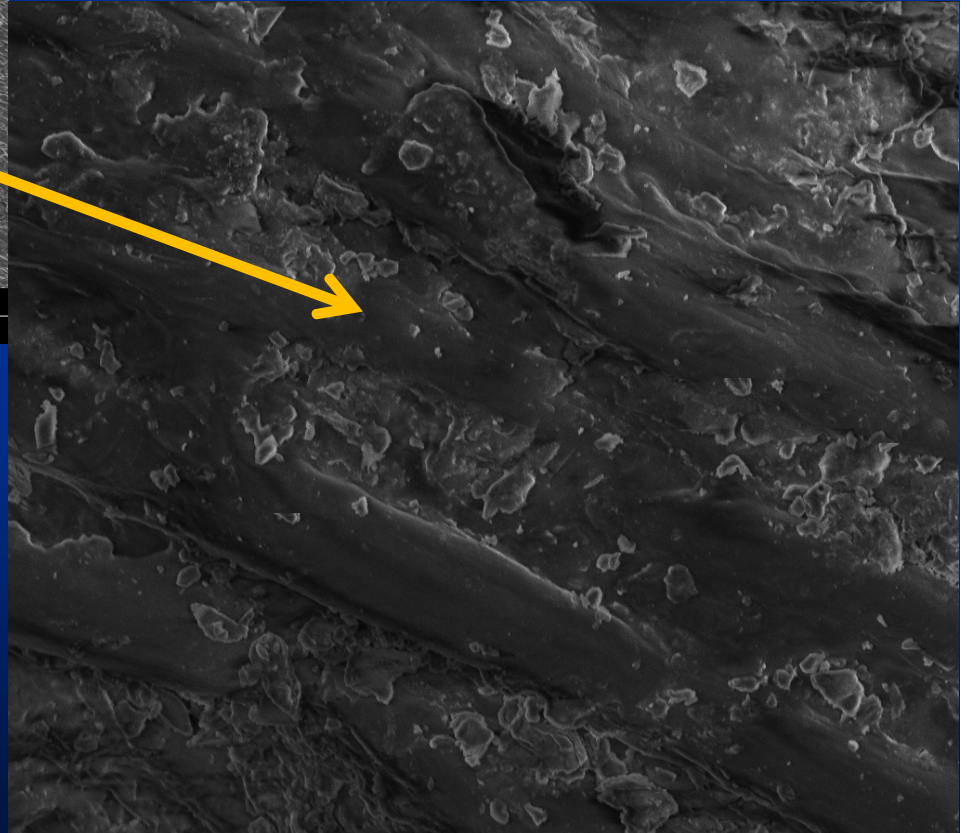
Quanta

SEM

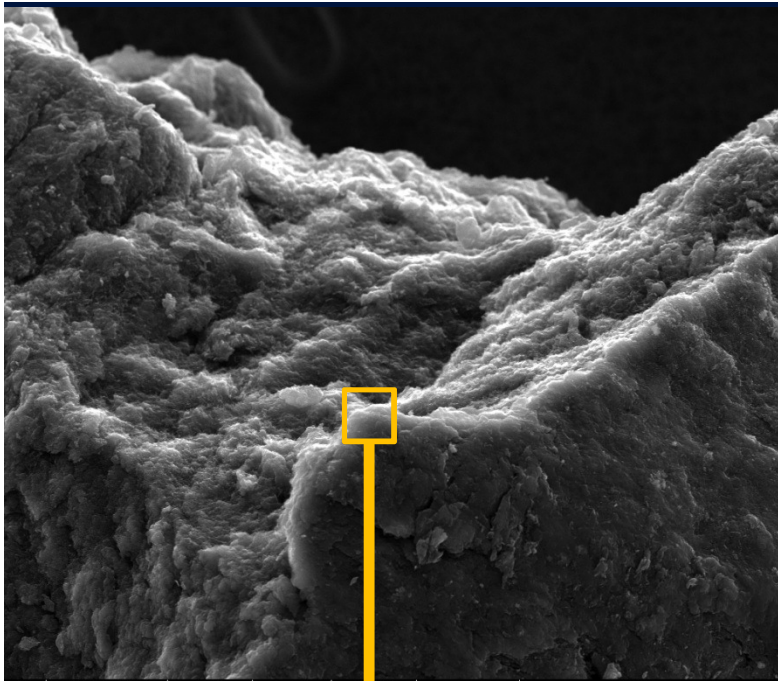


4/17/2012	HV	mag	WD	pressure	500 $\mu$ m
4:10:52 PM	5.00 kV	100 x	11.4 mm	6.68e-3 Pa	Quanta 3DFEG

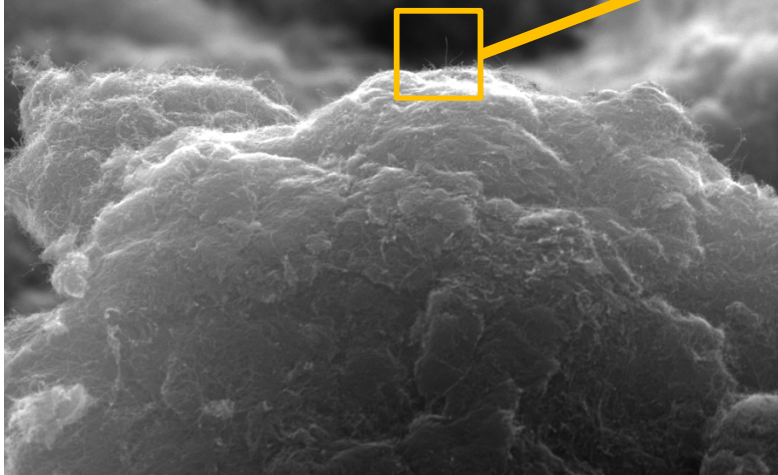
# Łodyga trawy



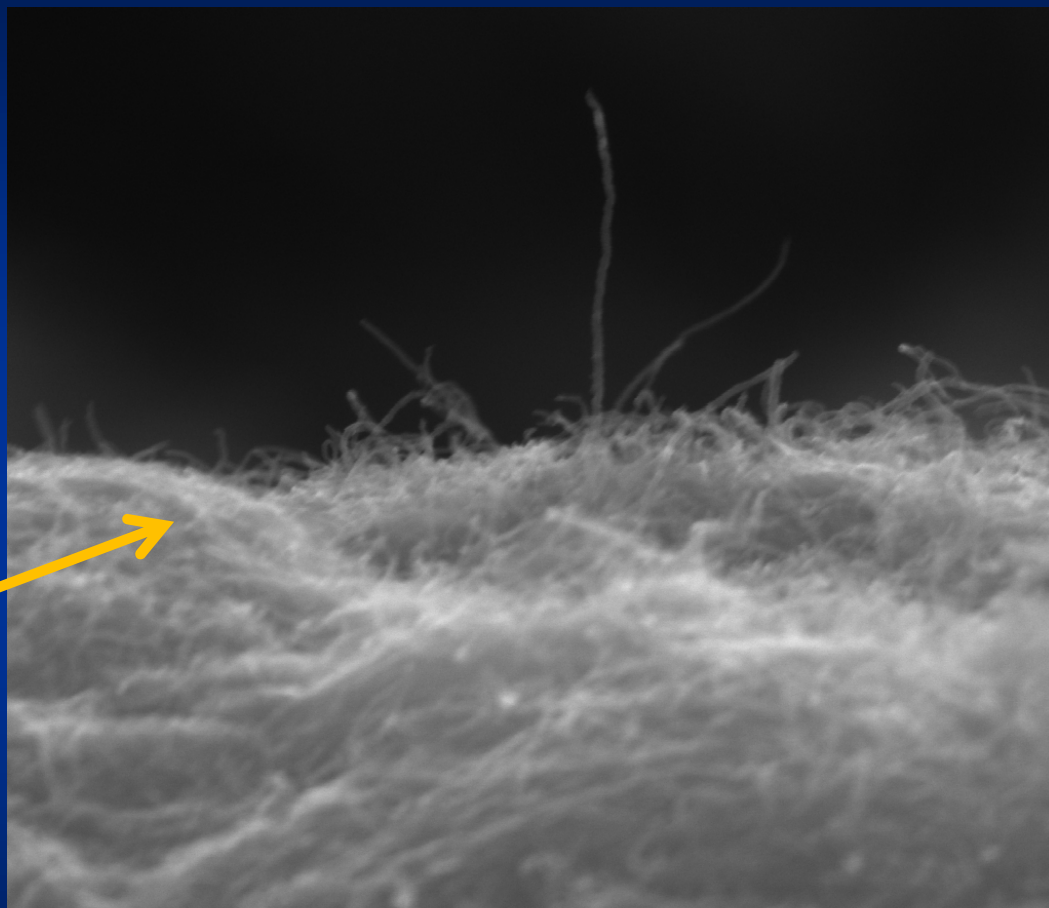
4/17/2012	HV	mag	WD	pressure	20 $\mu$ m
4:15:44 PM	5.00 kV	2 500 x	11.9 mm	2.71e-3 Pa	Quanta 3DFEG



1/20/2012	HV	mag	WD	pressure	50 µm
11:56:24 AM	20.00 kV	650 x	10.4 mm	2.73e-4 Pa	Quanta 3DFEG

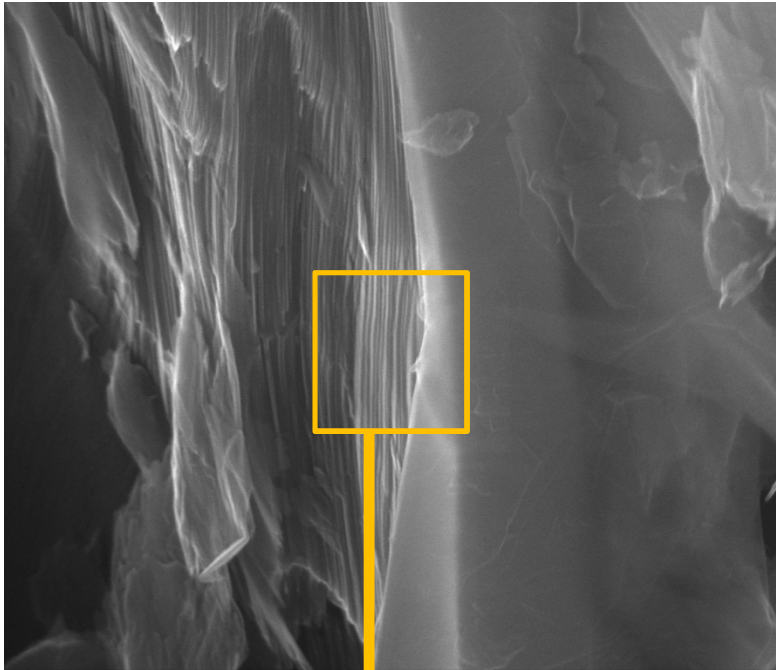


1/20/2012	HV	mag	WD	pressure	5 µm
11:57:33 AM	20.00 kV	8 000 x	10.4 mm	2.73e-4 Pa	Quanta 3DFEG

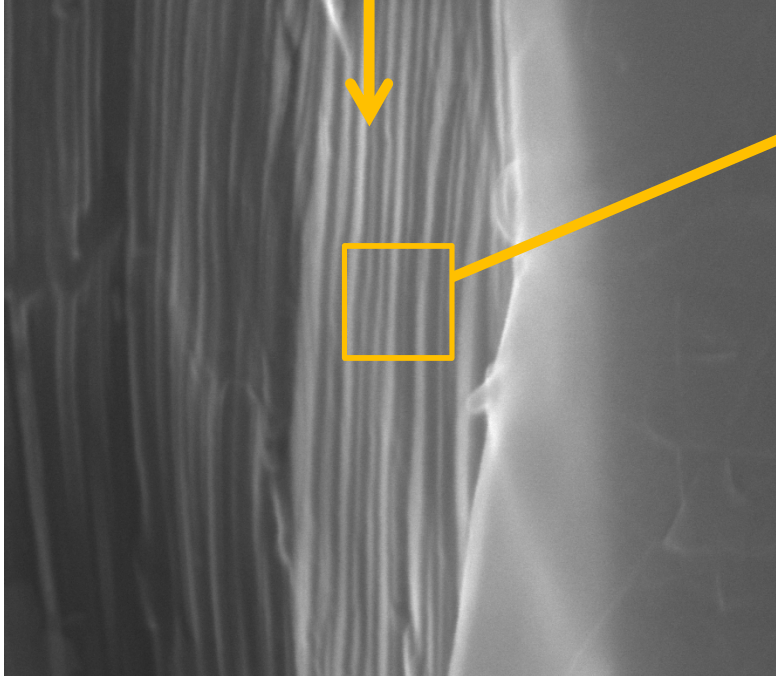


1/20/2012	HV	mag	WD	pressure	500 nm
12:00:04 PM	20.00 kV	65 000 x	10.4 mm	2.73e-4 Pa	Quanta 3DFEG

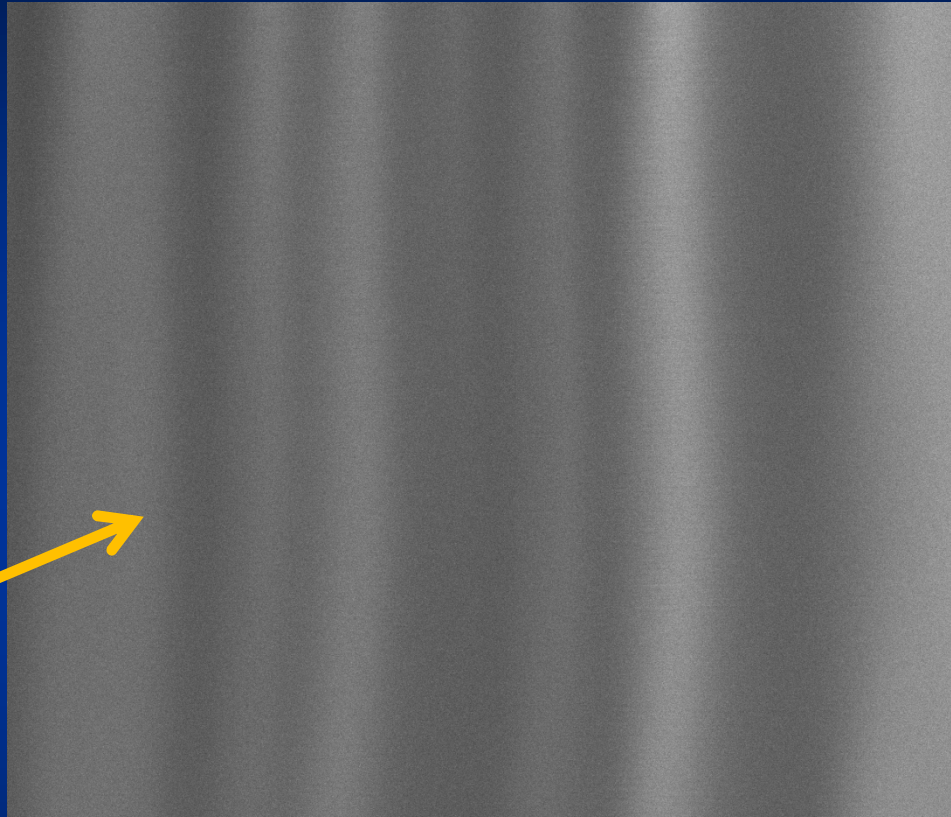
# Nanorurki węglowe



9/2/2011	HV	mag	WD	pressure	imRatio	1 $\mu$ m
12:46:06 PM	30.00 kV	80 000 x	9.8 mm	3.50e-4 Pa	1.000	Quanta 3DFEG

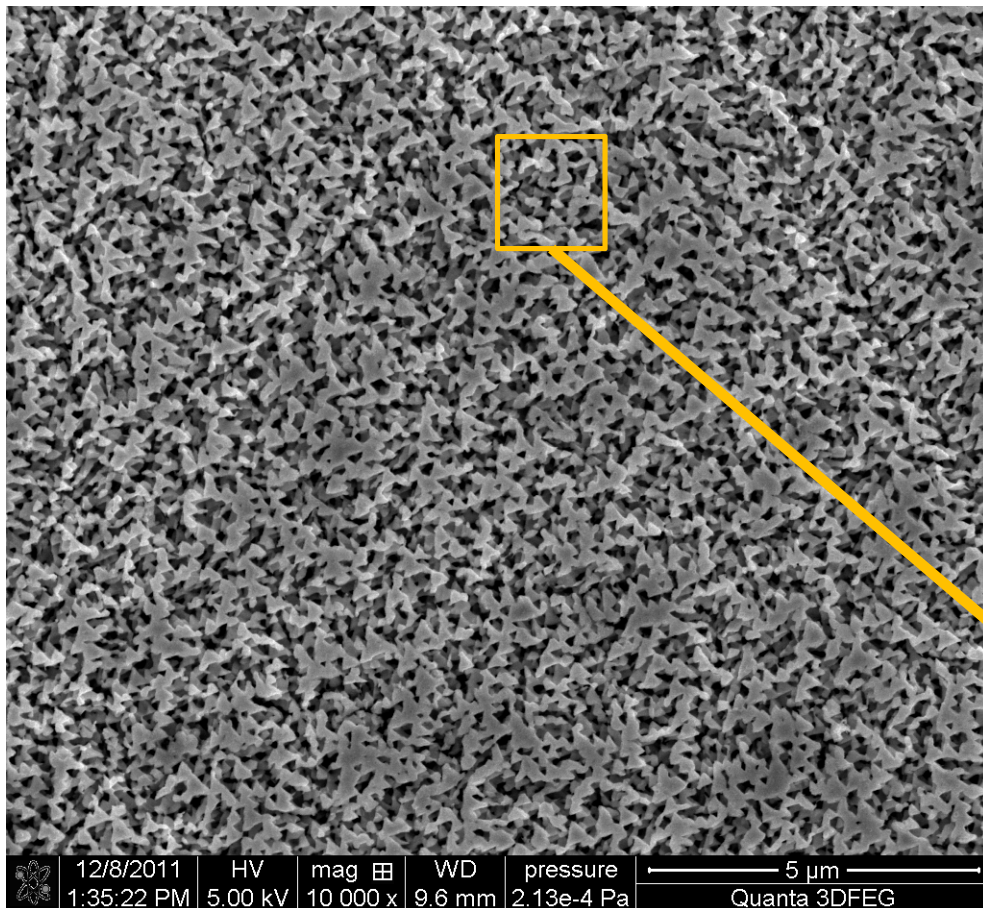


9/2/2011	HV	mag	WD	pressure	400 nm
12:44:35 PM	30.00 kV	250 063 x	9.8 mm	3.50e-4 Pa	Quanta 3DFEG



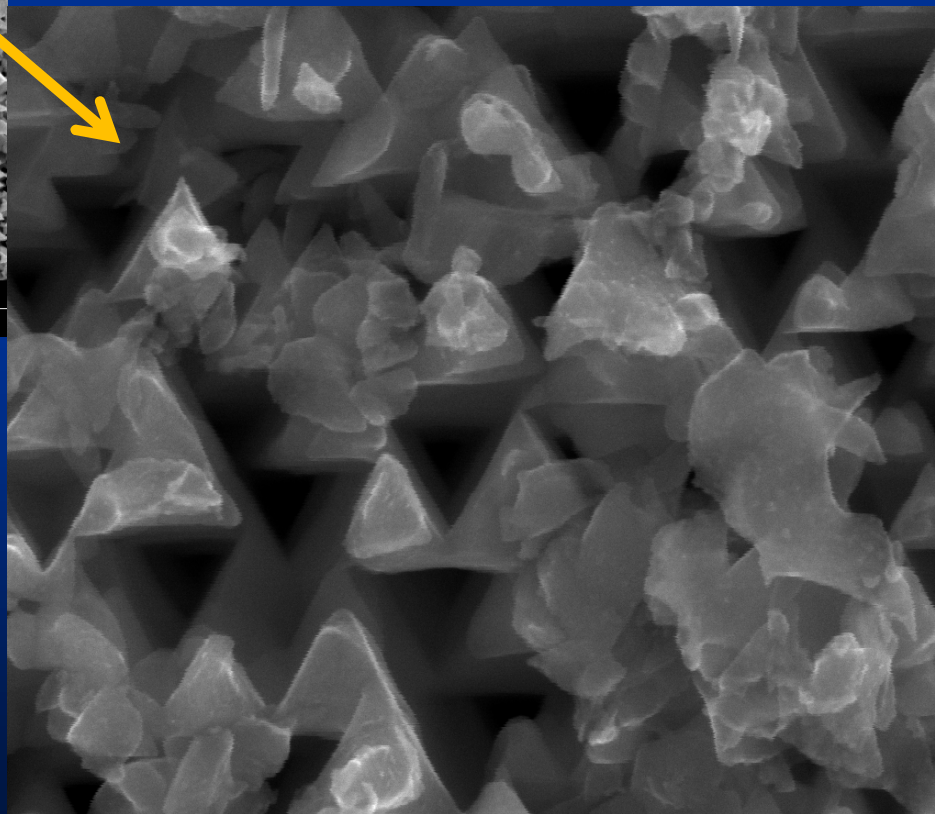
9/2/2011	HV	mag	WD	pressure	50 nm
1:06:41 PM	30.00 kV	2 000 000 x	9.8 mm	3.13e-4 Pa	Quanta 3DFEG

**Grafit**

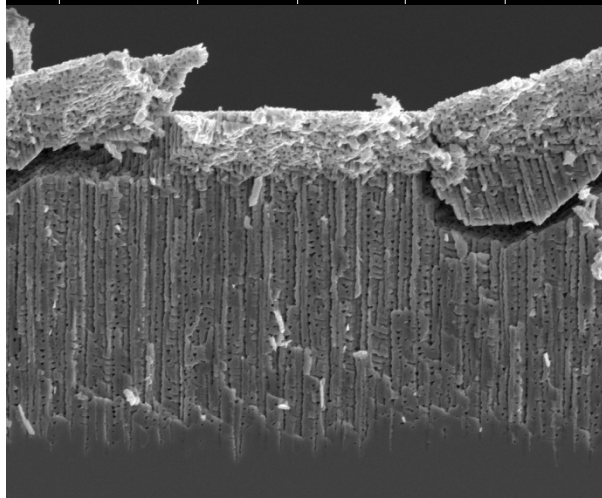


12/8/2011	HV	mag	WD	pressure	5 $\mu$ m
1:35:22 PM	5.00 kV	10 000 x	9.6 mm	2.13e-4 Pa	Quanta 3DFEG

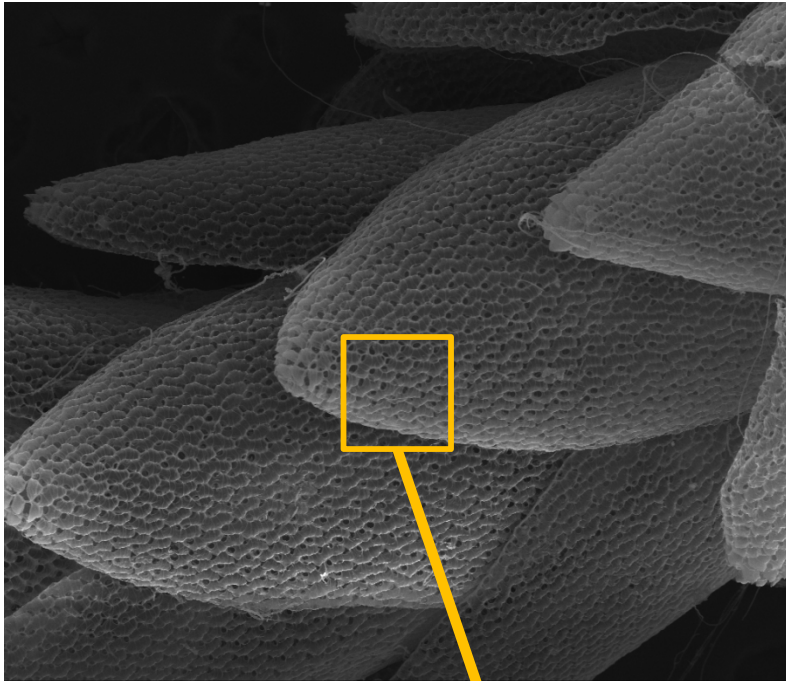
## Nanocząstki InP



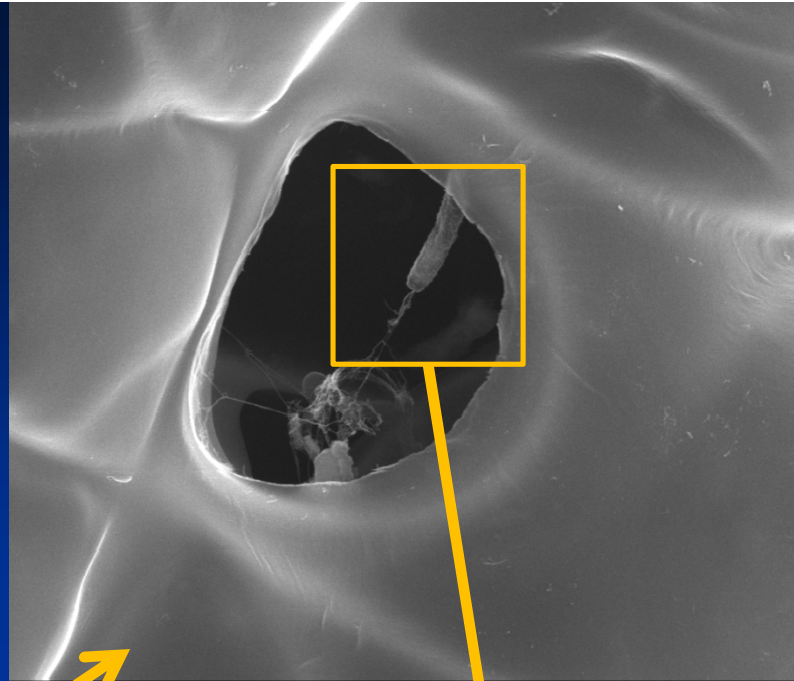
12/8/2011	HV	mag	WD	pressure	300 nm
1:43:30 PM	30.00 kV	125 000 x	9.5 mm	2.13e-4 Pa	Quanta 3DFEG



12/8/2011	HV	mag	WD	pressure	5 $\mu$ m
1:51:35 PM	5.00 kV	9 994 x	10.0 mm	2.13e-4 Pa	Quanta 3DFEG

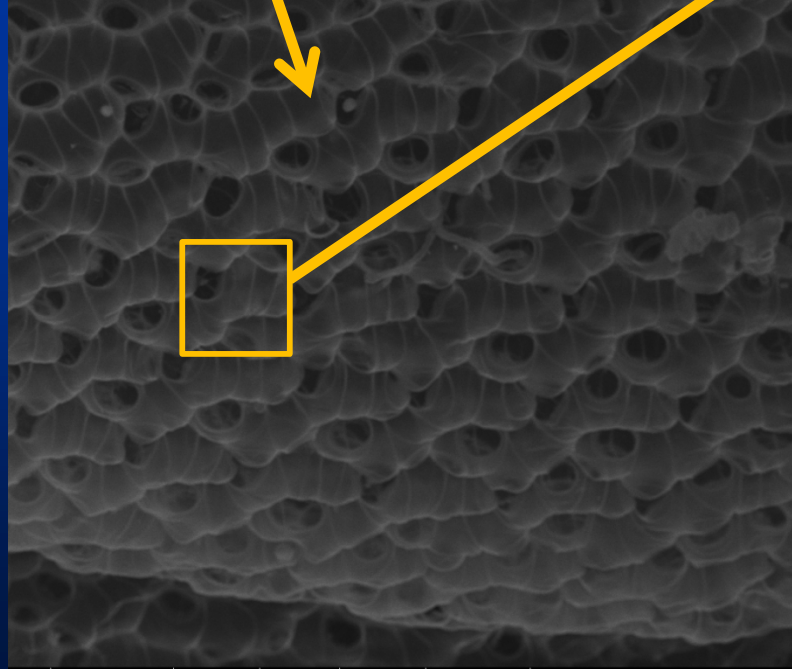


11/18/2011 HV mag □ WD pressure  
10:19:47 AM 30.00 kV 202 x 11.0 mm 5.10e-4 Pa  
400 μm  
Quanta 3DFEG

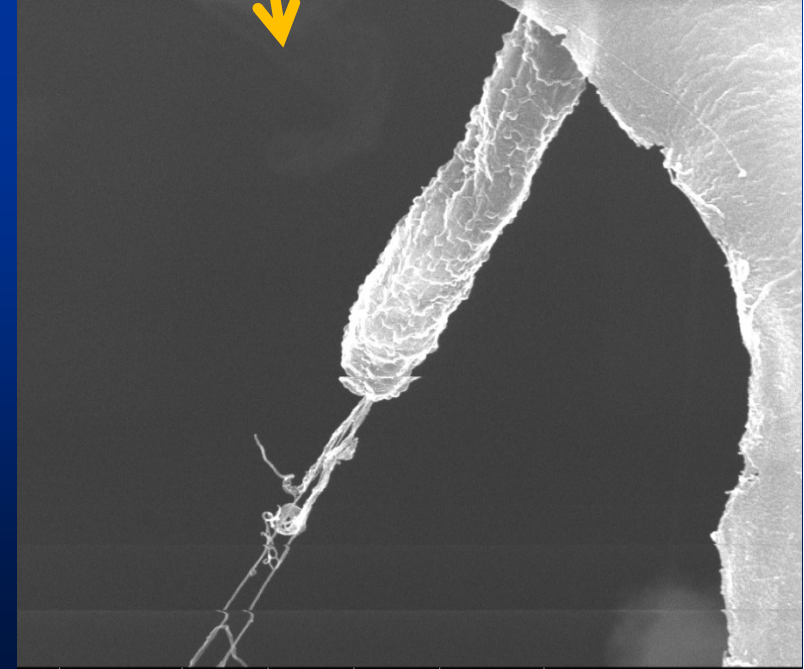


11/18/2011 HV mag □ WD pressure  
10:53:06 AM 20.00 kV 12 014 x 10.8 mm 4.29e-4 Pa  
5 μm  
Quanta 3DFEG

**Mech**



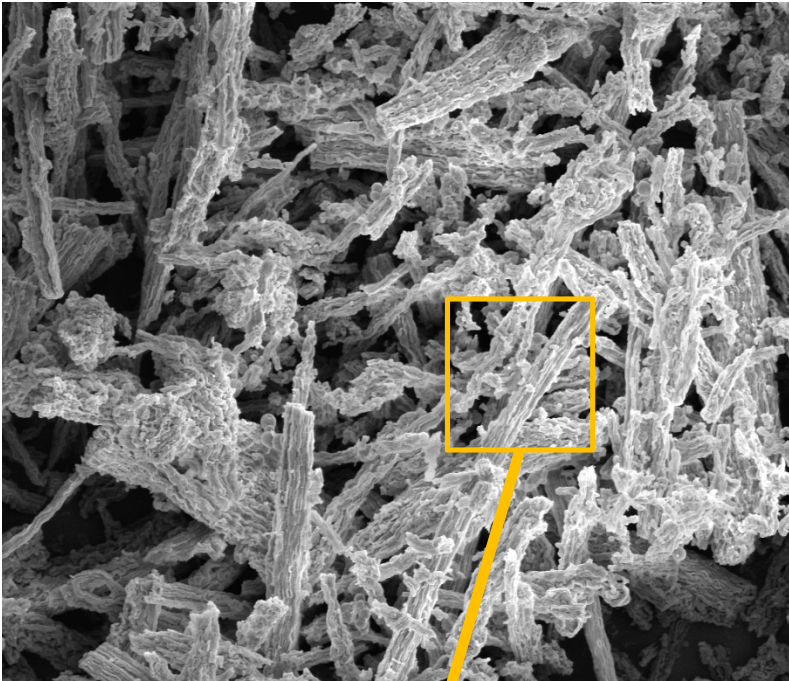
11/18/2011 HV mag □ WD pressure  
10:21:38 AM 30.00 kV 1 036 x 10.3 mm 3.64e-3 Pa  
50 μm  
Quanta 3DFEG



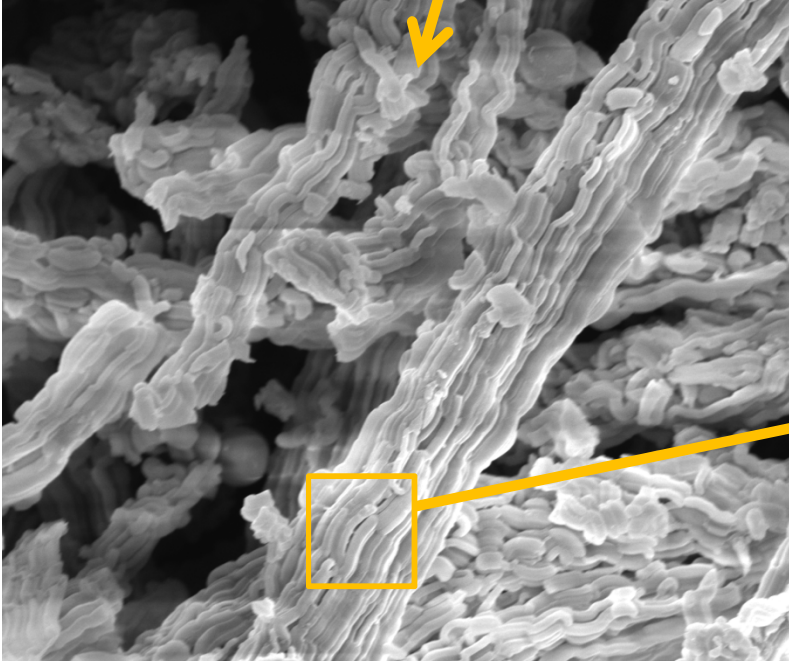
11/18/2011 HV mag □ WD pressure  
10:56:04 AM 20.00 kV 49 969 x 10.8 mm 3.83e-4 Pa  
1 μm  
Quanta 3DFEG



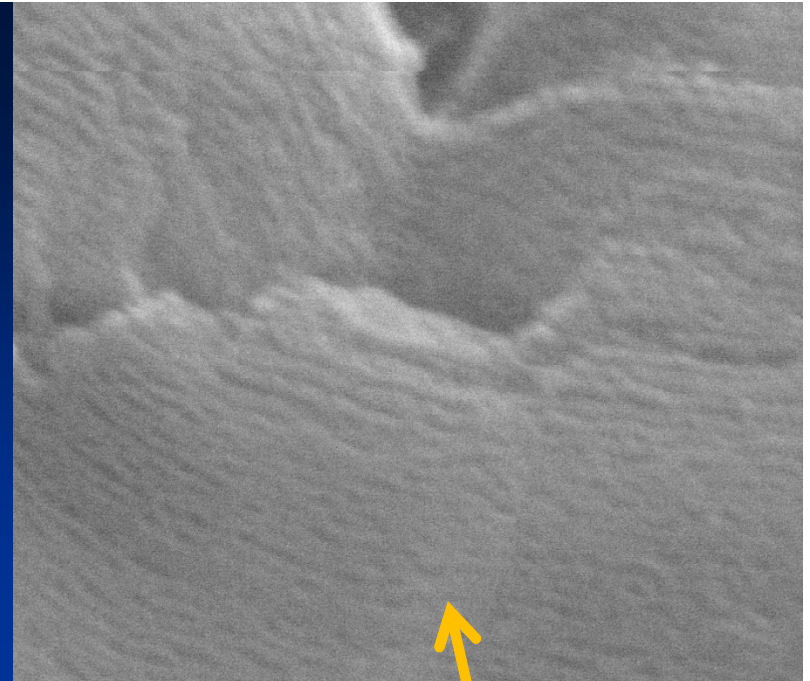
# Włókna krzemionkowe



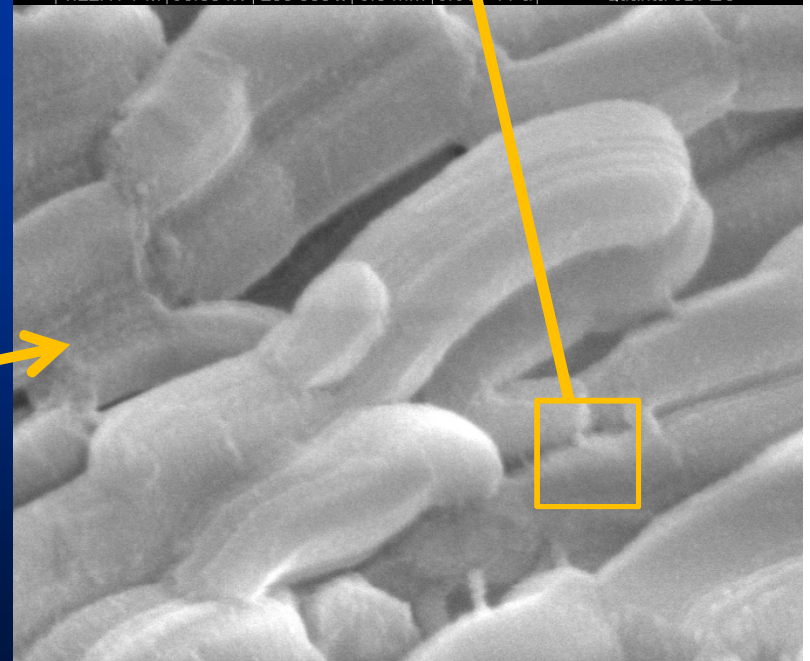
6/26/2012 HV mag WD pressure 50  $\mu$ m  
1:10:42 PM 5.00 kV 1 000 x 10.5 mm 7.01e-4 Pa Quanta 3DFEG



6/26/2012 HV mag WD pressure 10  $\mu$ m  
1:08:56 PM 5.00 kV 5 000 x 10.5 mm 7.03e-4 Pa Quanta 3DFEG

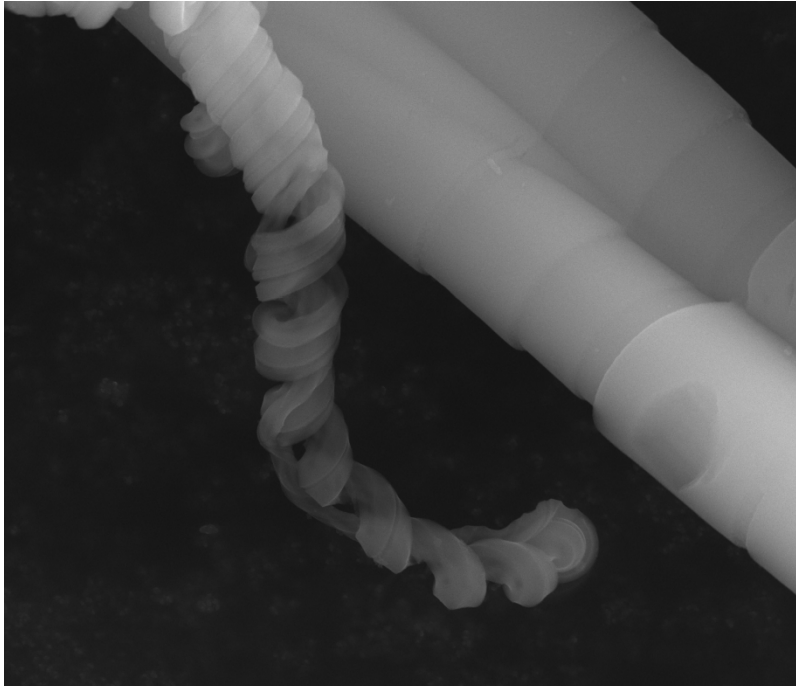


6/26/2012 HV mag WD pressure 200 nm  
1:22:17 PM 30.00 kV 200 000 x 9.8 mm 5.61e-4 Pa Quanta 3DFEG

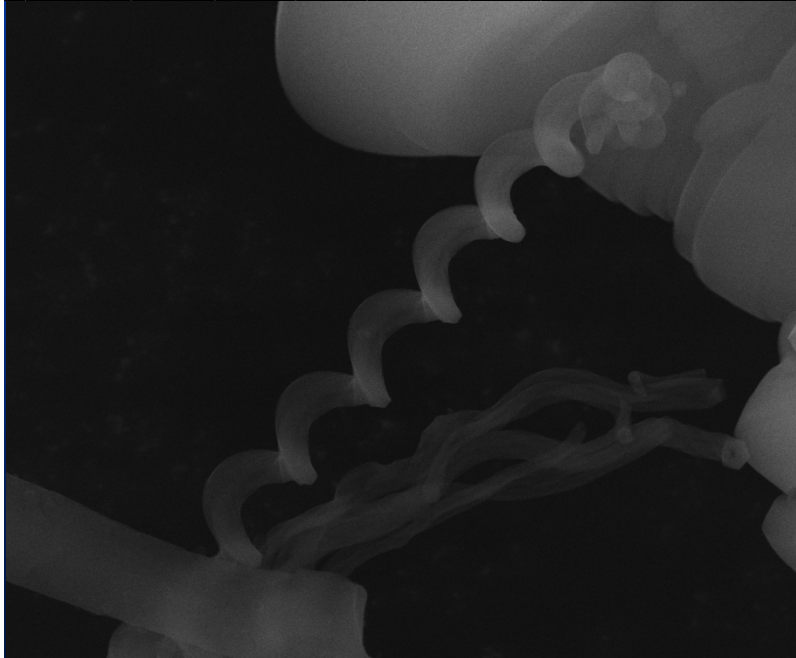


6/26/2012 HV mag WD pressure 500 nm  
1:14:25 PM 5.00 kV 65 003 x 10.5 mm 6.28e-4 Pa Quanta 3DFEG

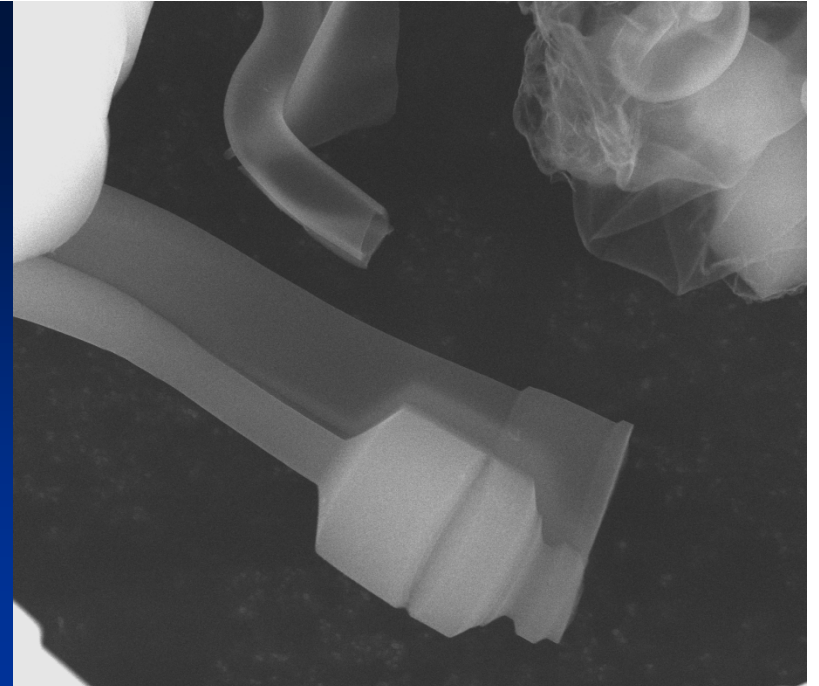
# Włókna krzemionkowe



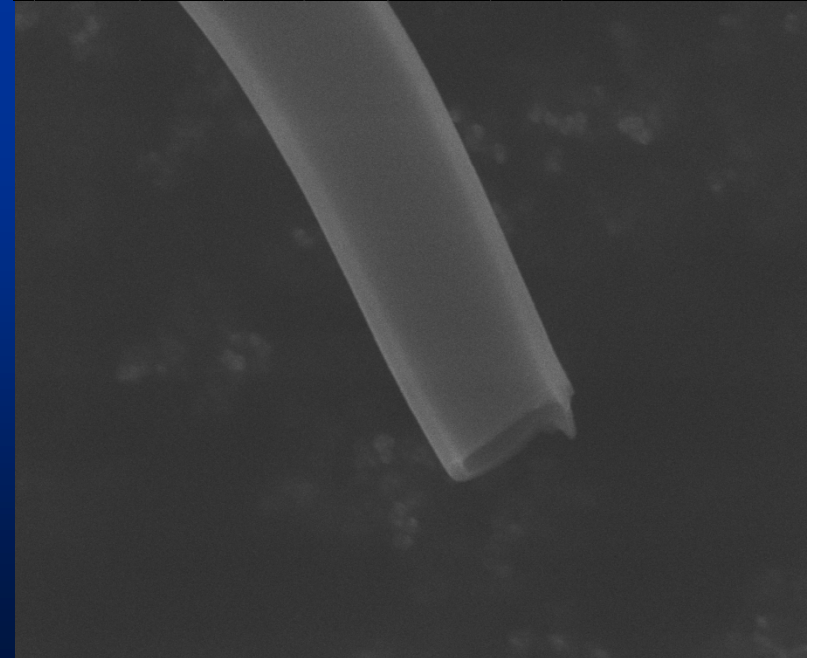
11/2/2011 HV mag □ WD pressure imRatio  
1:58:39 PM 30.00 kV 25 000 x 9.9 mm 2.50e-4 Pa 1.000  
3 μm  
Quanta 3DFEG



11/2/2011 HV mag □ WD pressure imRatio  
1:40:52 PM 30.00 kV 25 000 x 9.8 mm 3.06e-4 Pa 1.000  
3 μm  
Quanta 3DFEG

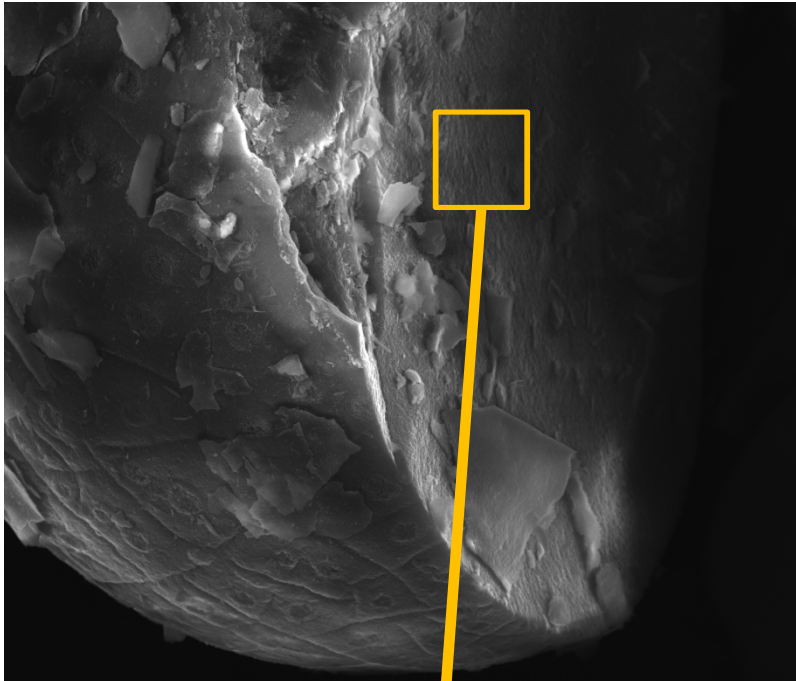


11/3/2011 HV mag □ WD pressure imRatio  
9:44:53 AM 30.00 kV 25 003 x 10.4 mm 1.26e-3 Pa 1.000  
3 μm  
Quanta 3DFEG

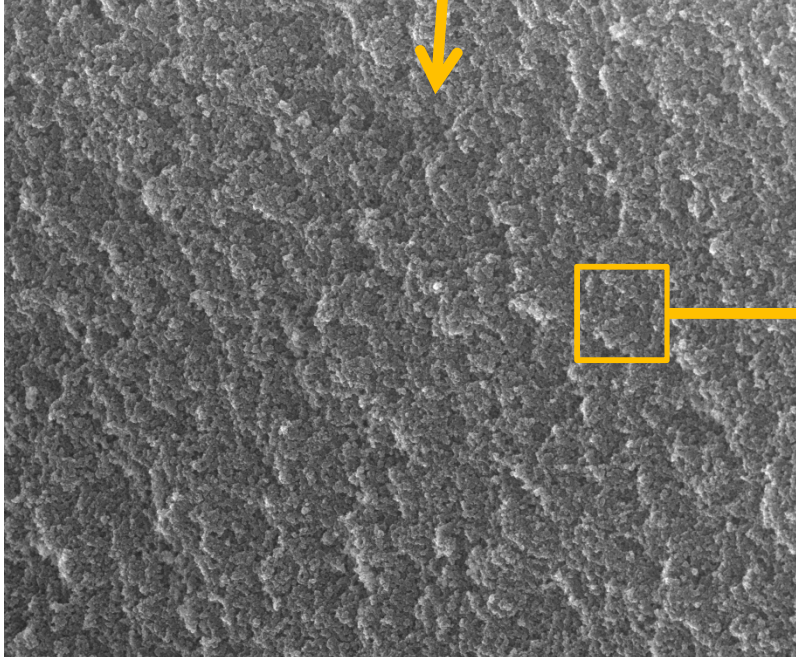


11/3/2011 HV mag □ WD pressure imRatio  
9:42:28 AM 30.00 kV 65 047 x 10.4 mm 1.41e-3 Pa 1.000  
1 μm  
Quanta 3DFEG

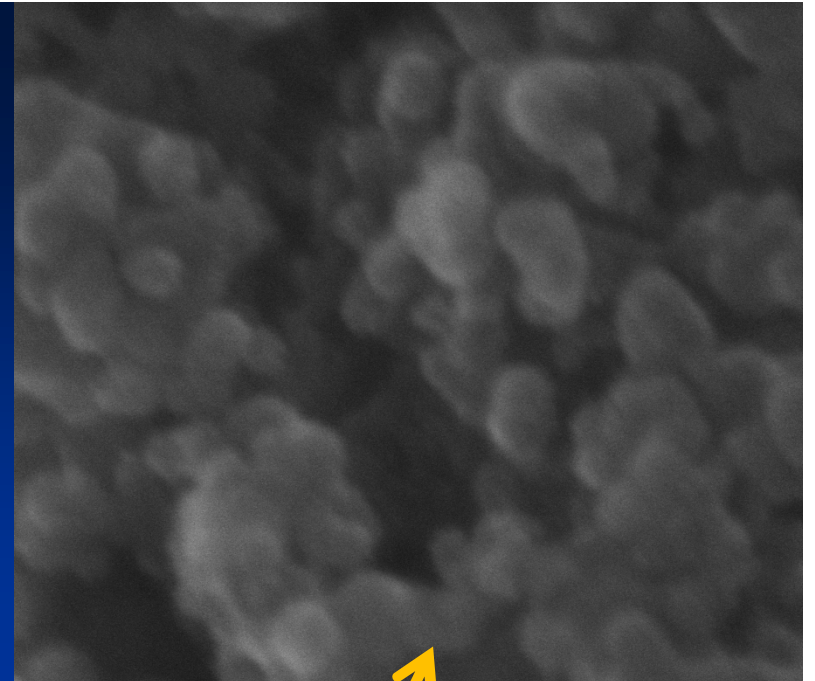
# Kulki krzemionkowe



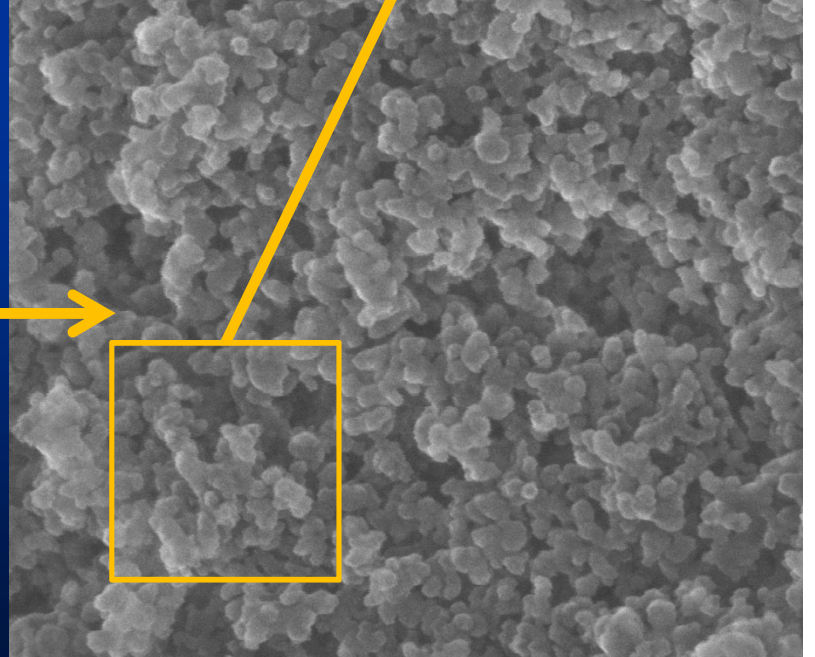
10/31/2011 HV mag □ WD pressure imRatio  
8:39:40 AM 30.00 kV 1 200 x 9.7 mm 1.04e-4 Pa 1.000  
50 μm  
Quanta 3DFEG



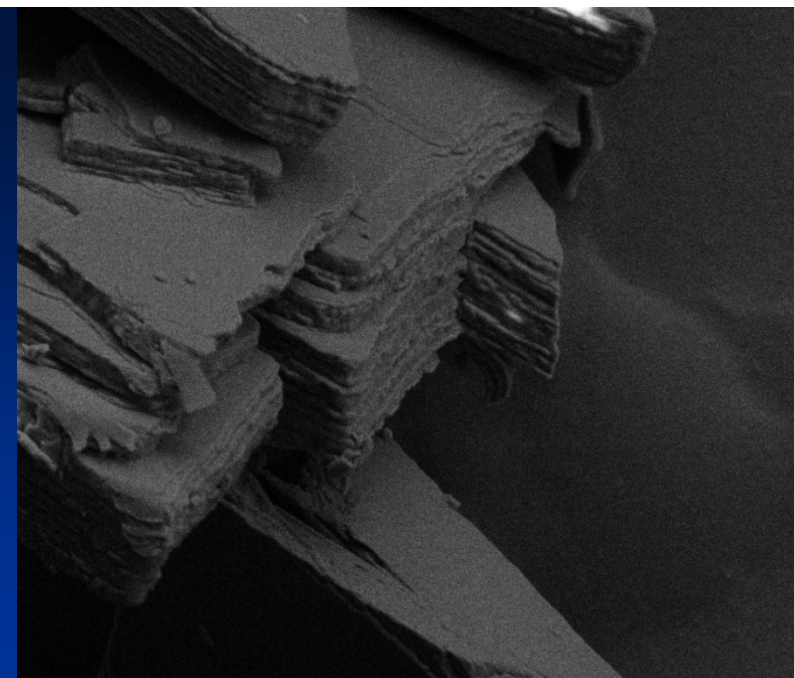
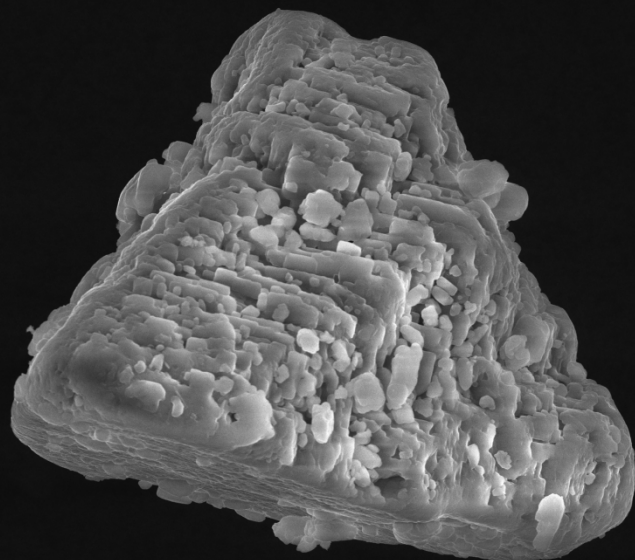
11/2/2011 HV mag □ WD pressure imRatio  
9:14:42 AM 30.00 kV 25 000 x 9.9 mm 4.80e-4 Pa 1.000  
3 μm  
Quanta 3DFEG



11/2/2011 HV mag □ WD pressure  
8:51:37 AM 30.00 kV 1 000 000 x 10.0 mm 1.18e-3 Pa  
100 nm  
Quanta 3DFEG



11/2/2011 HV mag □ WD pressure  
9:04:21 AM 30.00 kV 300 000 x 10.0 mm 6.72e-4 Pa  
300 nm  
Quanta 3DFEG



9/23/2011 HV mag □ WD pressure imRatio  
8:44:35 AM 30.00 kV 1 500 x 10.0 mm 1.59e-4 Pa 1.000

50 μm  
Quanta 3DFEG

2/22/2012 HV mag ▣ WD pressure  
2:11:06 PM 5.00 kV 1 750 x 10.8 mm 5.25e-4 Pa

20 μm  
Quanta 3DFEG

**Sól kuchenna**

**Krystaliczny  
cholesterol**



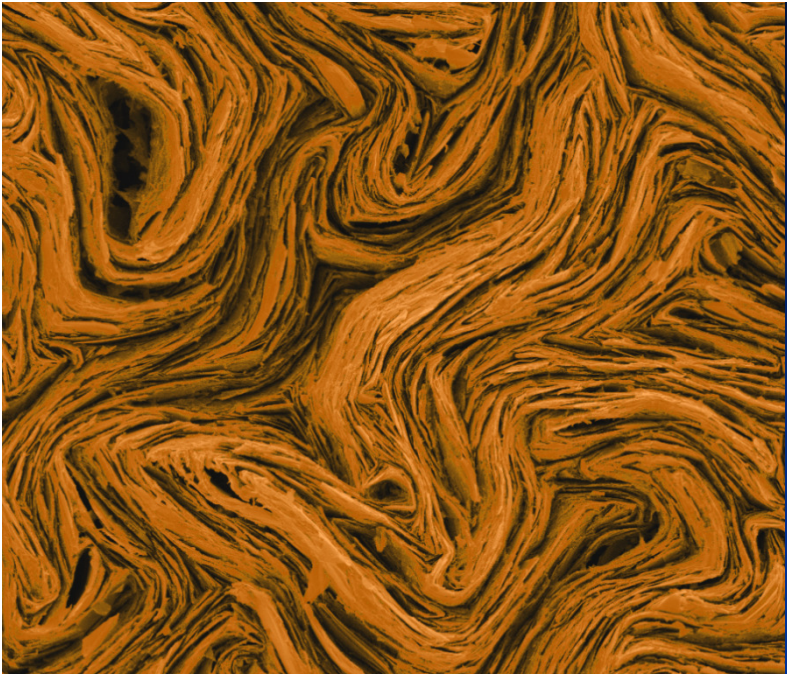
**Kulka  $\text{CaCO}_3$**

10/12/2011 HV mag □ WD pressure  
2:47:54 PM 30.00 kV 130 000 x 10.3 mm 1.21e-3 Pa

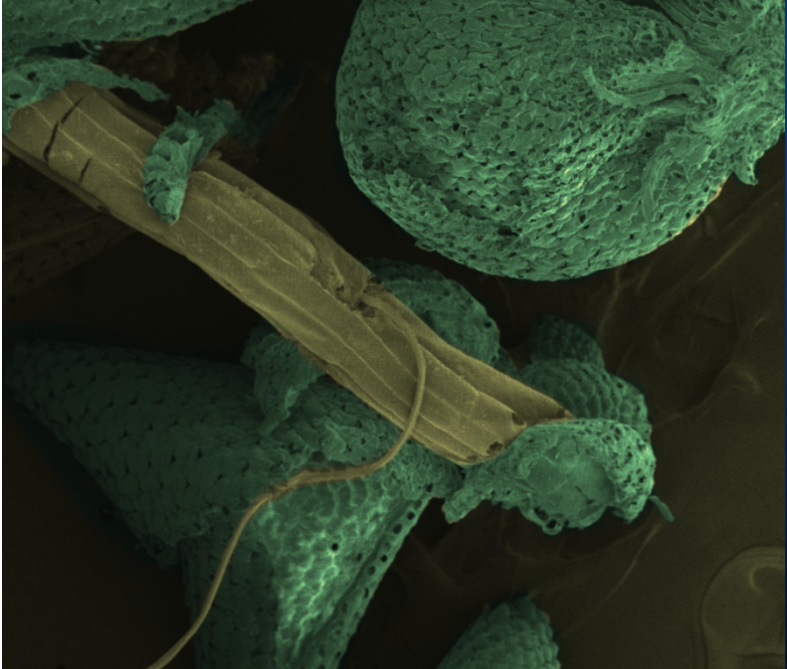
500 nm  
Quanta 3DFEG

**Drut Cu w przekroju**

**Mech**



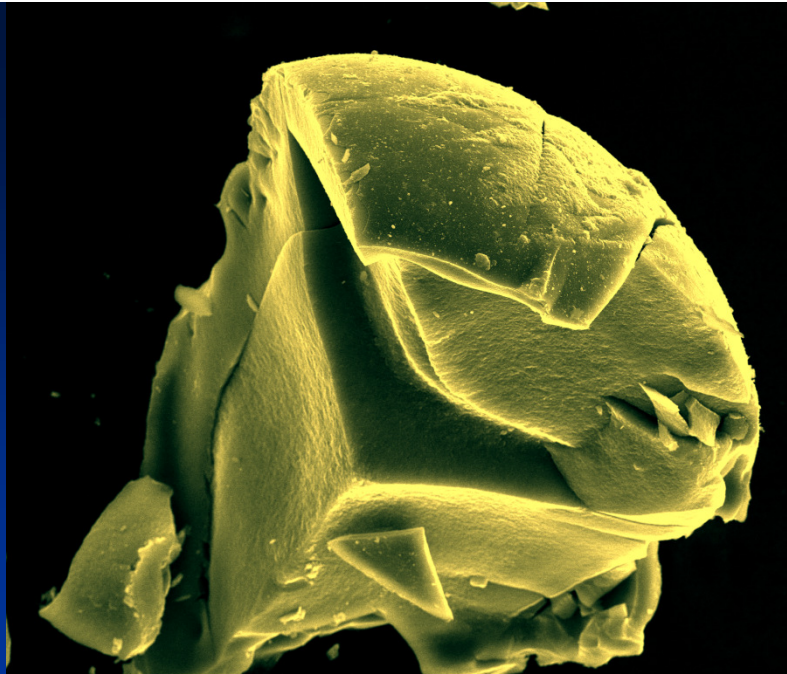
2/16/2012 HV mag 田 WD pressure 20 μm  
12:39:16 PM 5.00 kV 2 500 x 11.1 mm 6.05e-5 Pa Quanta 3DFEG



10/17/2011 HV mag □ WD pressure 200 μm  
12:29:13 PM 2.00 kV 500 x 9.6 mm 2.13e-4 Pa Quanta 3DFEG

**Kulka z krzemionki**

**Bakterie ecoli**



8/30/2011 HV mag □ WD pressure imRatio 50 μm  
2:32:24 PM 30.00 kV 1 077 x 9.5 mm 2.86e-4 Pa 1.000 Quanta 3DFEG



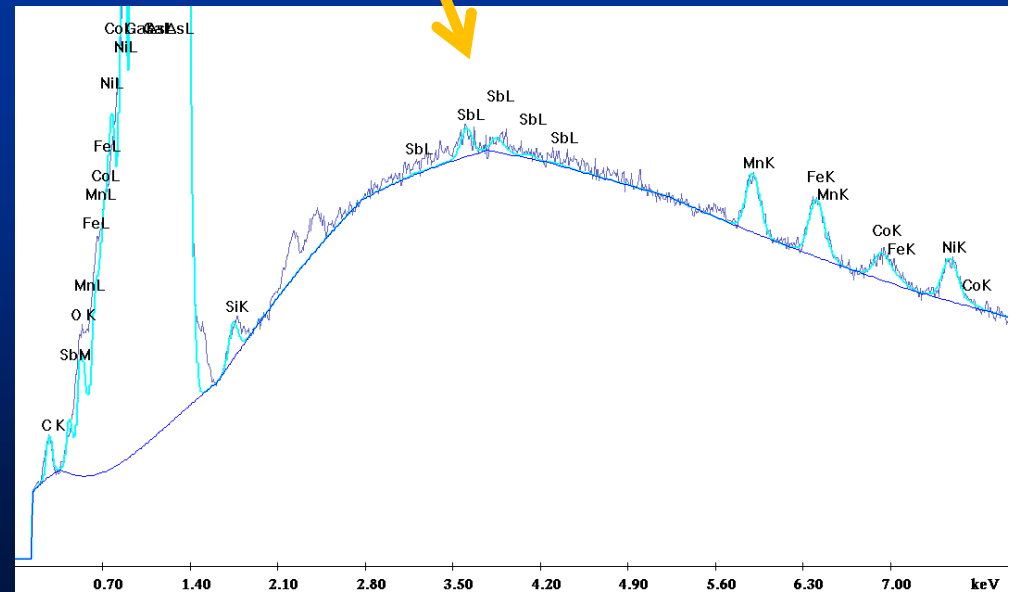
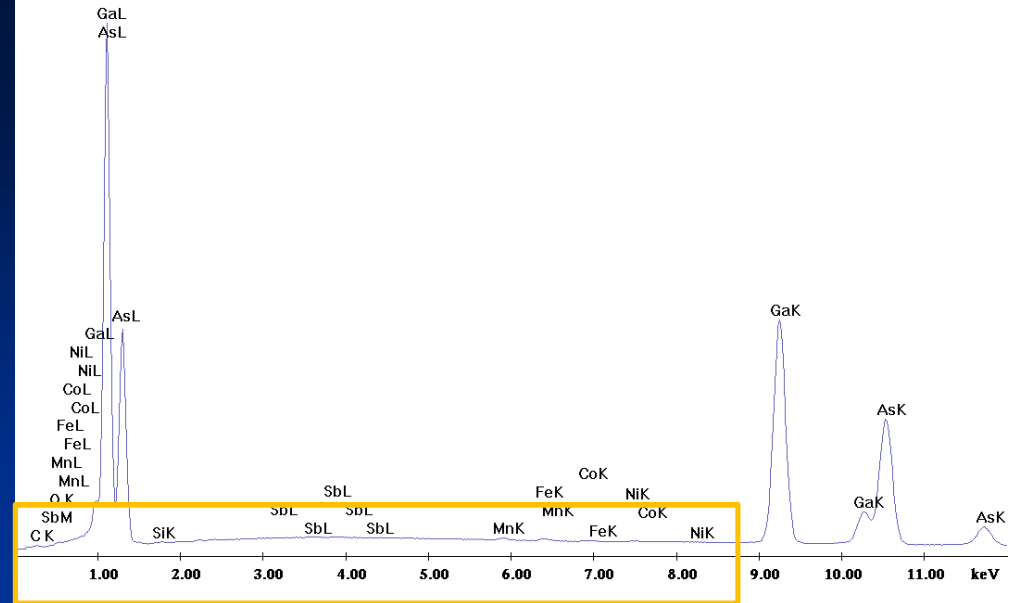
11/3/2011 HV mag □ WD pressure imRatio 1 μm  
1:06:42 PM 30.00 kV 50 027 x 10.3 mm 7.52e-4 Pa 1.000 Quanta 3DFEG

Quanta

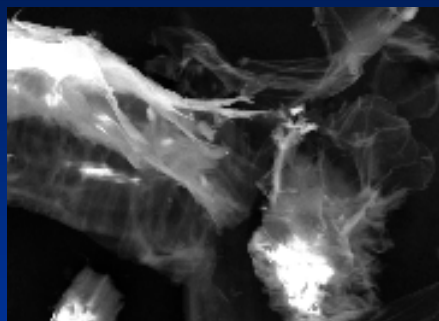
EDS

# Epitaksjalna warstwa GaAs

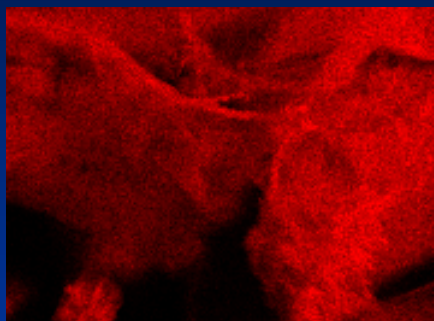
Element	Wt %	At %
C K	0.59	3.37
O K	0.55	2.36
SiK	0.15	0.37
SbL	0.15	0.08
MnK	0.15	0.18
FeK	0.15	0.19
CoK	0.08	0.10
NiK	0.14	0.16
<u>GaK</u>	<u>47.31</u>	<u>46.64</u>
<u>AsK</u>	<u>50.74</u>	<u>46.55</u>
<b>Total</b>	<b>100.000</b>	<b>100.000</b>



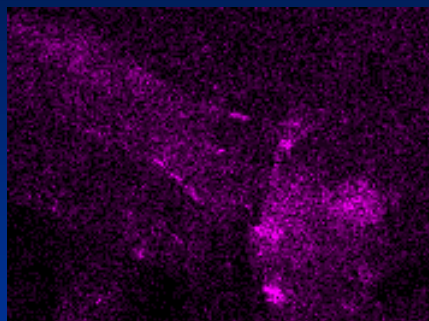
# Trawa z naniesioną krzemionką



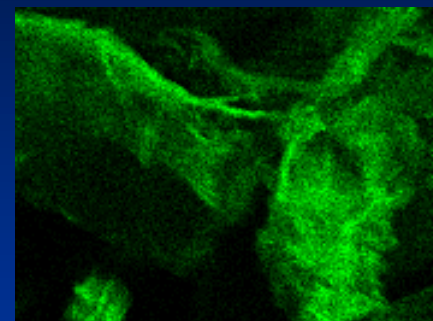
SE



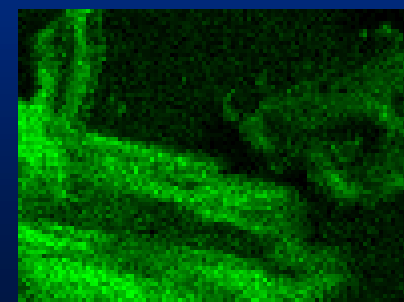
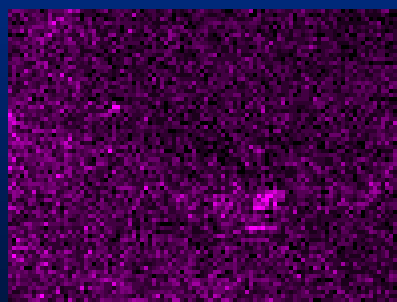
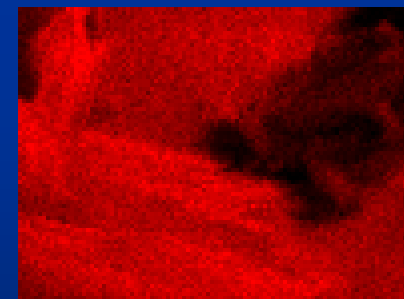
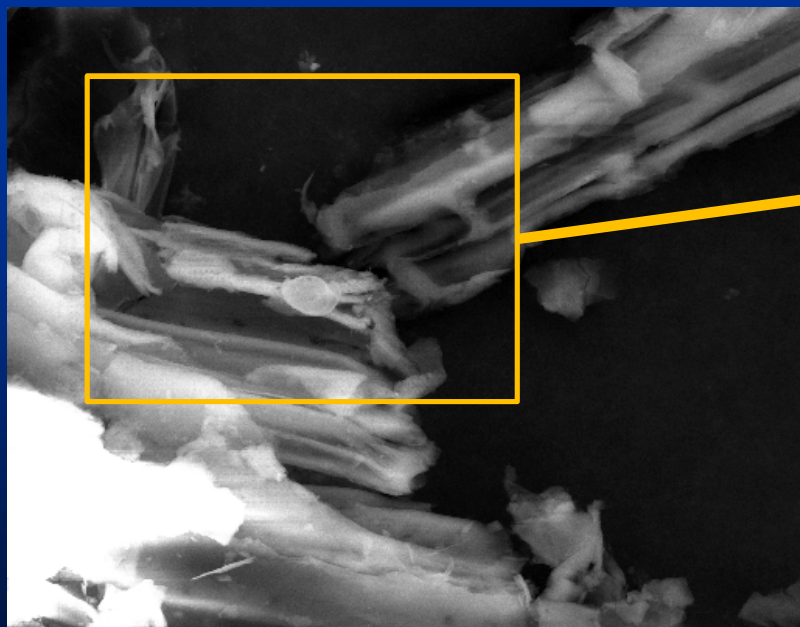
C



Si

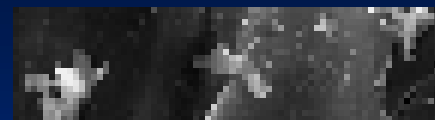
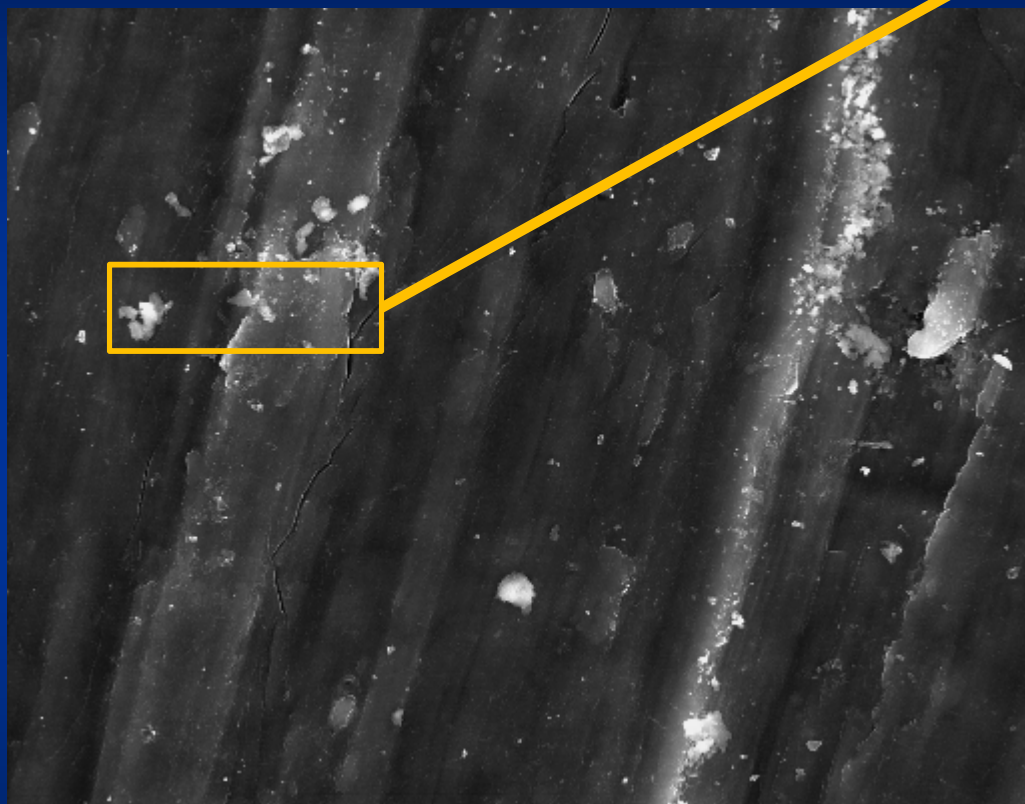


O





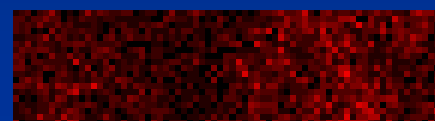
# Uszkodzony nośnik XPS



SE



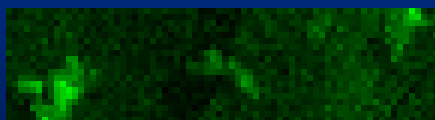
Al



C

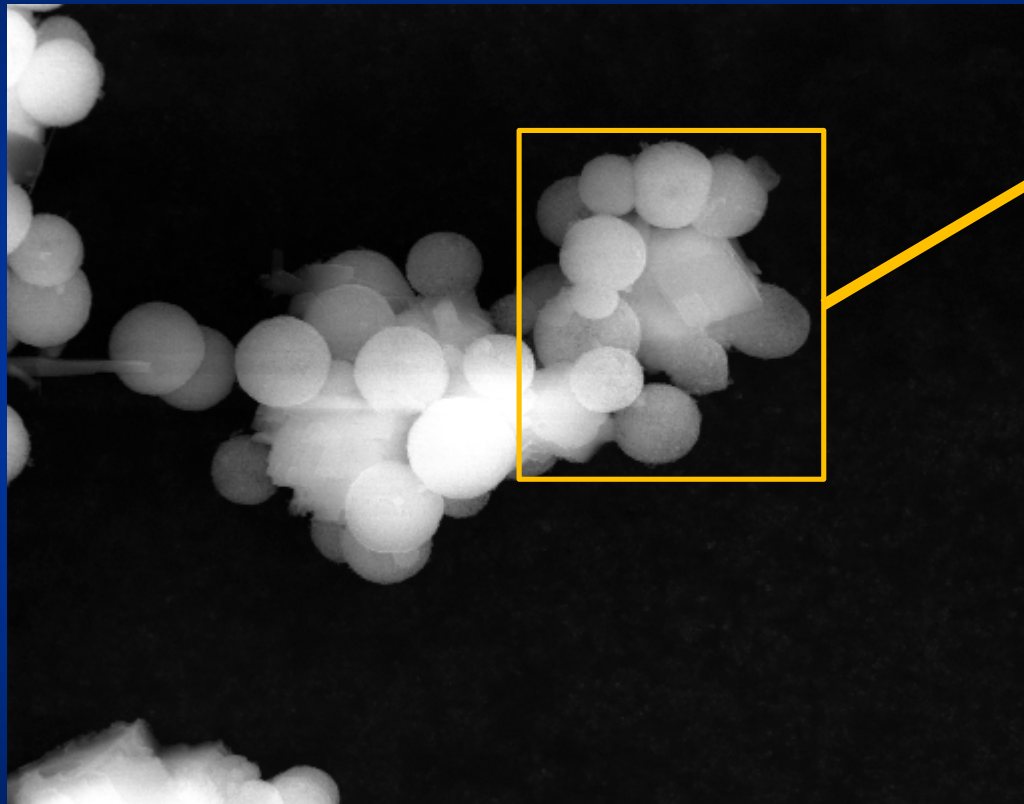


Ti

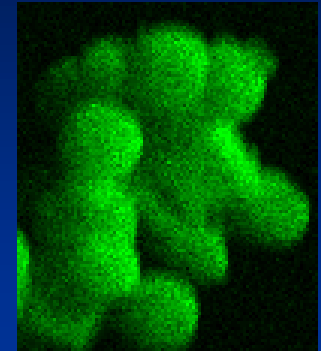


O

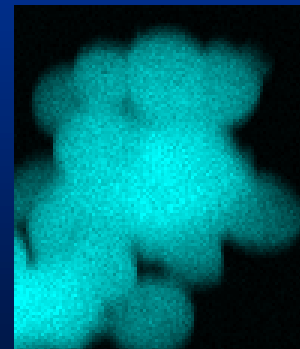
# Kulki $\text{CaCO}_3$



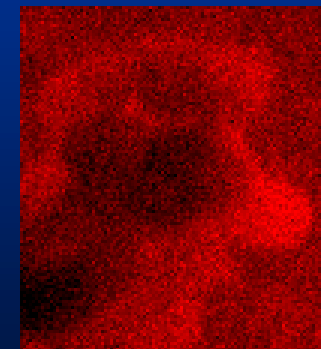
SE



O

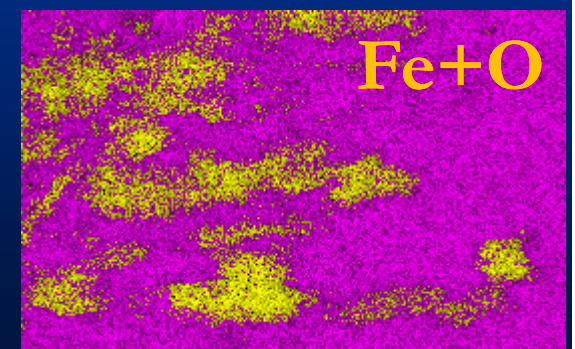
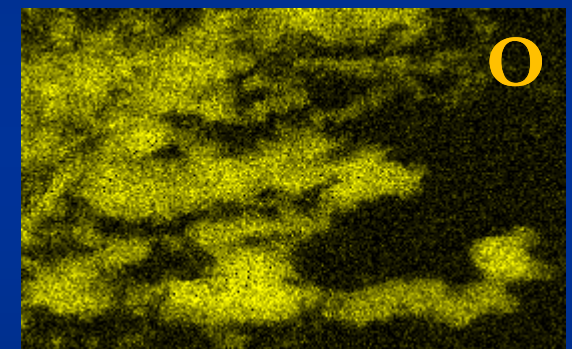
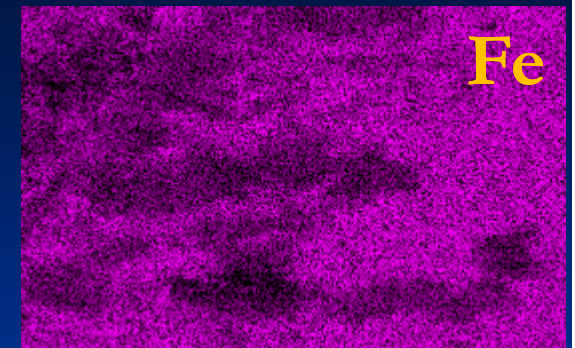
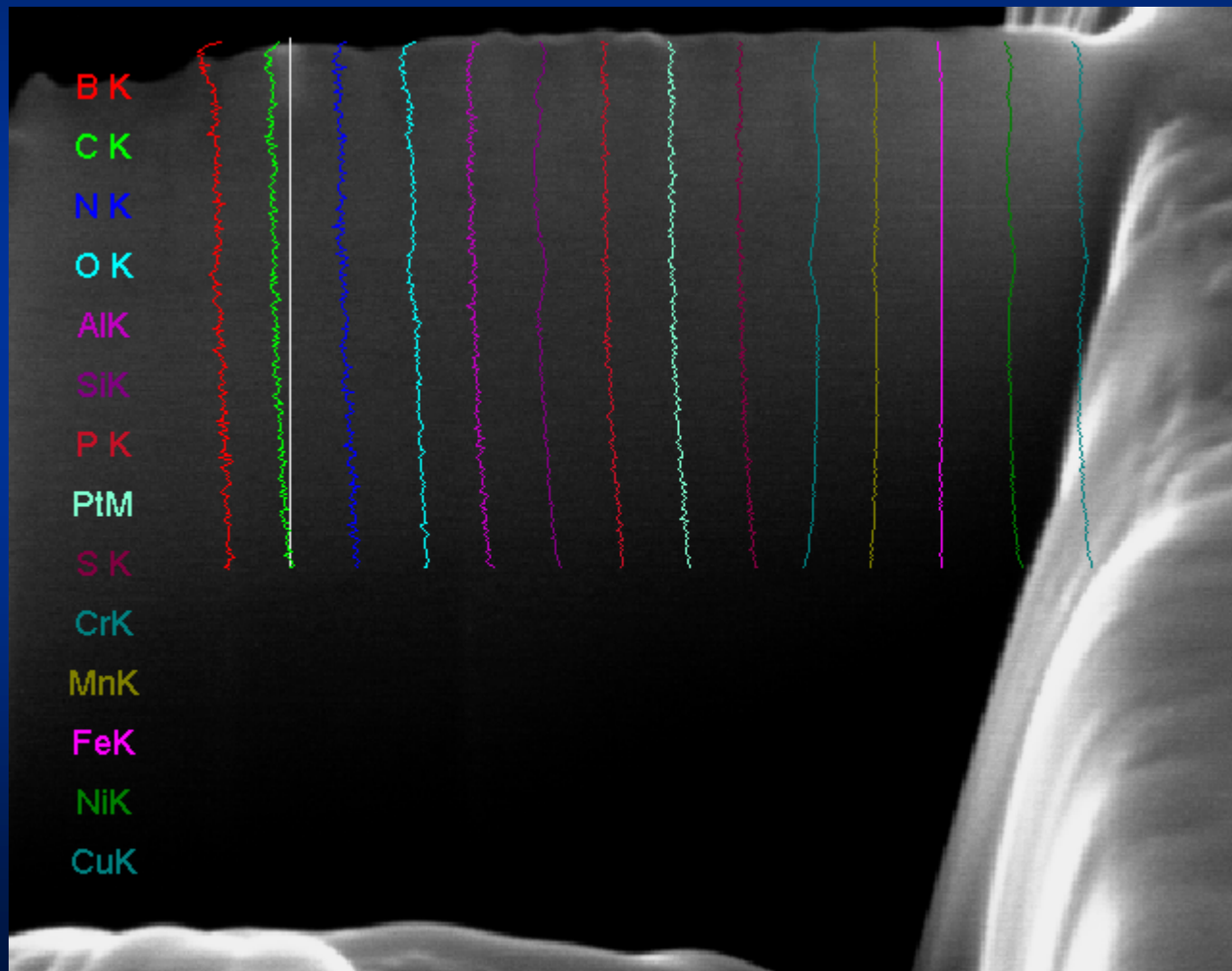


Ca



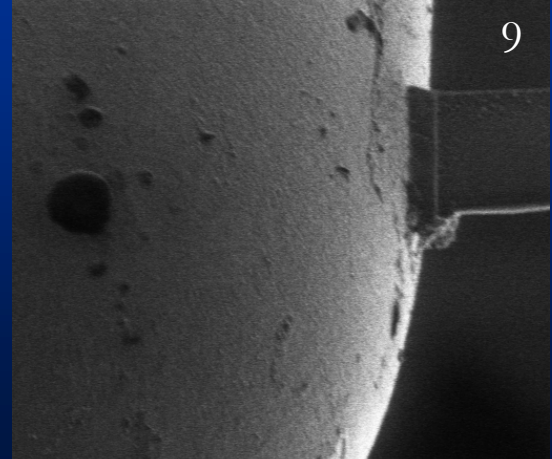
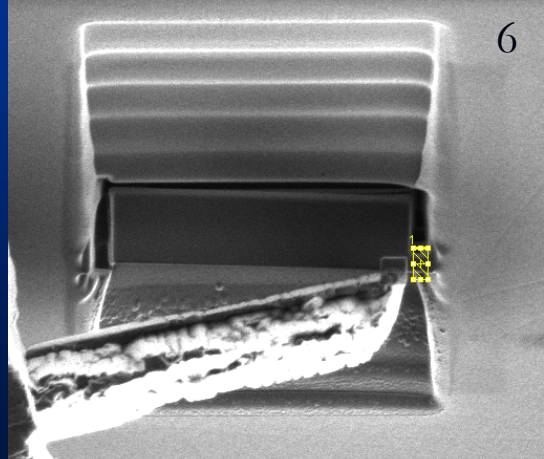
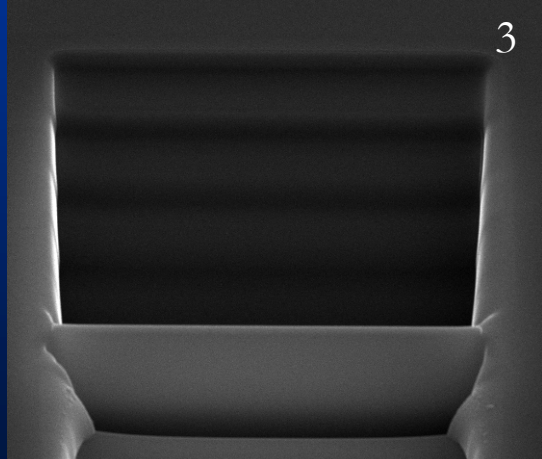
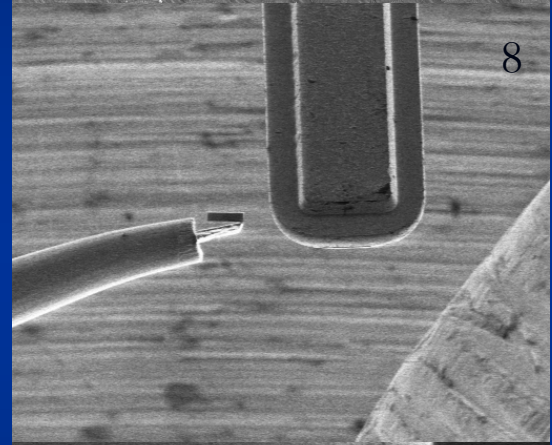
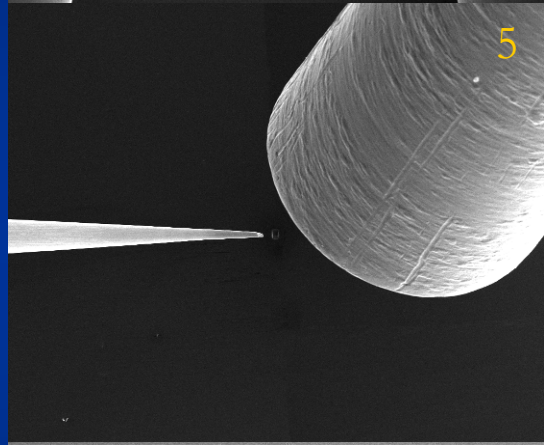
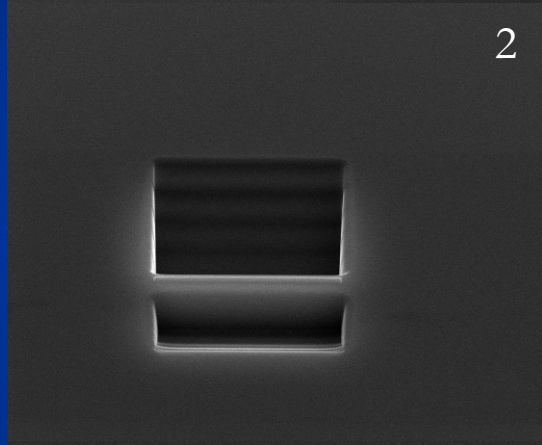
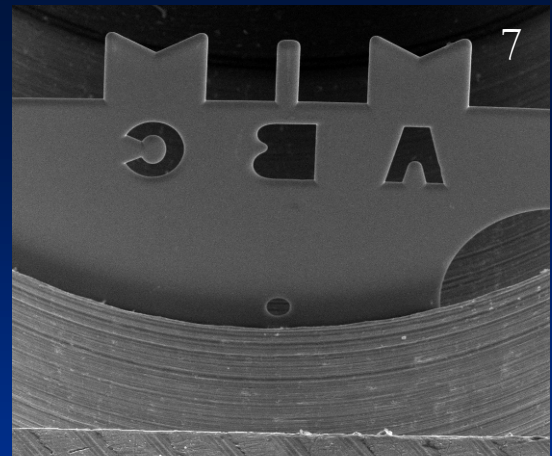
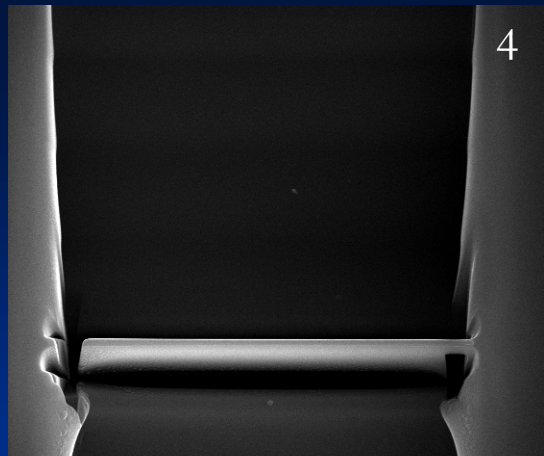
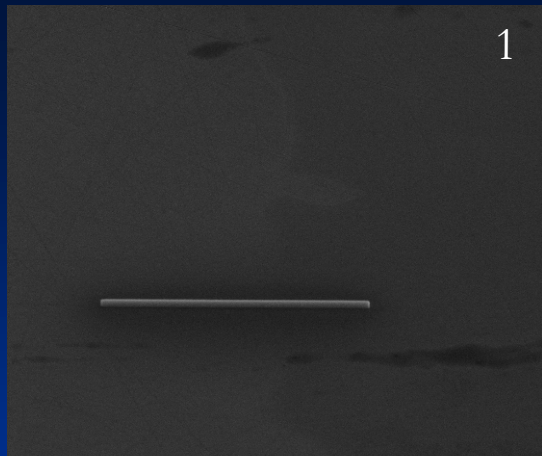
C

# Powierzchnie trące stali



Quanta

FIB

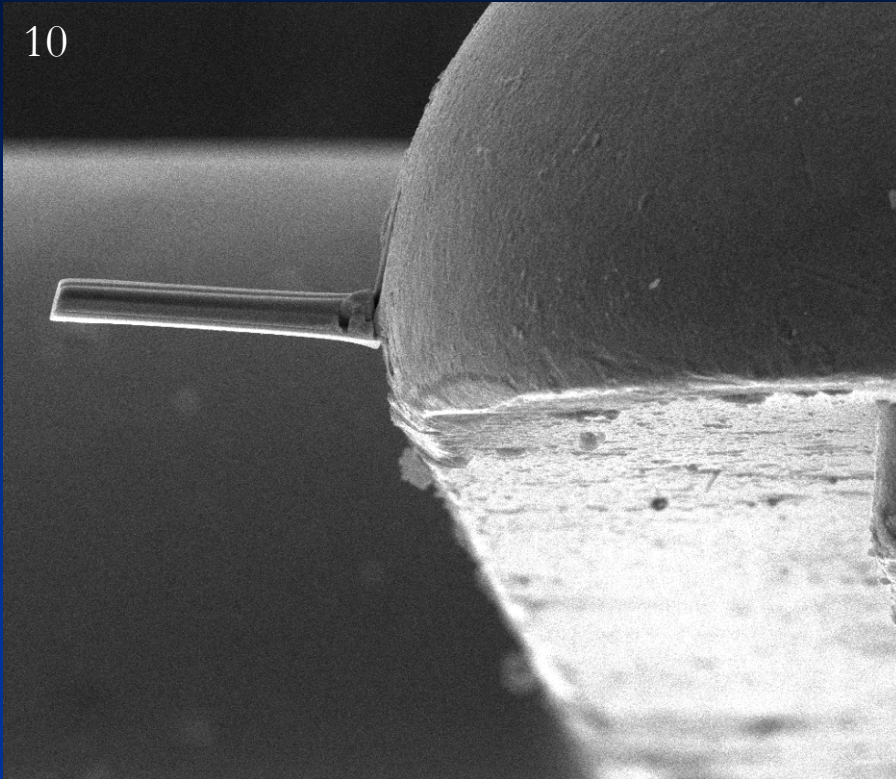


4/30/2012 HV mag 田 WD pressure 5 μm  
10:01:46 AM 30.00 kV 8 000 x 9.8 mm 1.19e-4 Pa  
Quanta 3DFEG

5/1/2012 dwell HV HPW pressure 5 μm  
11:04:20 AM 1 μs 30.0 kV 23.0 μm 1.58e-4 Pa  
Quanta 3D FEG

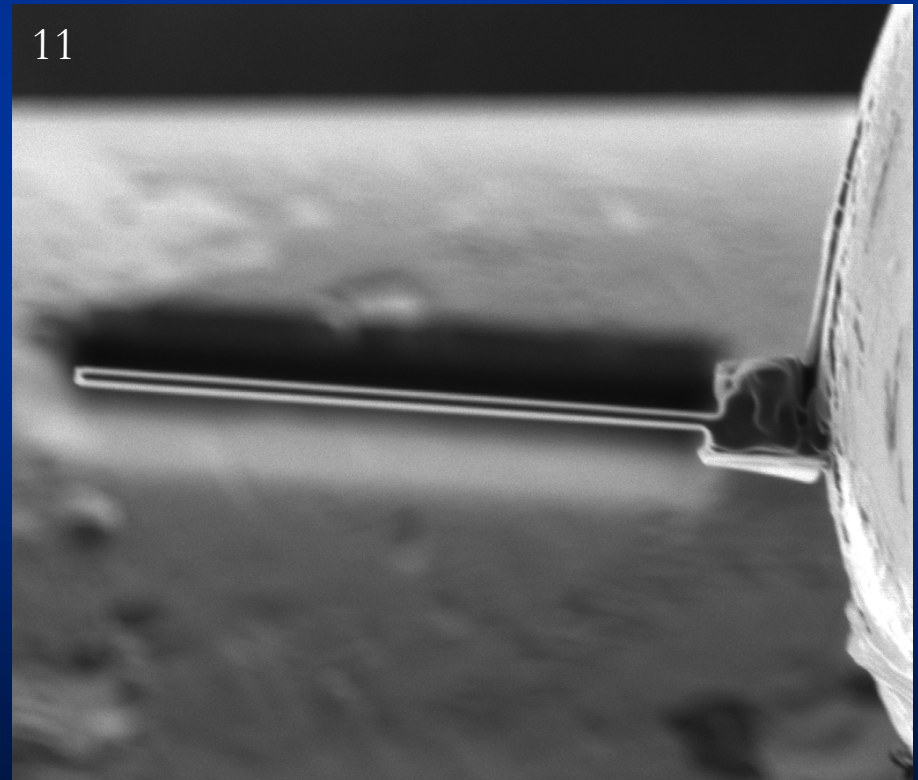
5/1/2012 dwell HV HPW pressure 5 μm  
11:44:45 AM 100 ns 30.0 kV 18.6 μm 3.92e-4 Pa  
Quanta 3D FEG

10



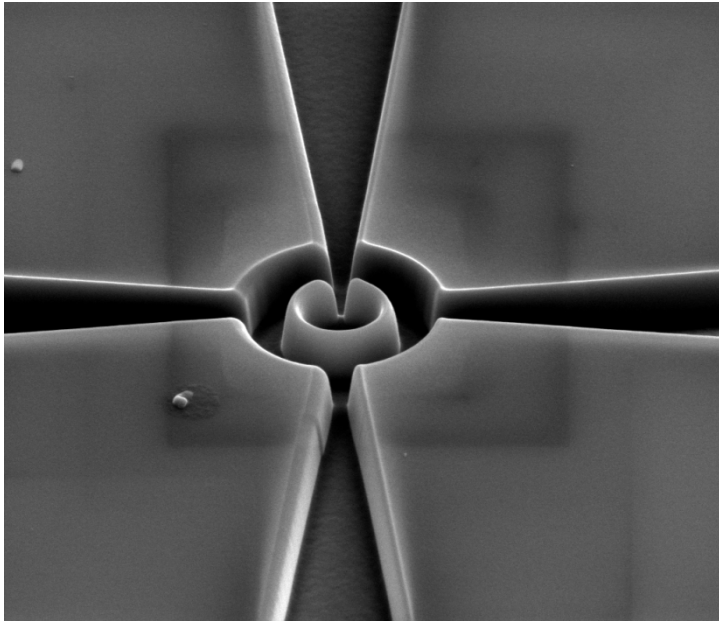
4/18/2012	HV	mag	WD	pressure	5 μm
8:16:48 AM	5.00 kV	6 500 x	10.0 mm	4.19e-4 Pa	Quanta 3DFEG

11

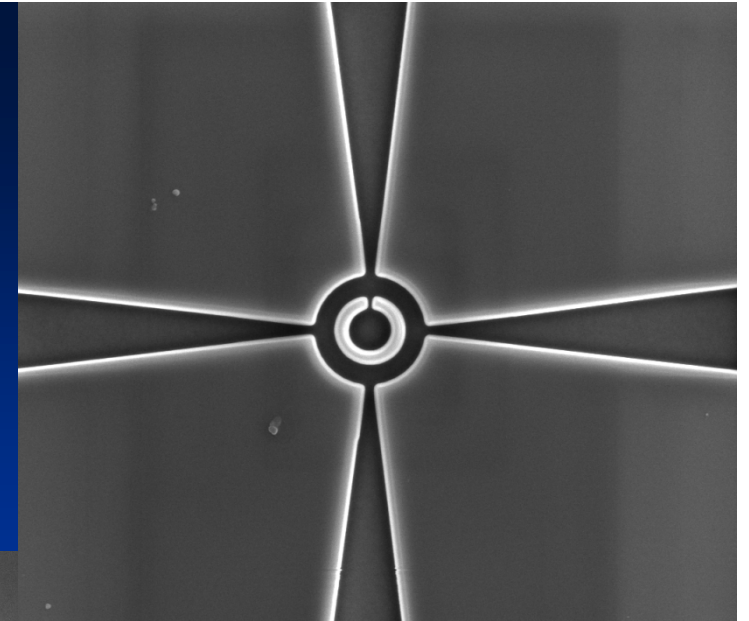


4/18/2012	dwell	HV	HFW	pressure	det	3 μm
9:51:07 AM	30 μs	30.0 kV	9.95 μm	1.11e-4 Pa	ETD	Quanta 3D FEG

**Próbka 6H-SiC gotowa do badania TEM**

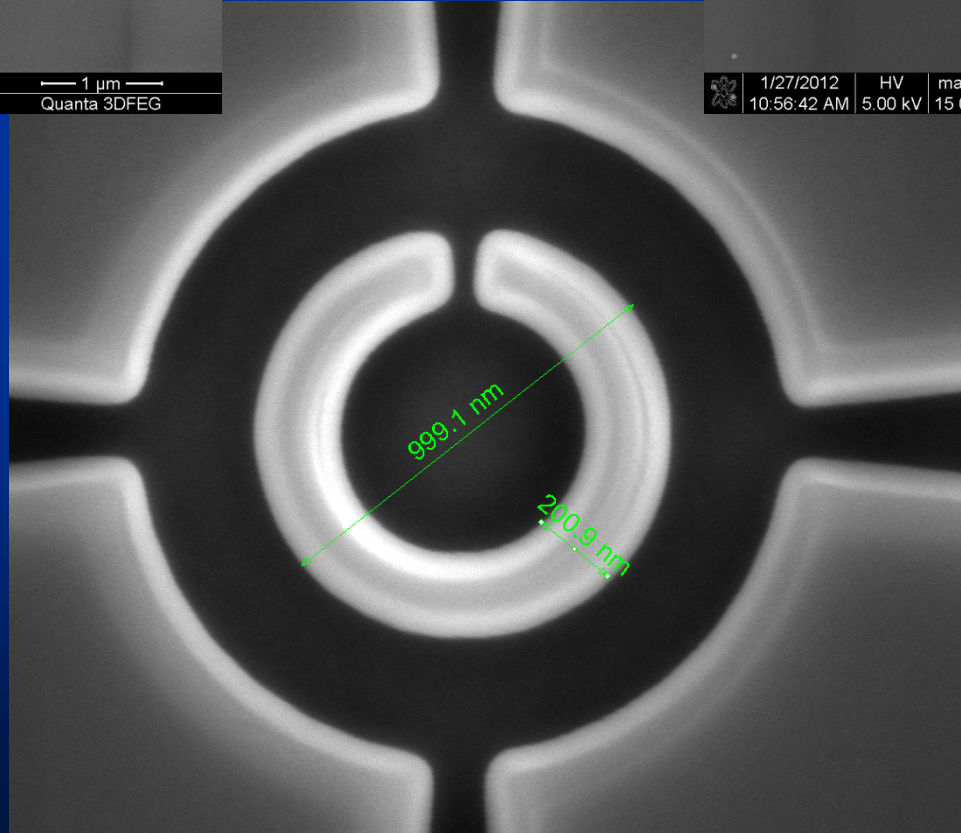


1/27/2012	HV	mag	WD	pressure	1 μm
10:45:21 AM	5.00 kV	25 000 x	10.0 mm	7.24e-5 Pa	Quanta 3DFEG



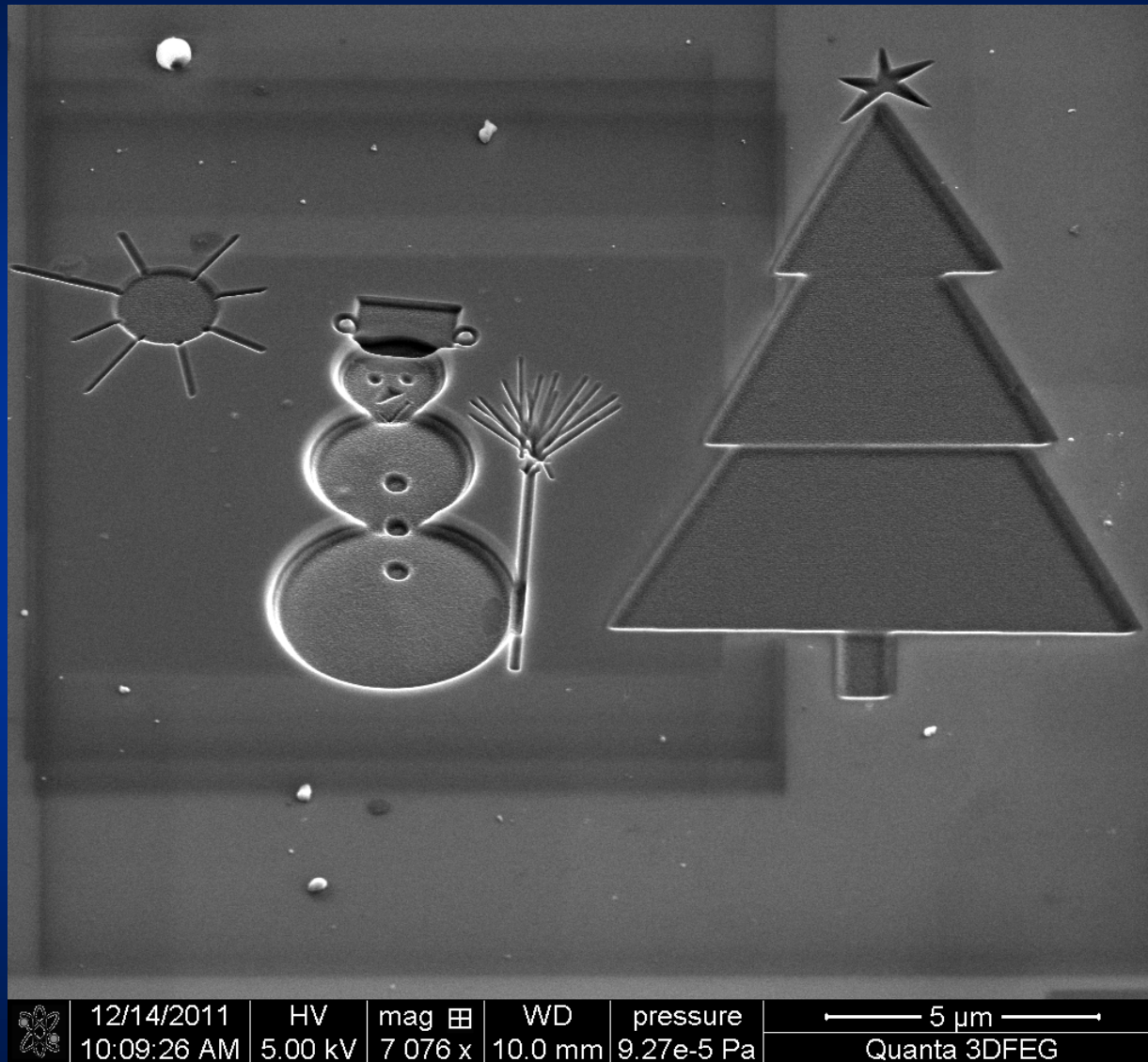
1/27/2012	HV	mag	WD	pressure	3 μm
10:56:42 AM	5.00 kV	15 000 x	10.1 mm	7.40e-5 Pa	Quanta 3DFEG

# Struktury spintroniczne



1/27/2012	HV	mag	WD	pressure	500 nm
10:52:11 AM	5.00 kV	65 000 x	10.1 mm	7.40e-5 Pa	Quanta 3DFEG

# Testy rozdzielcze (operatora) FIB

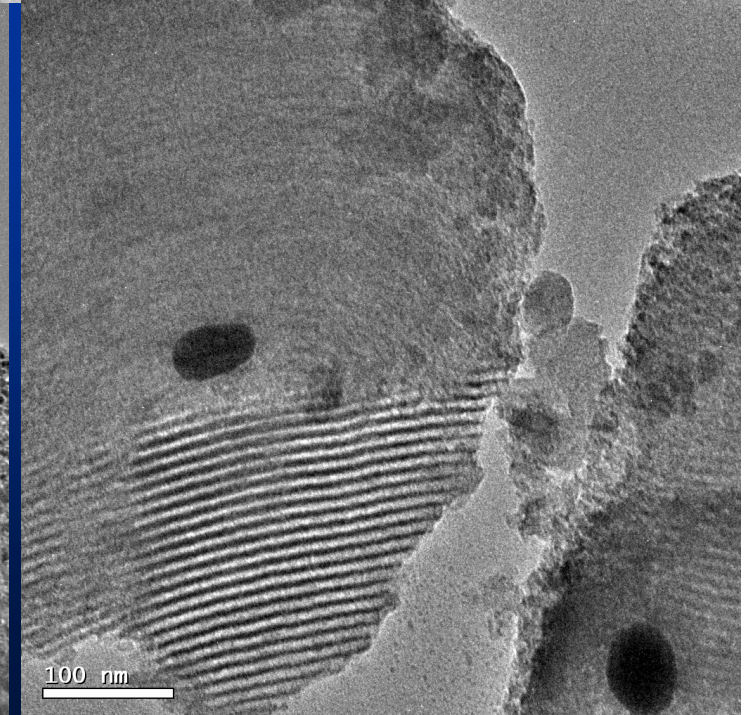
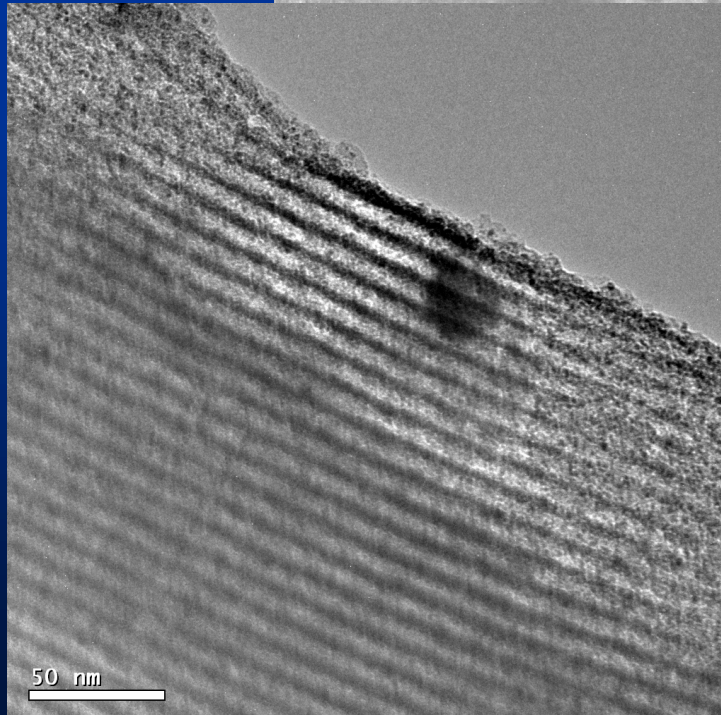
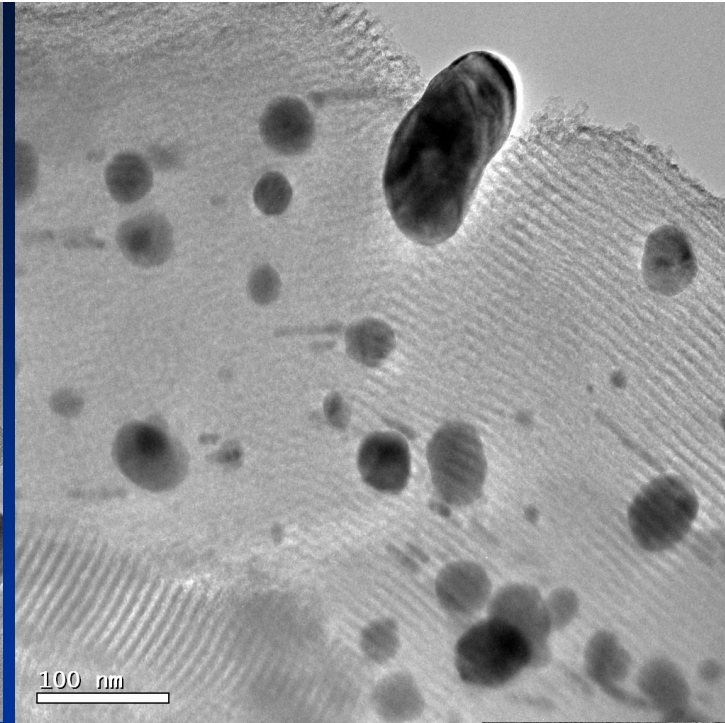
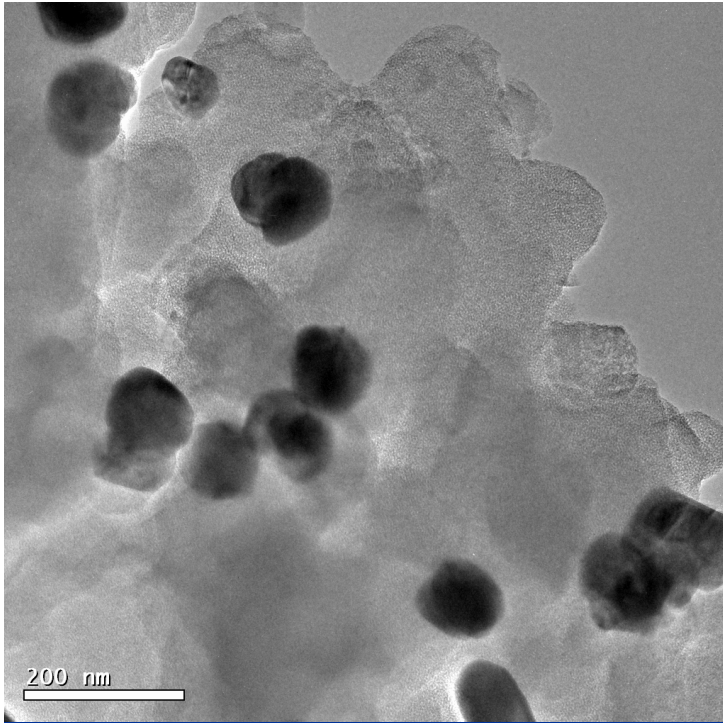




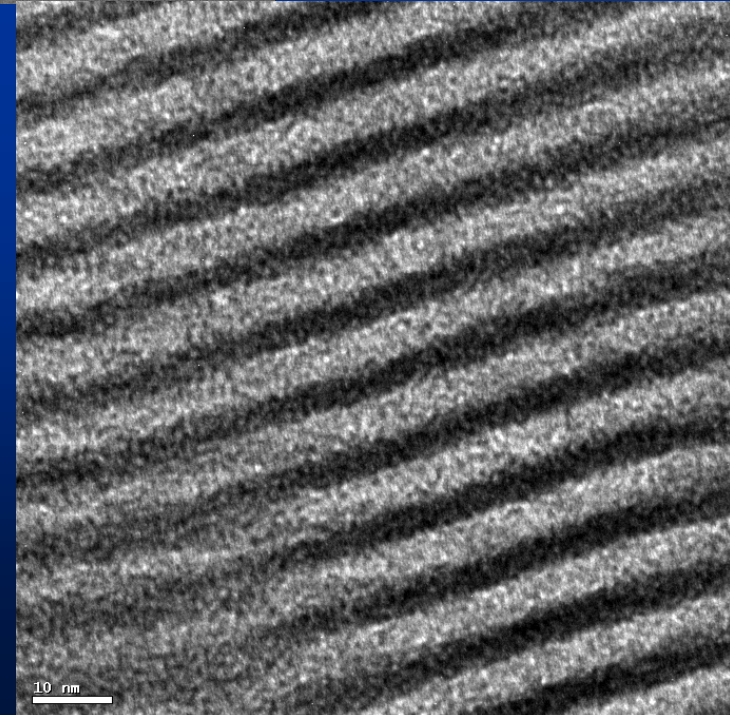
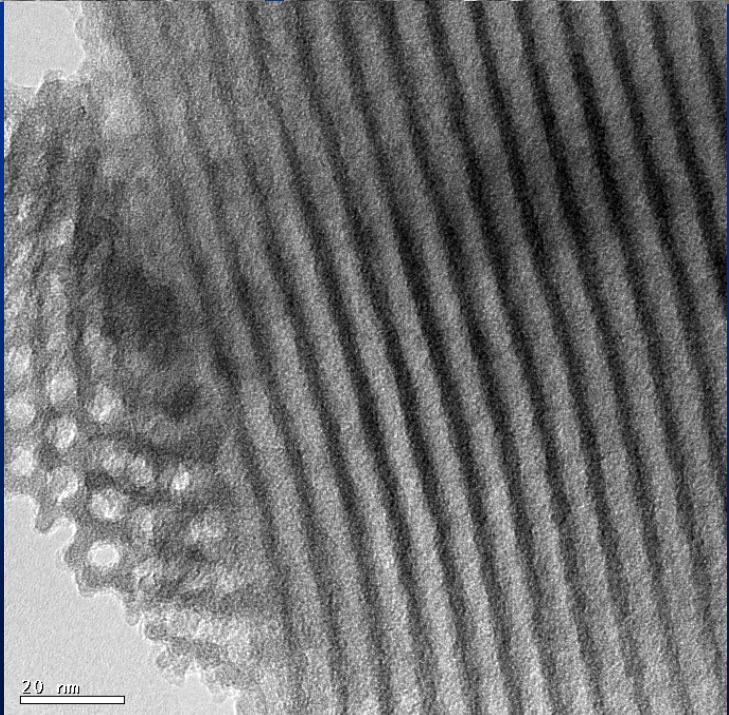
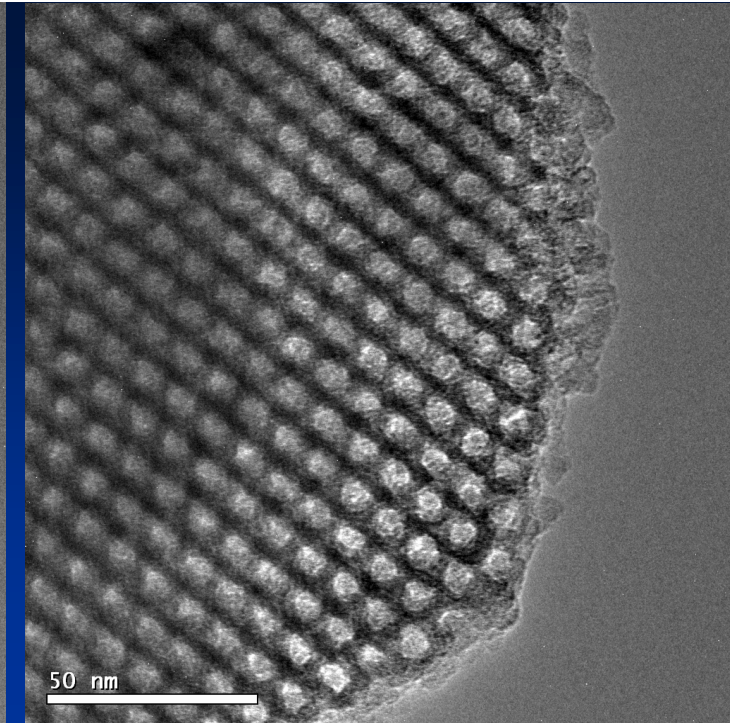
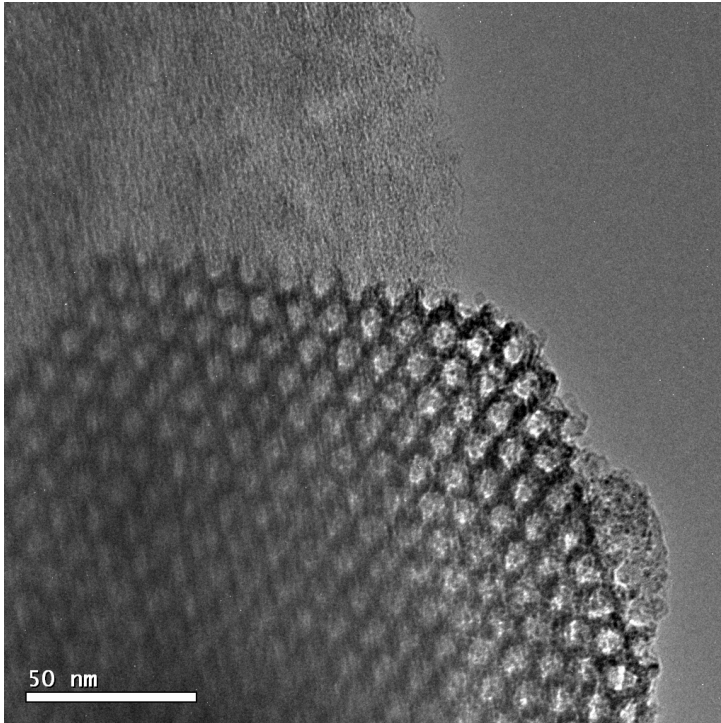
**Titan**

**TEM**

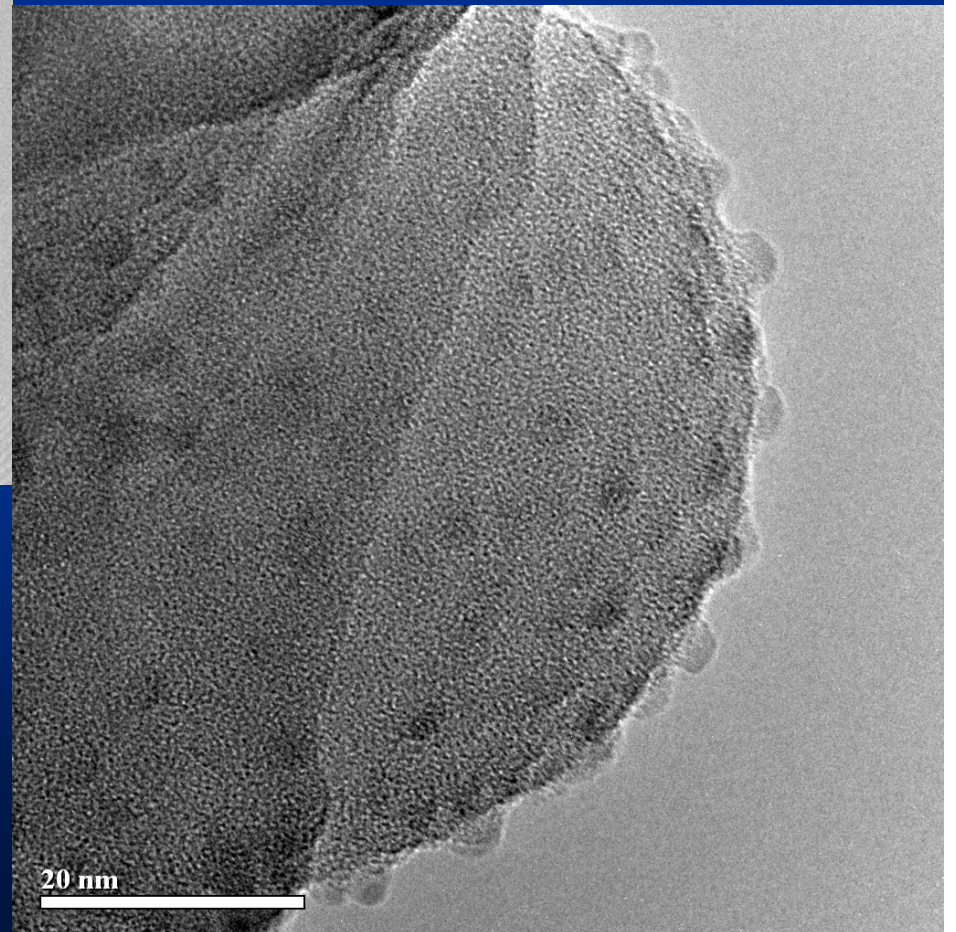
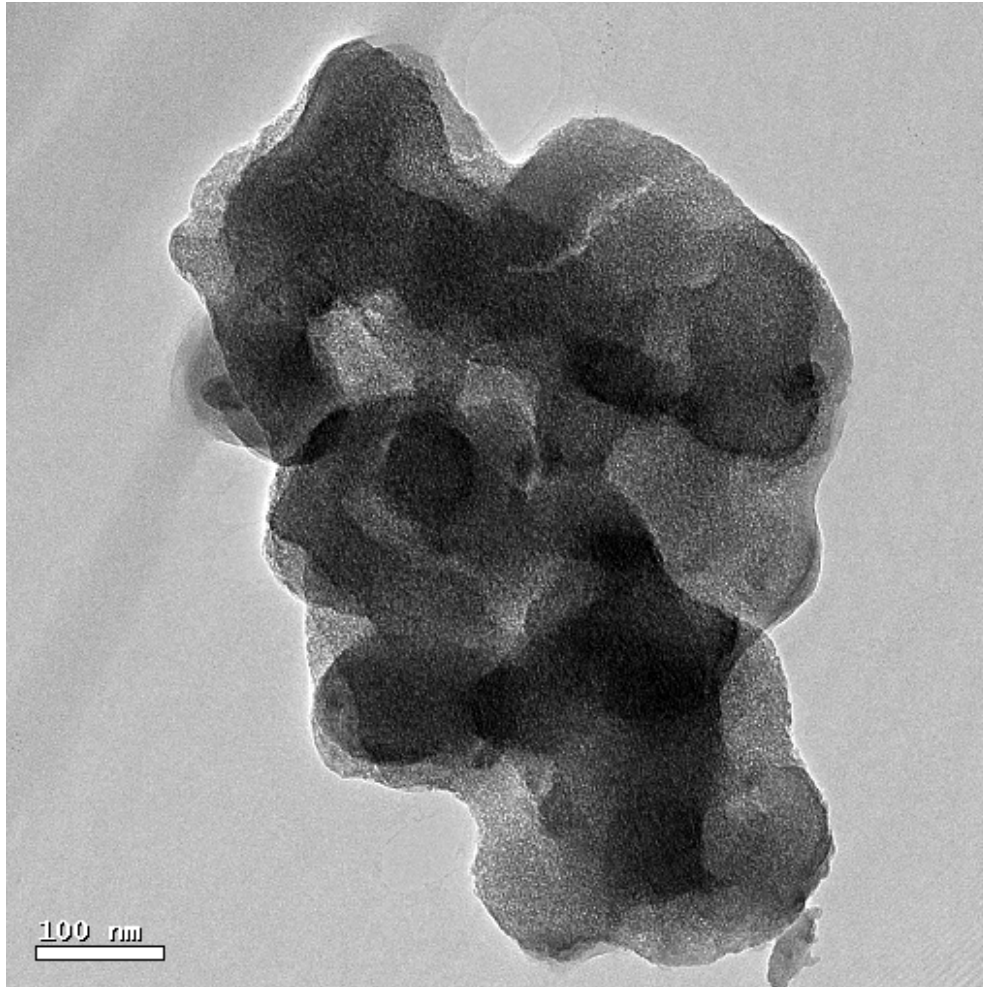
**Nanocząstki  
metaliczne  
w matrycy  
SiO<sub>2</sub>**



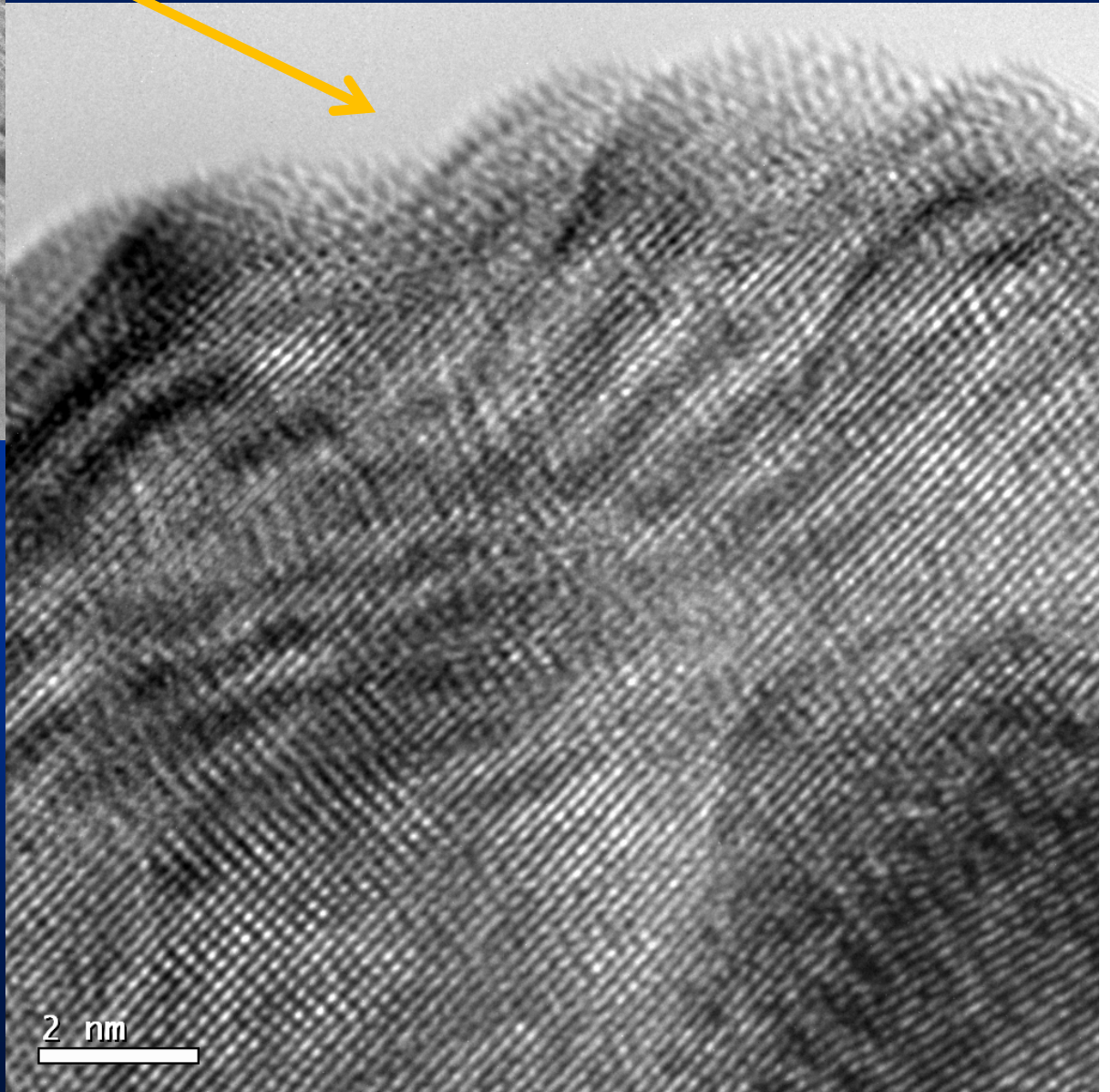
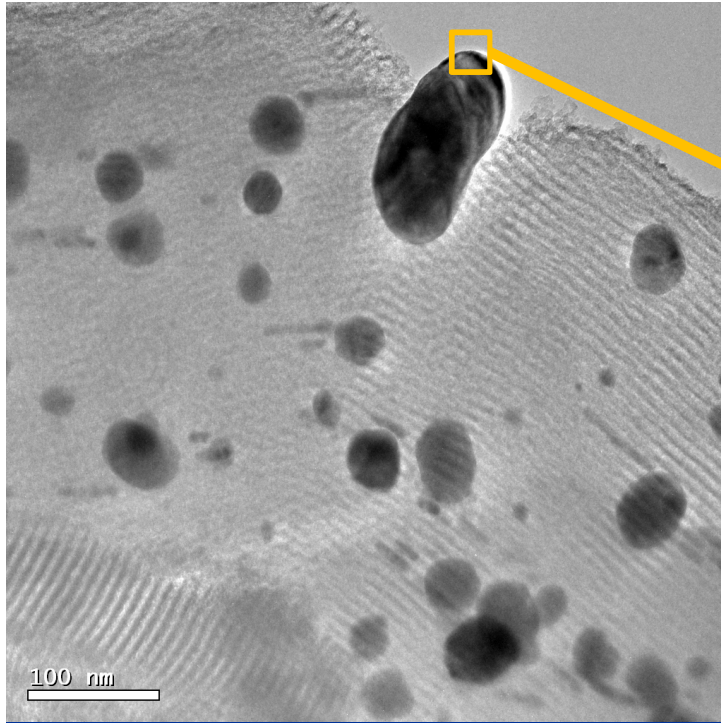
# Krzemionka SBA15



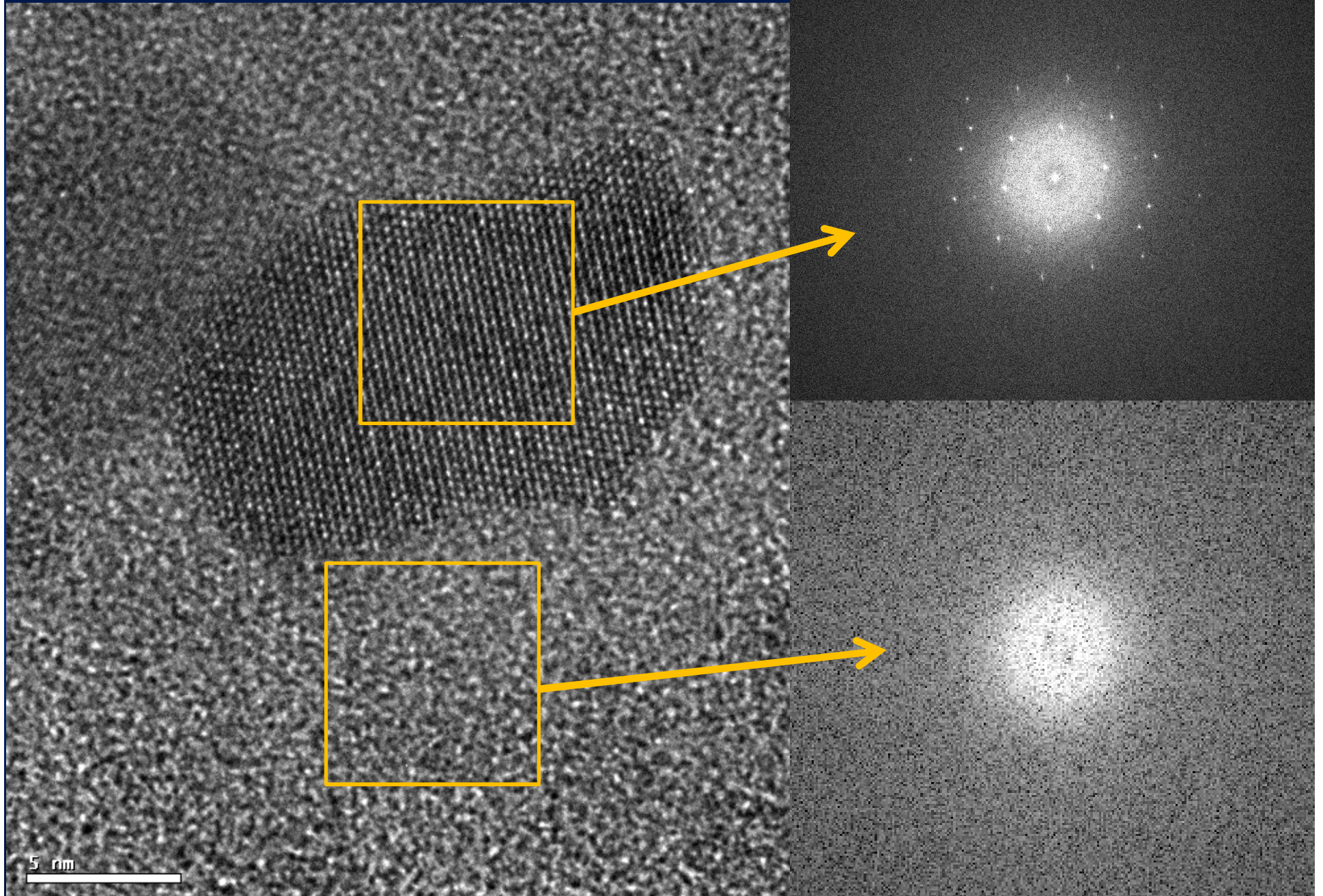
# Krzemionki porowate

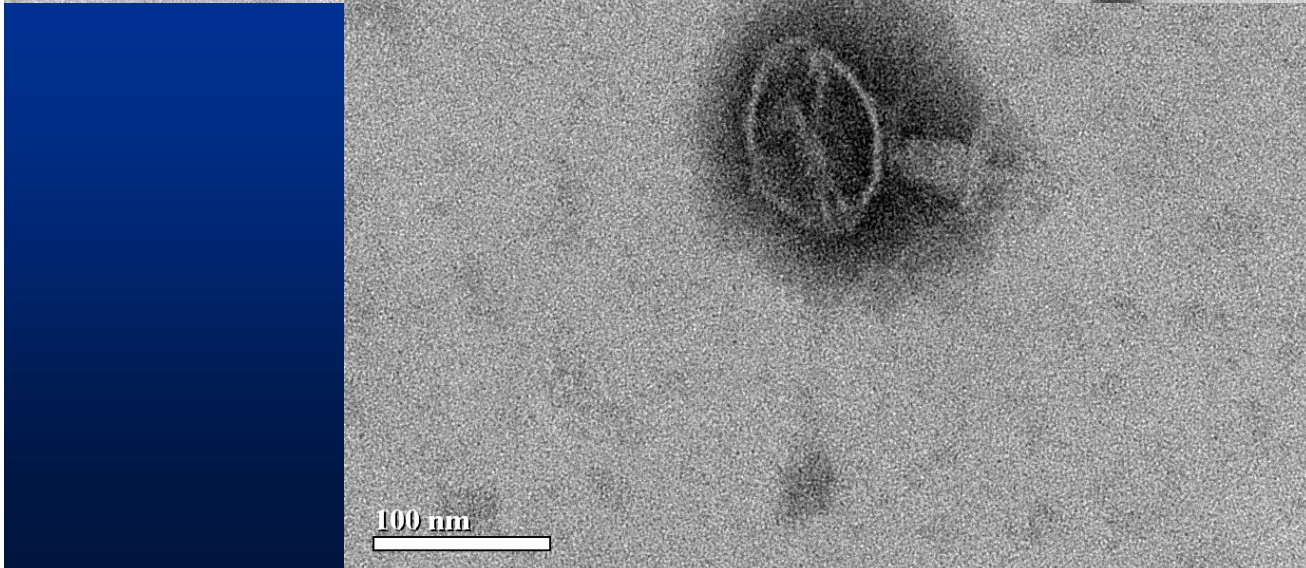
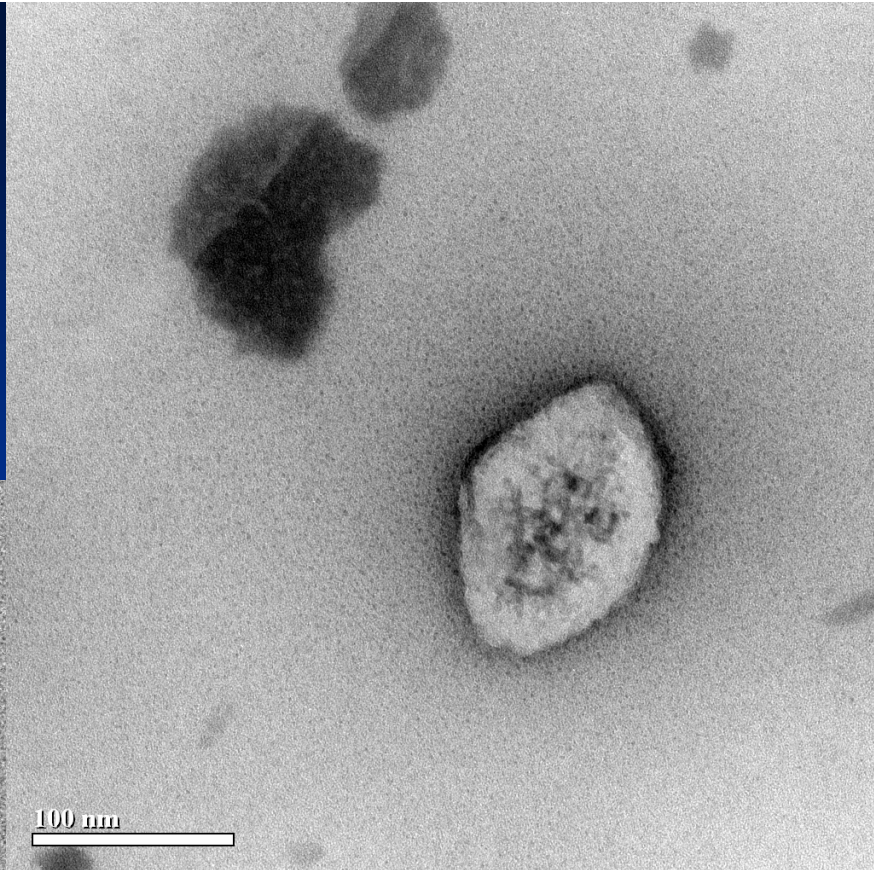
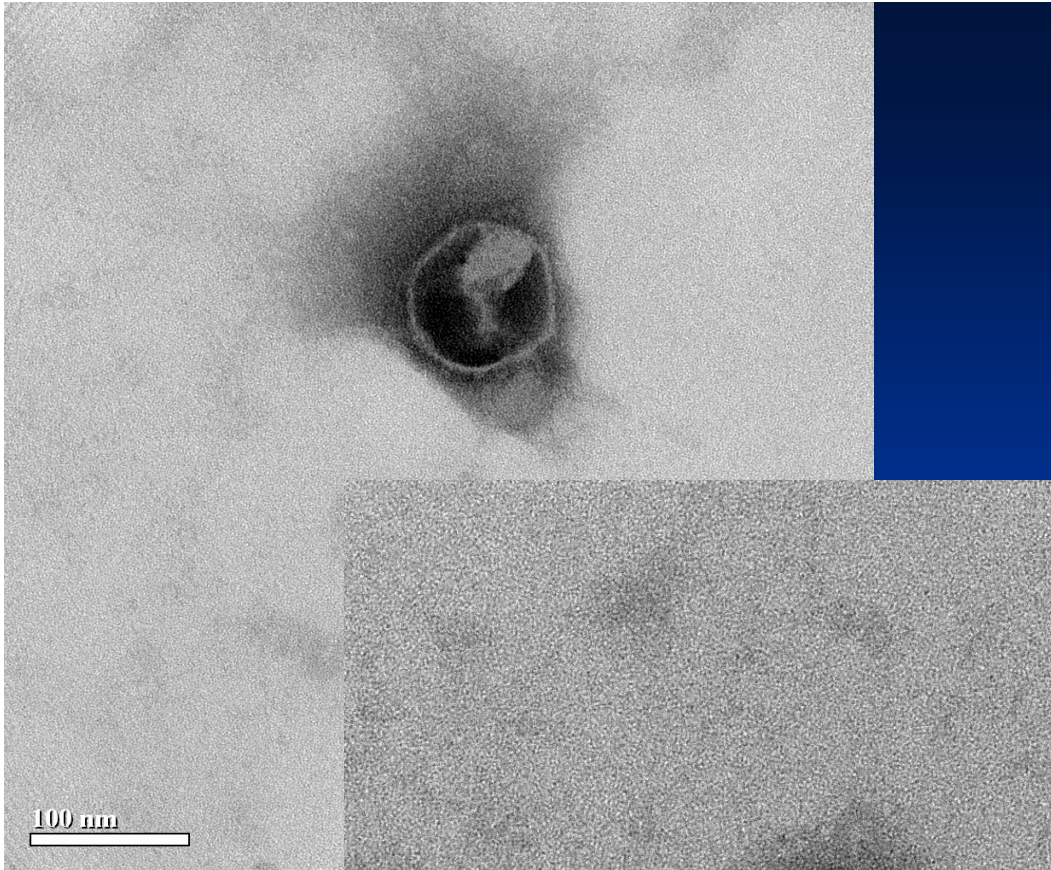


# Badanie krystalografii nanocząstek



# Badanie krystalografii nanocząstek





**Bakteriofagi**

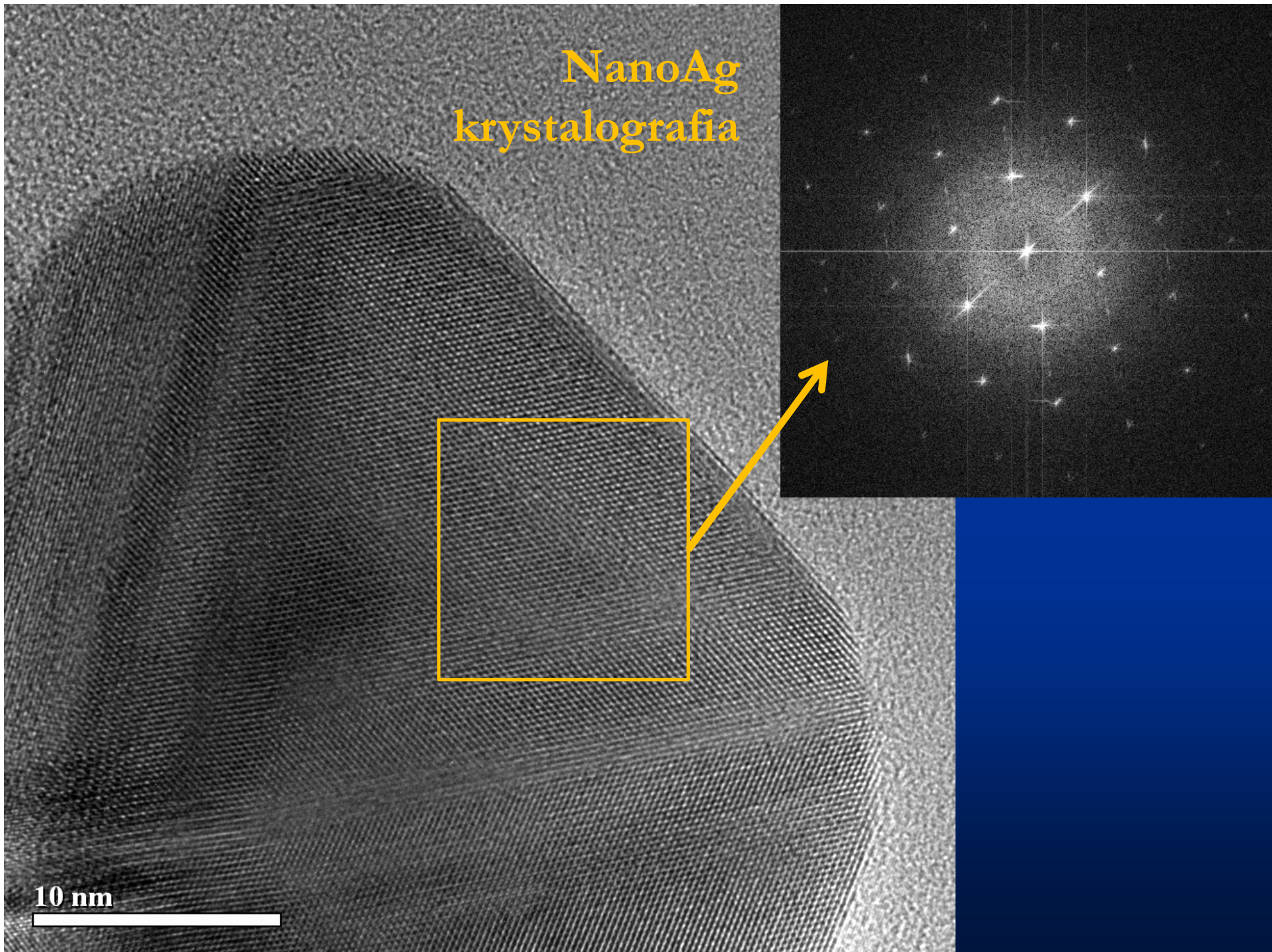
Nanocząstki Ag z  
warstwą lipidu

20 nm



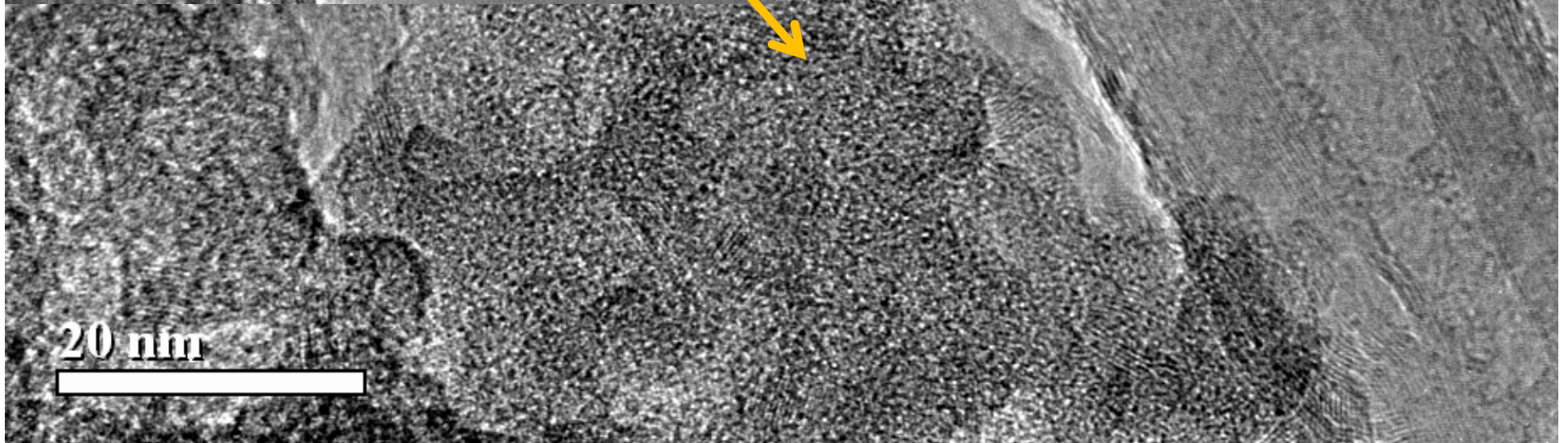
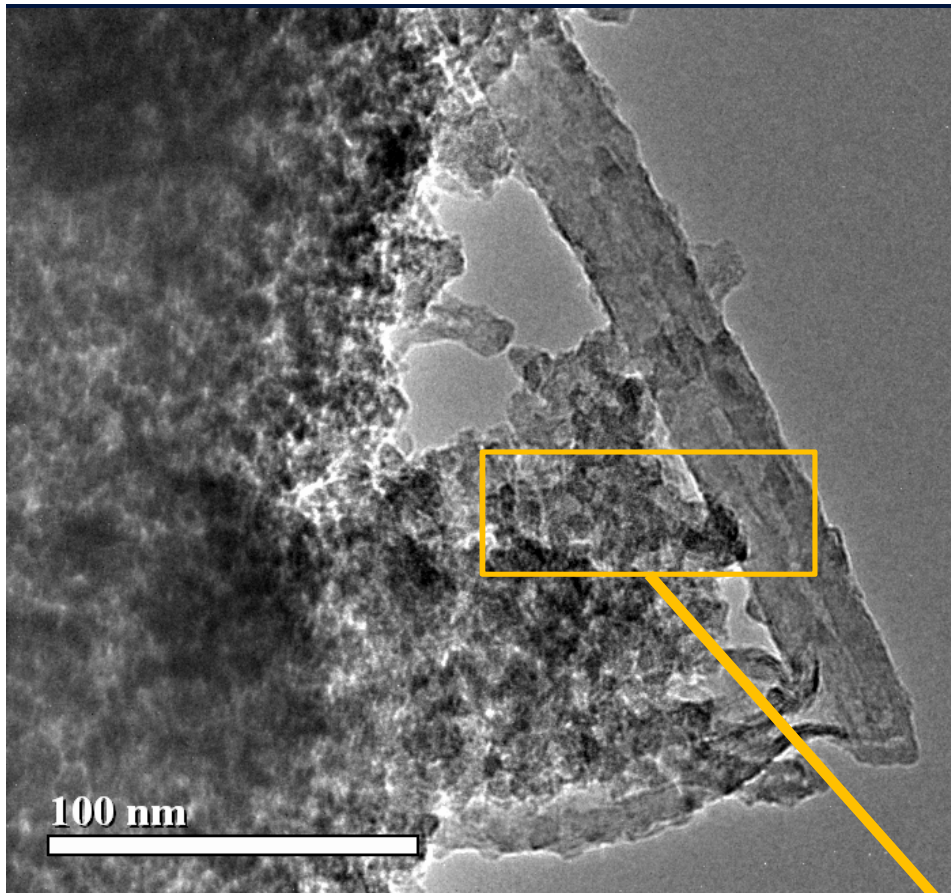


NanoAg  
krystalografia

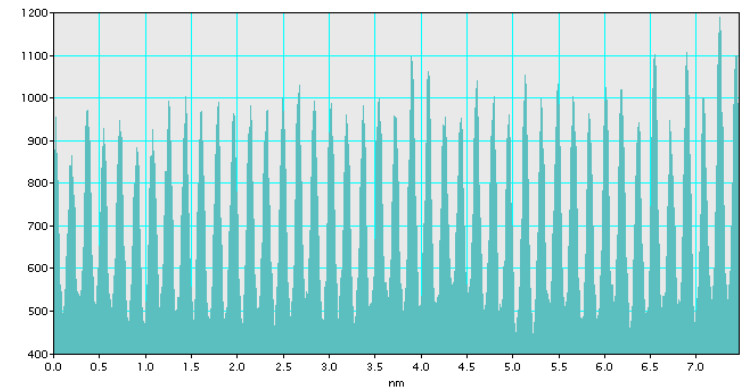
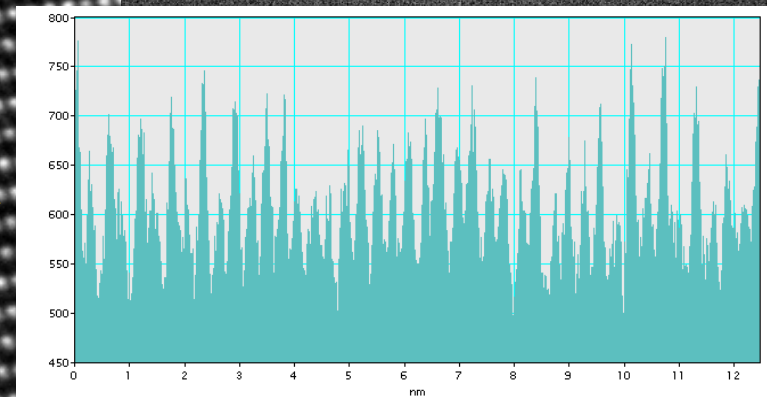
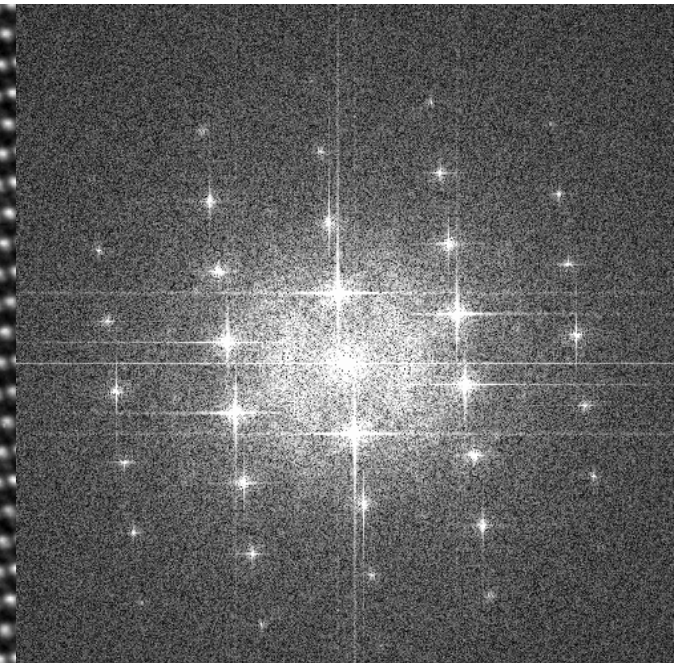
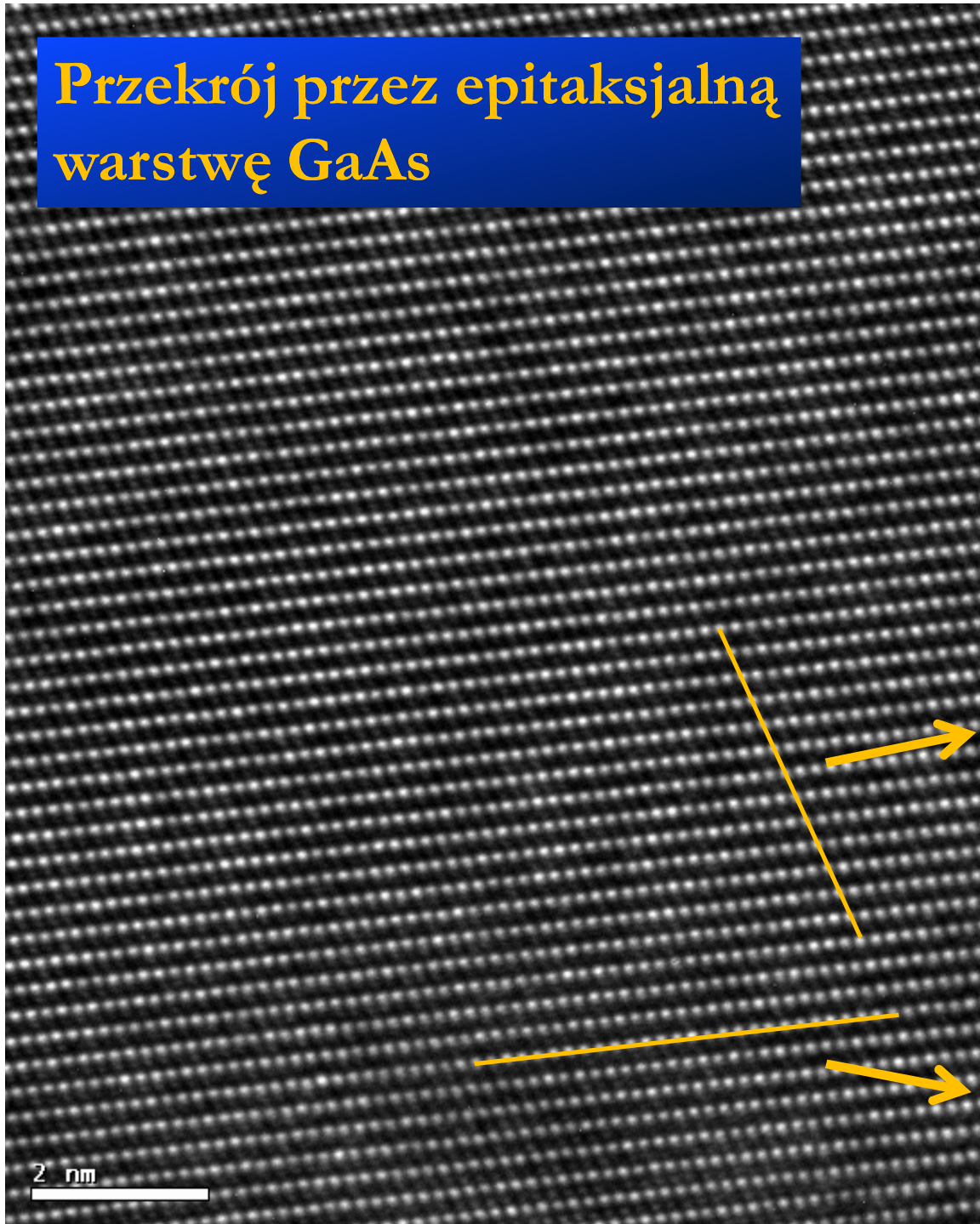


10 nm

**Porowata krzemionka z  
nanorurkami węglowymi**



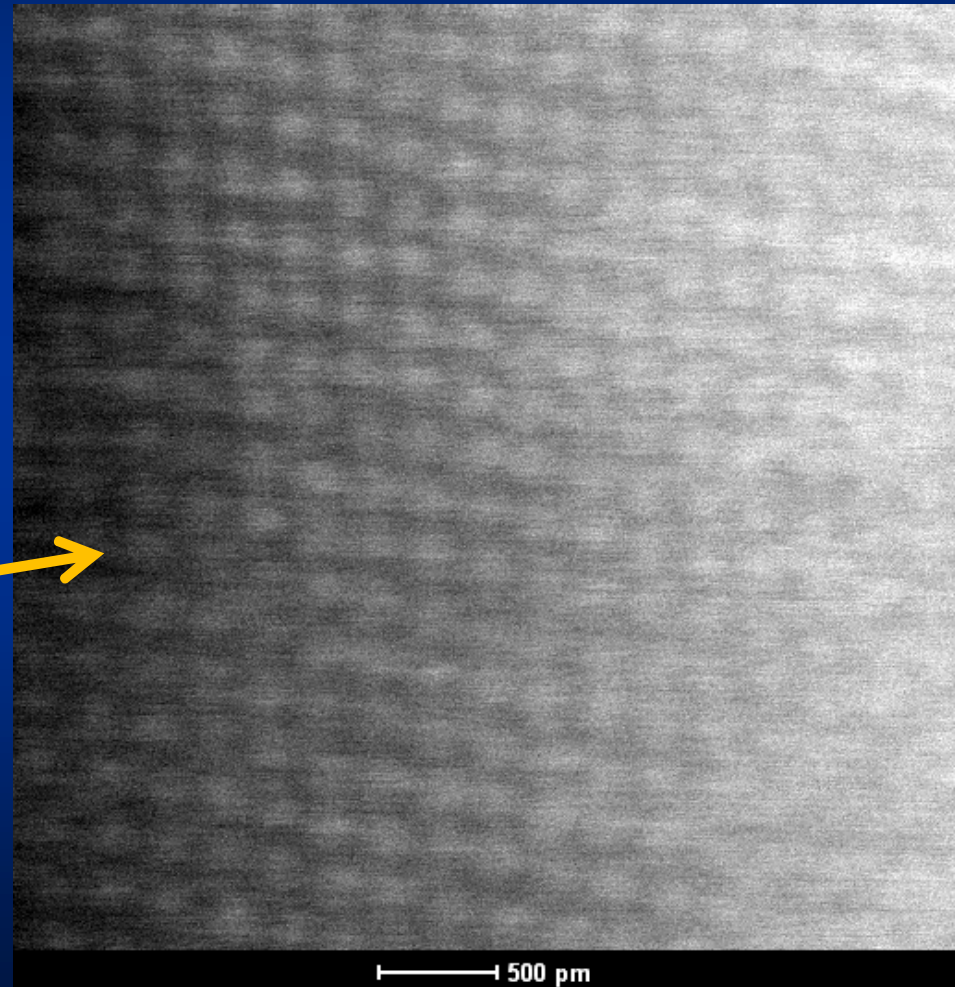
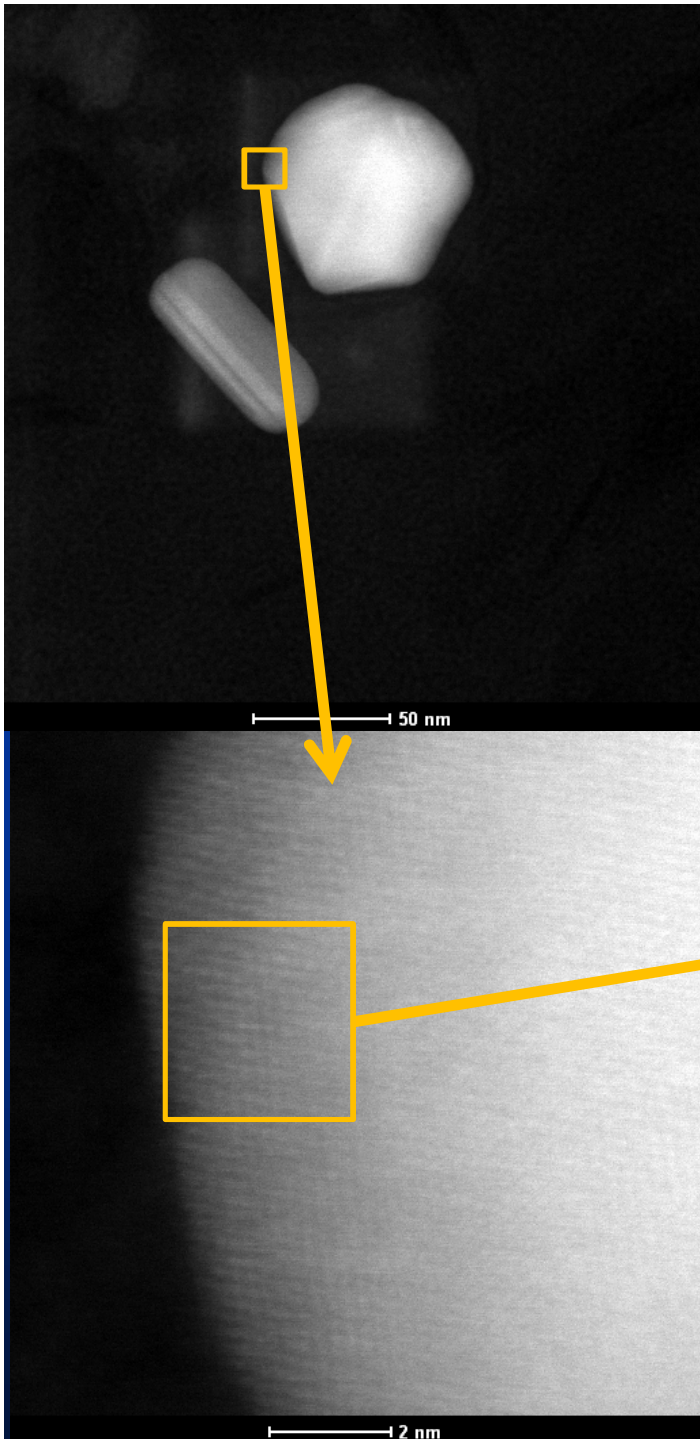
# Przekrój przez epitaksjalną warstwę GaAs



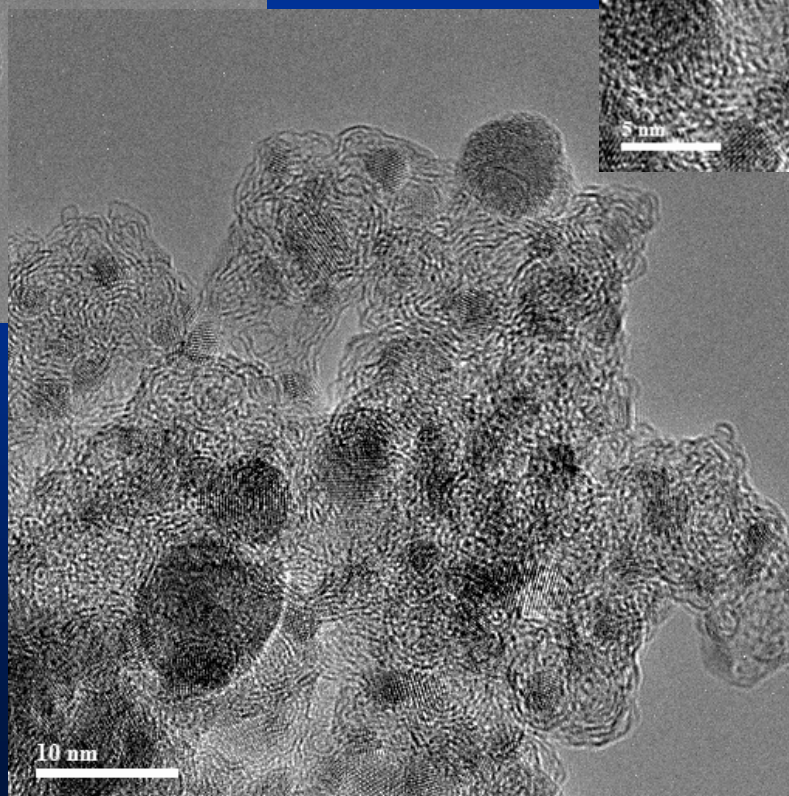
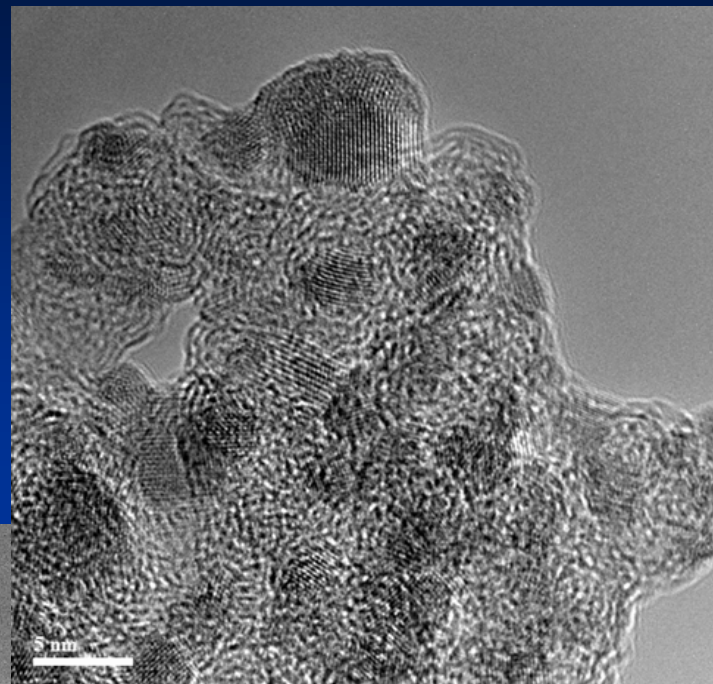
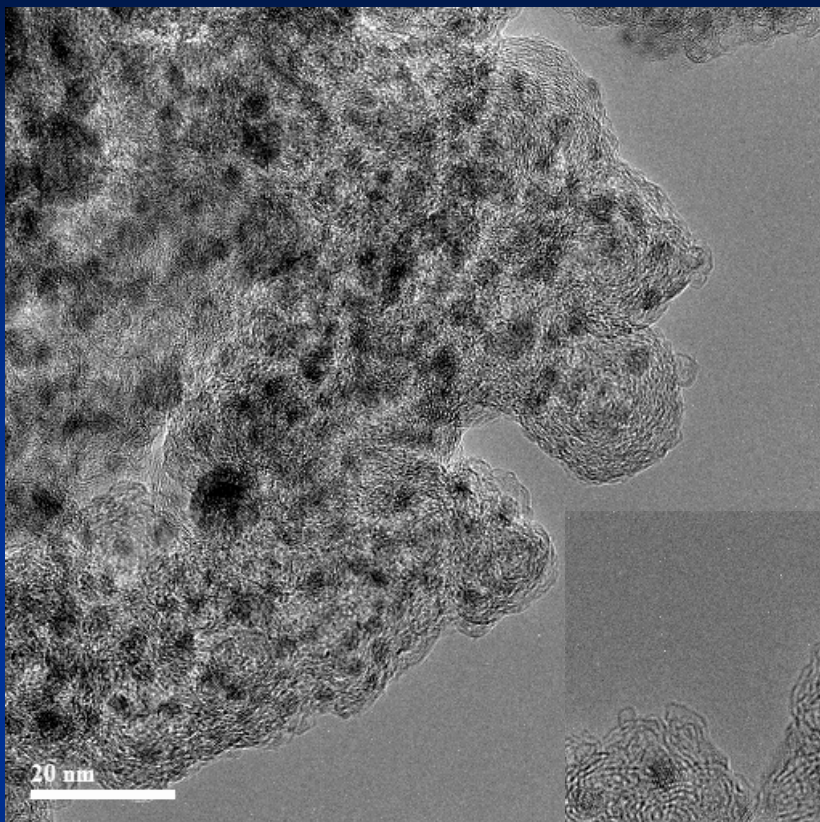
**Titan**

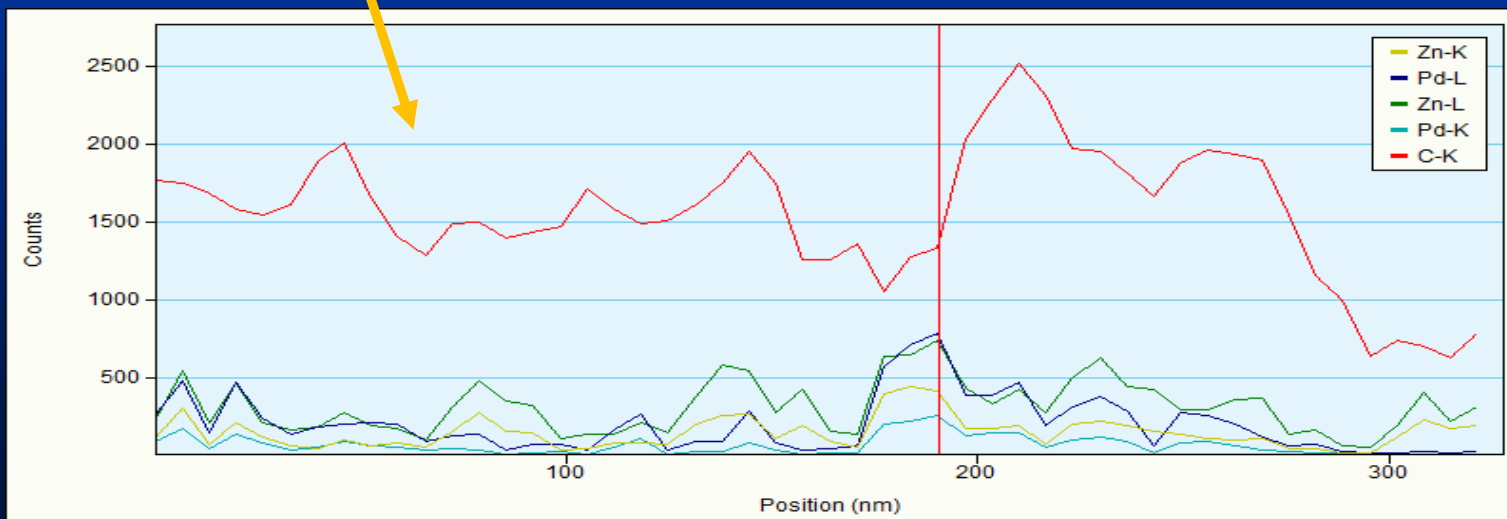
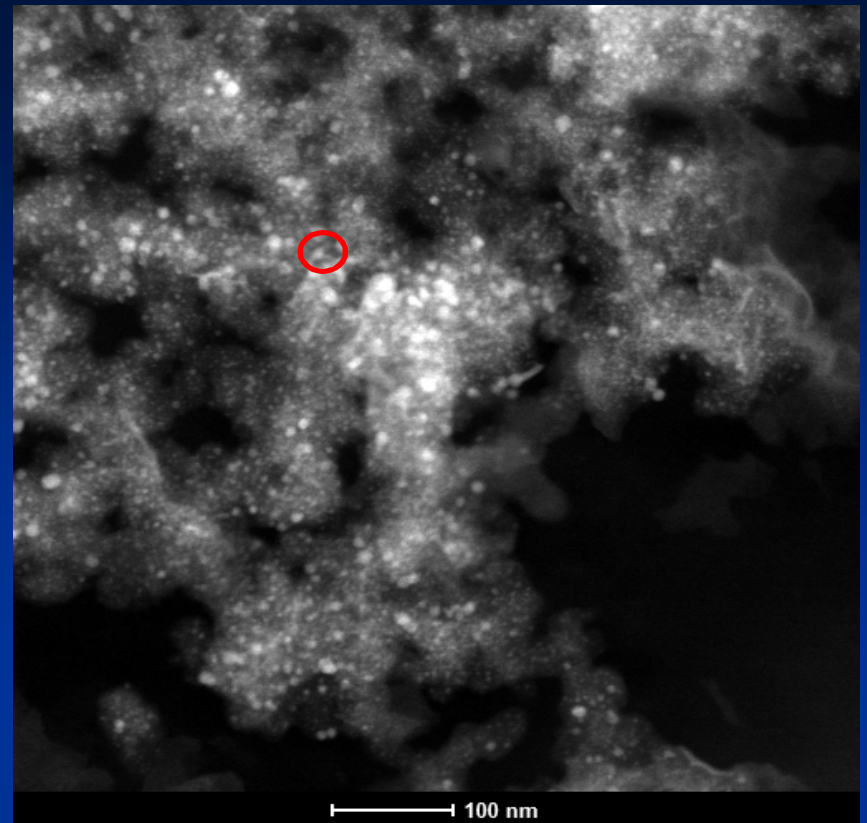
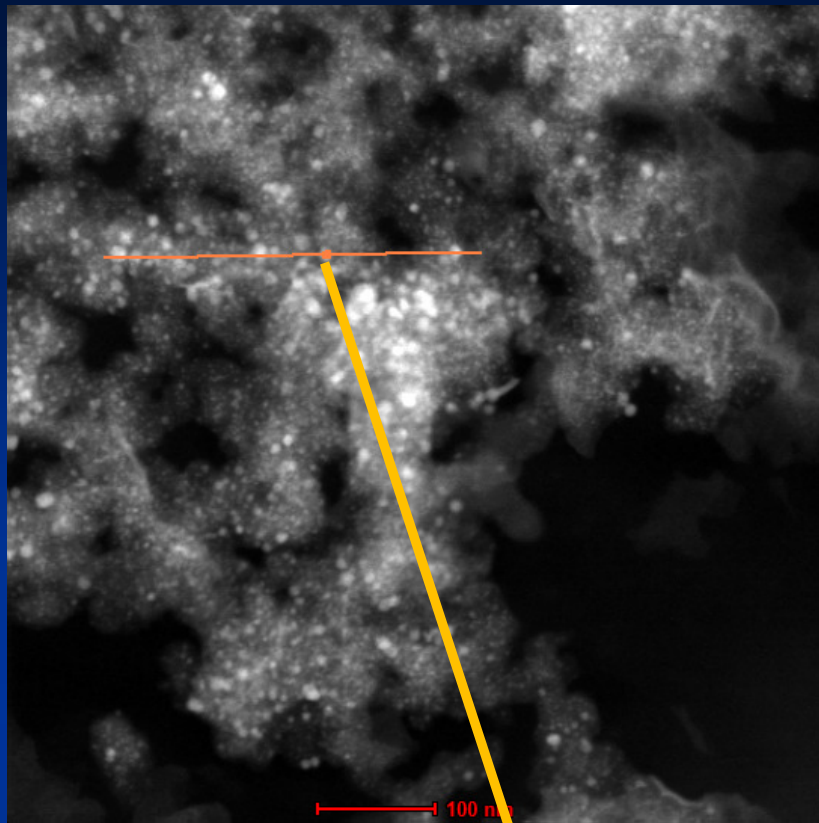
**STEM**

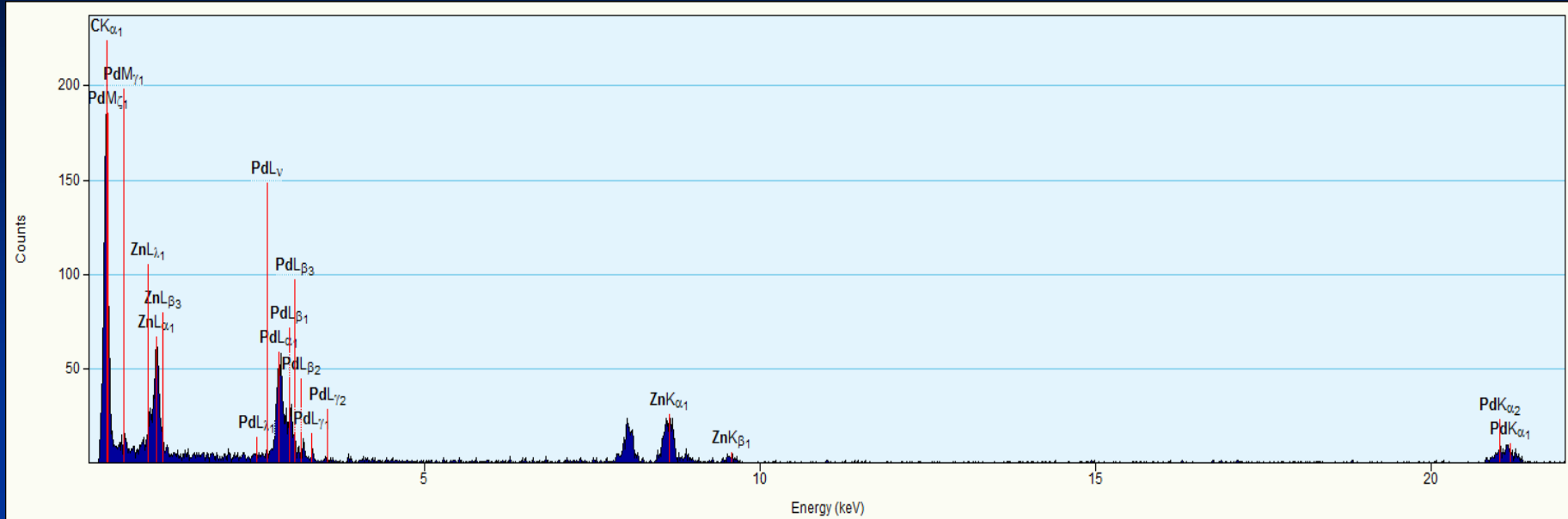
# Krystaliczne nanocząstki Ag



# Katalizator Pd-Zn/C

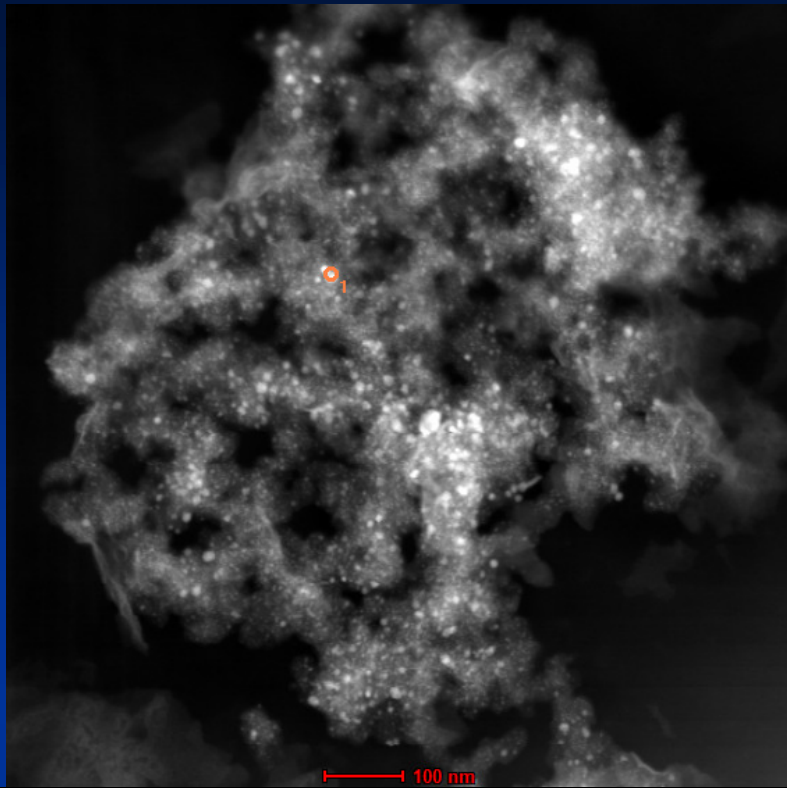




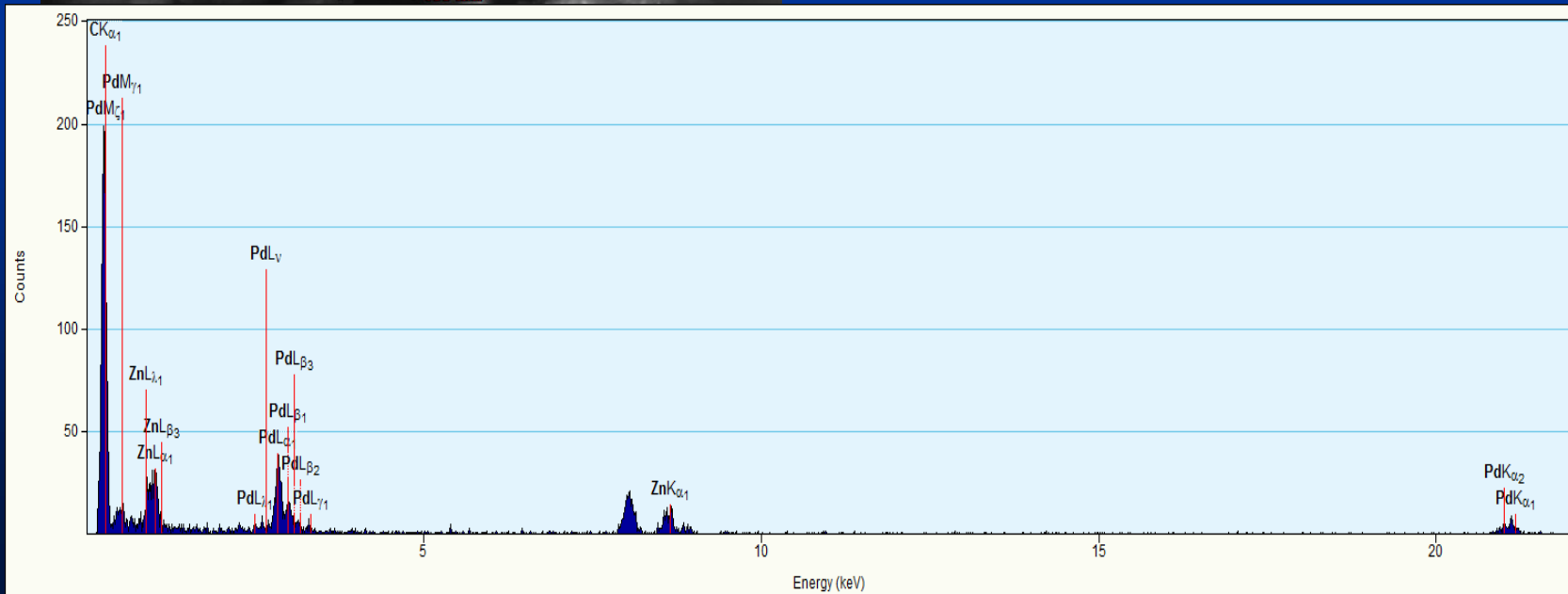


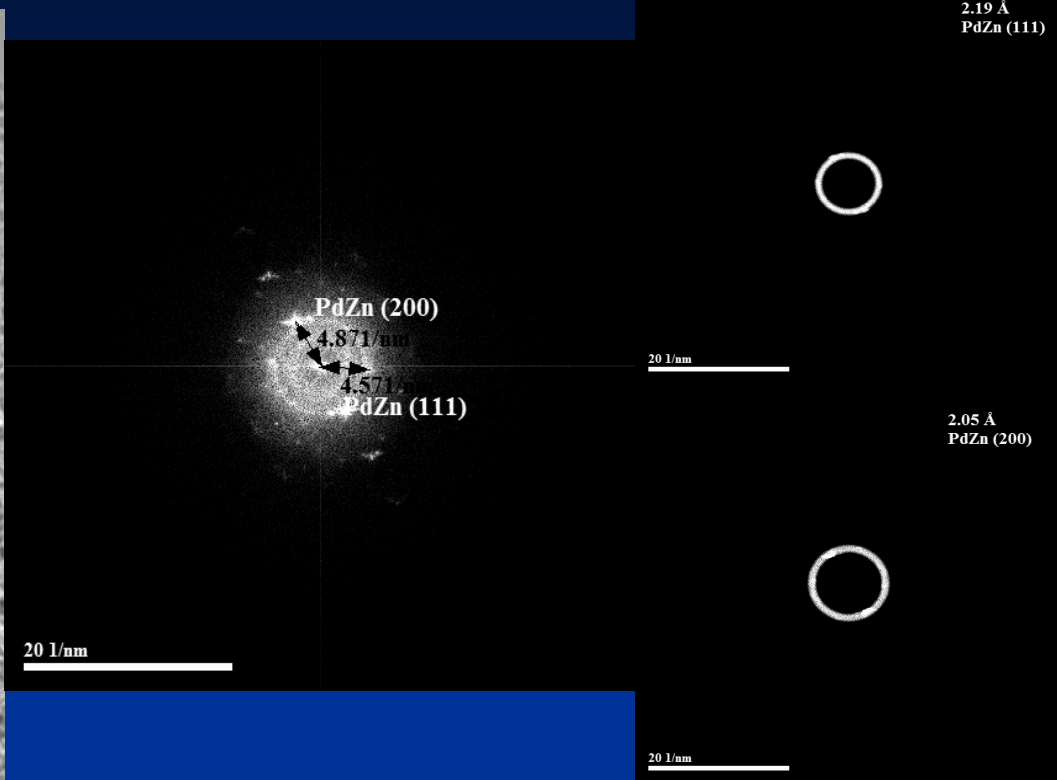
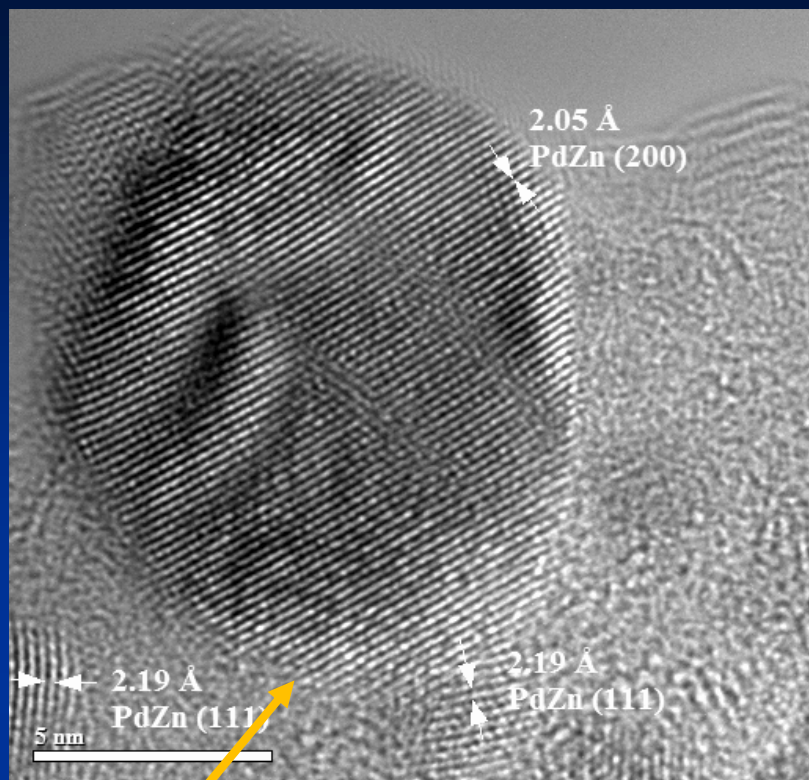
Element	Weight %	Atomic %
C(K)	58.24	90.73
Zn(K)	17.41	4.98
Pd(K)	24.33	4.27



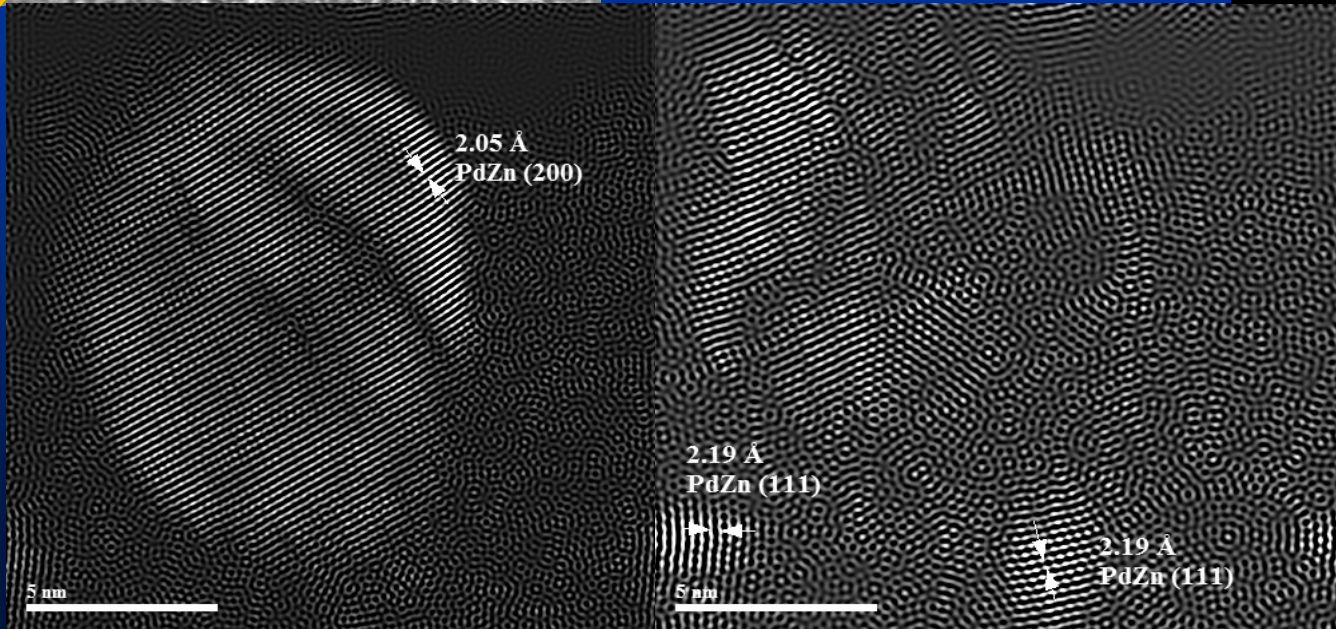


Element	Weight %	Atomic %
C(K)	82.97	97.16
Zn(K)	7.09	1.52
Pd(K)	9.92	1.31



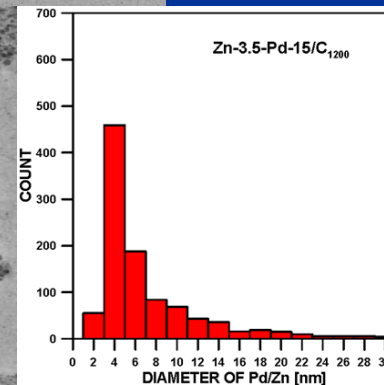
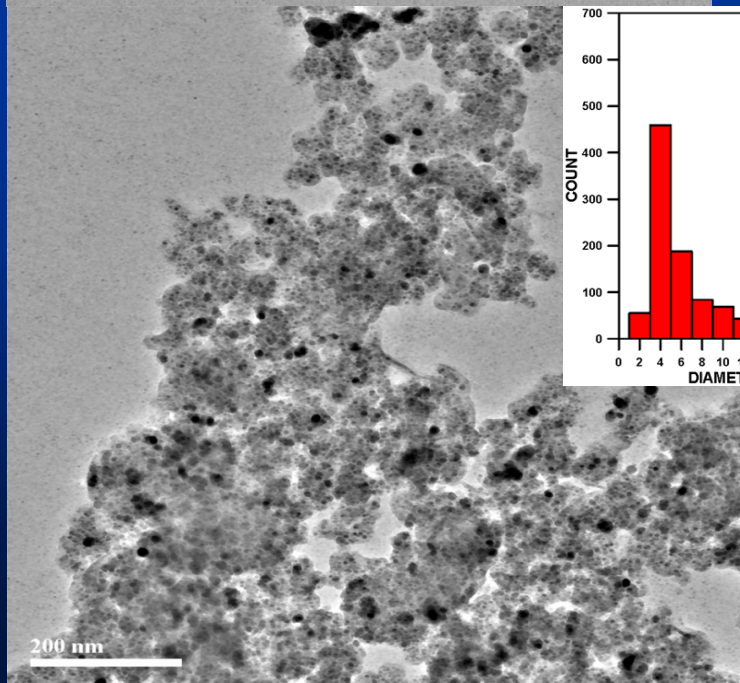
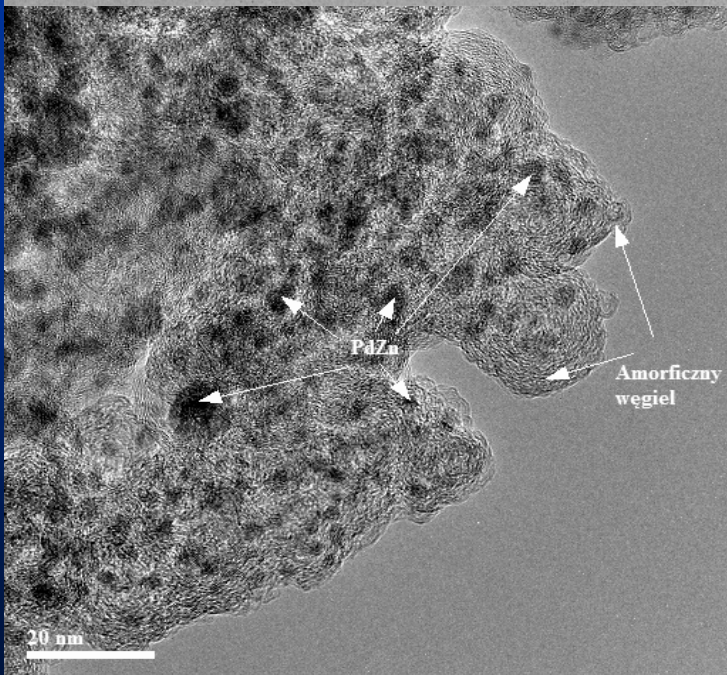
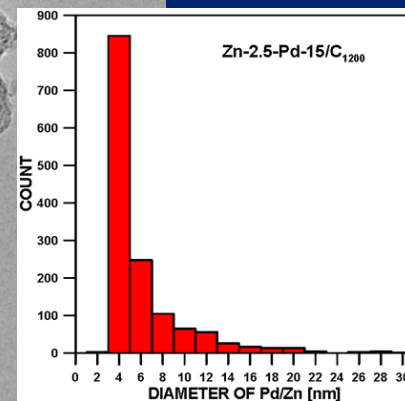
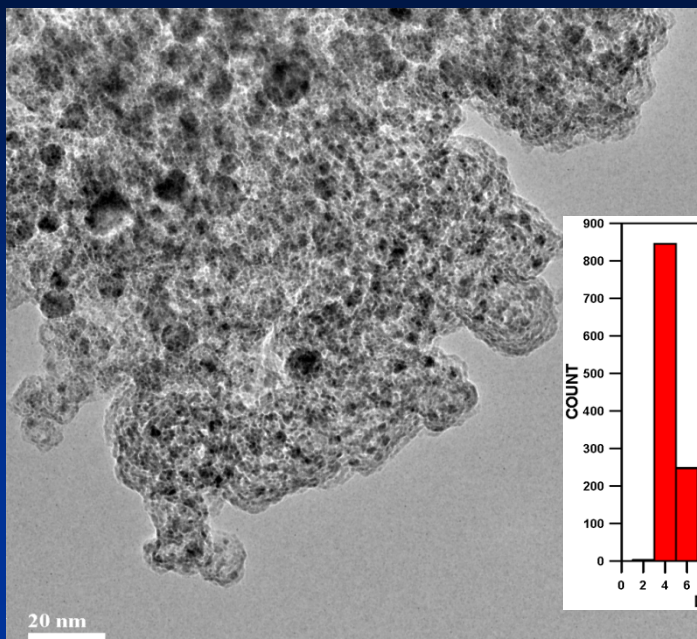
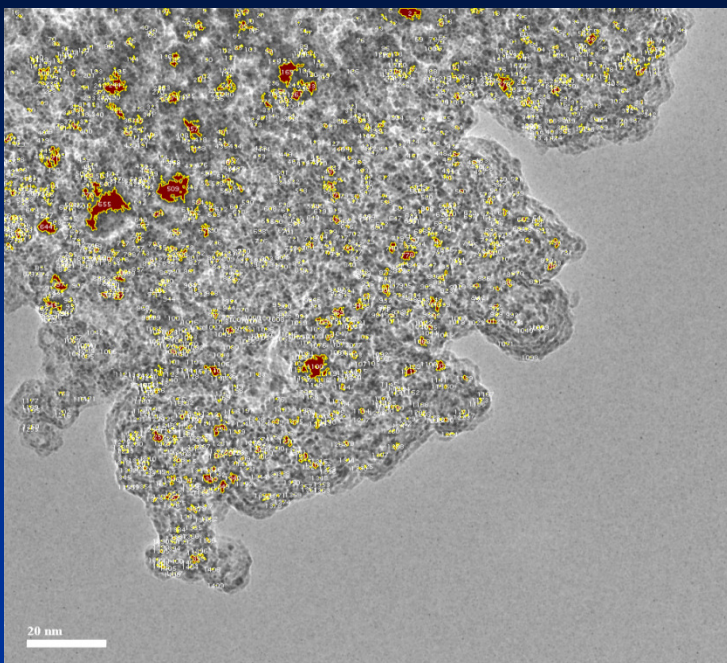


**krystalit  
PdZn**

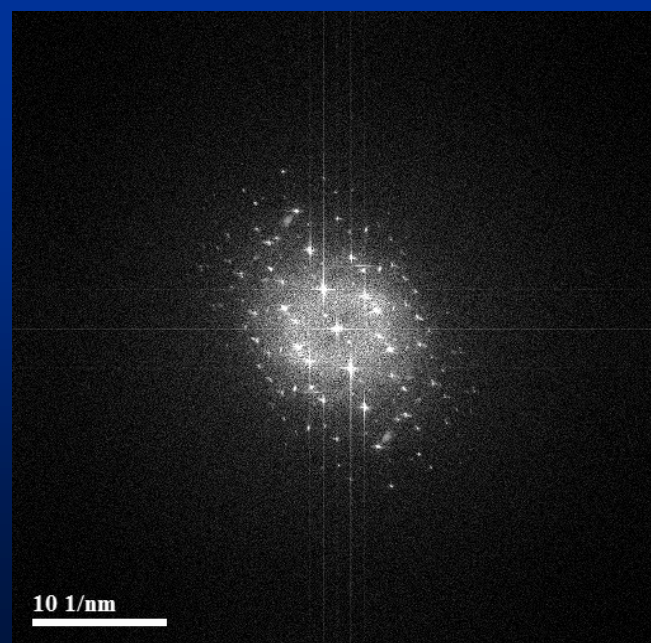
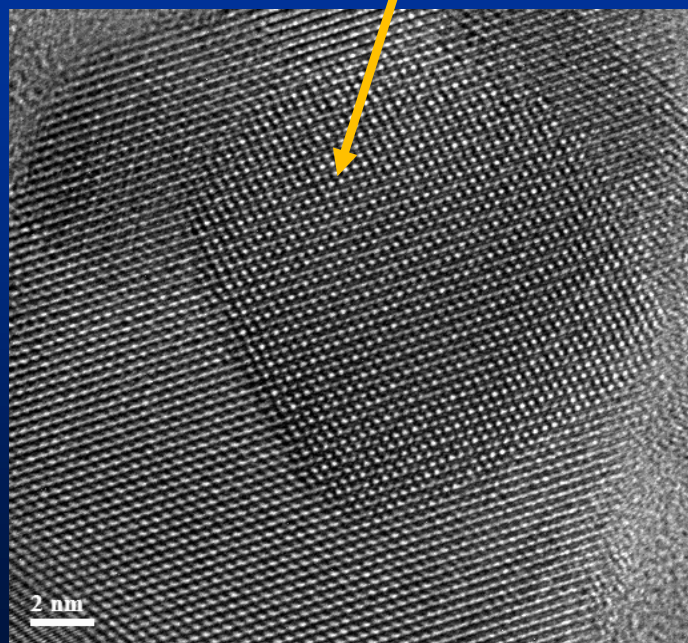
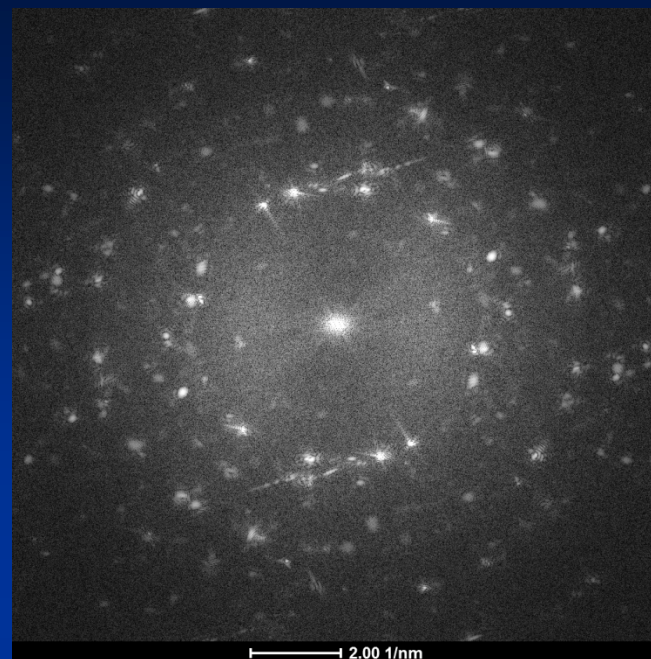
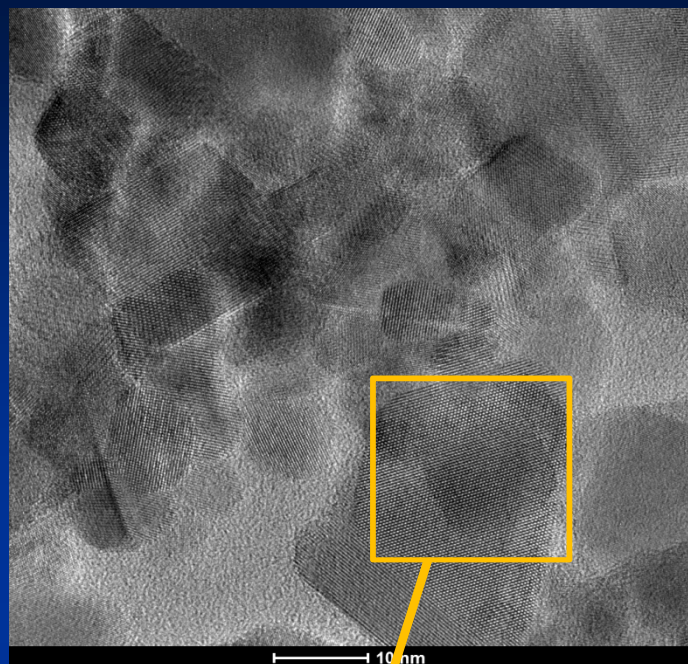


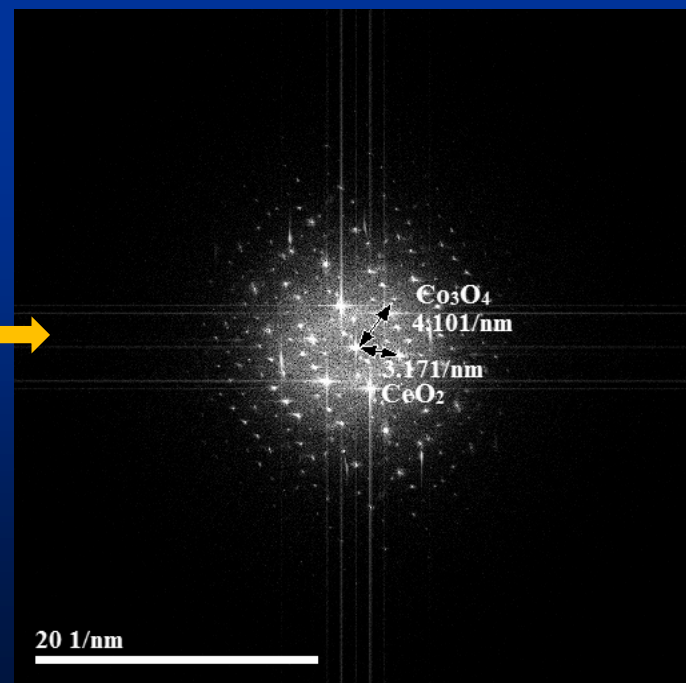
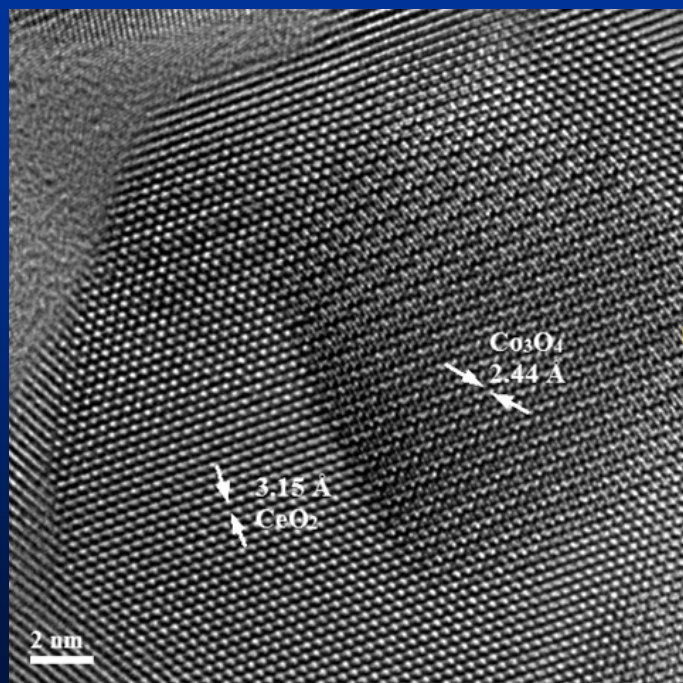
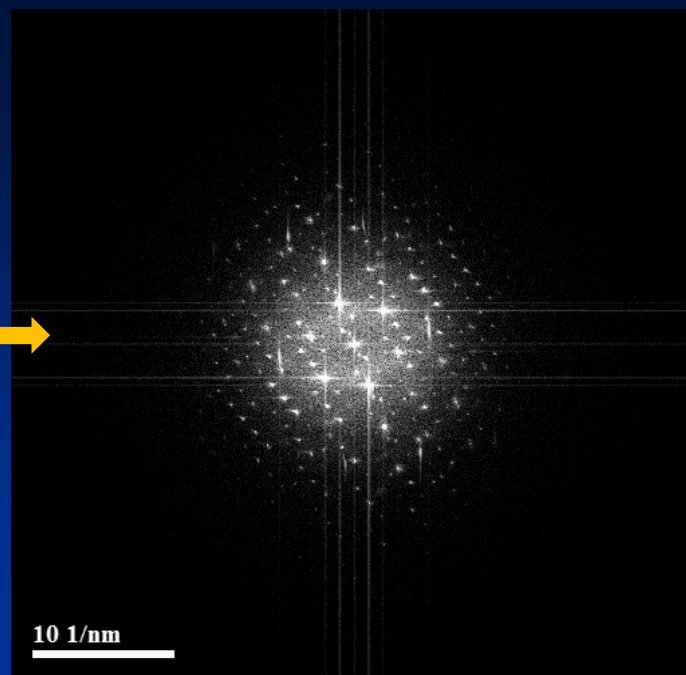
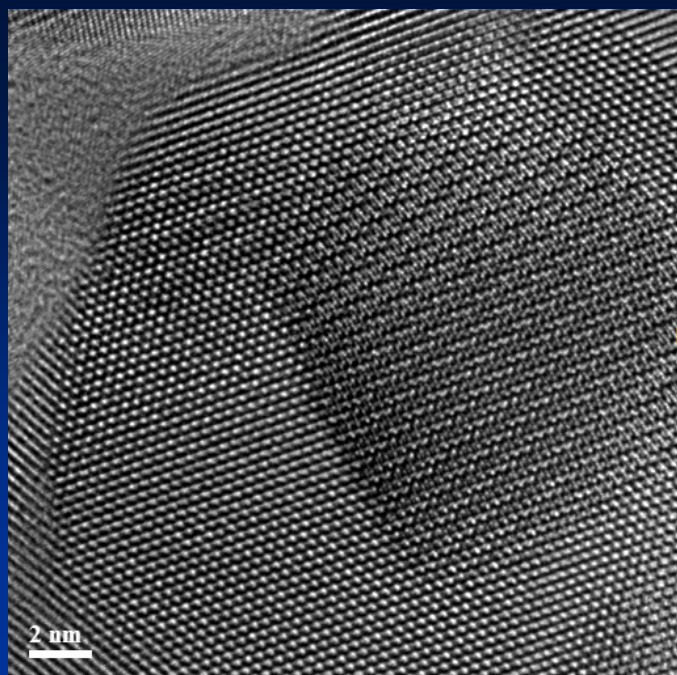


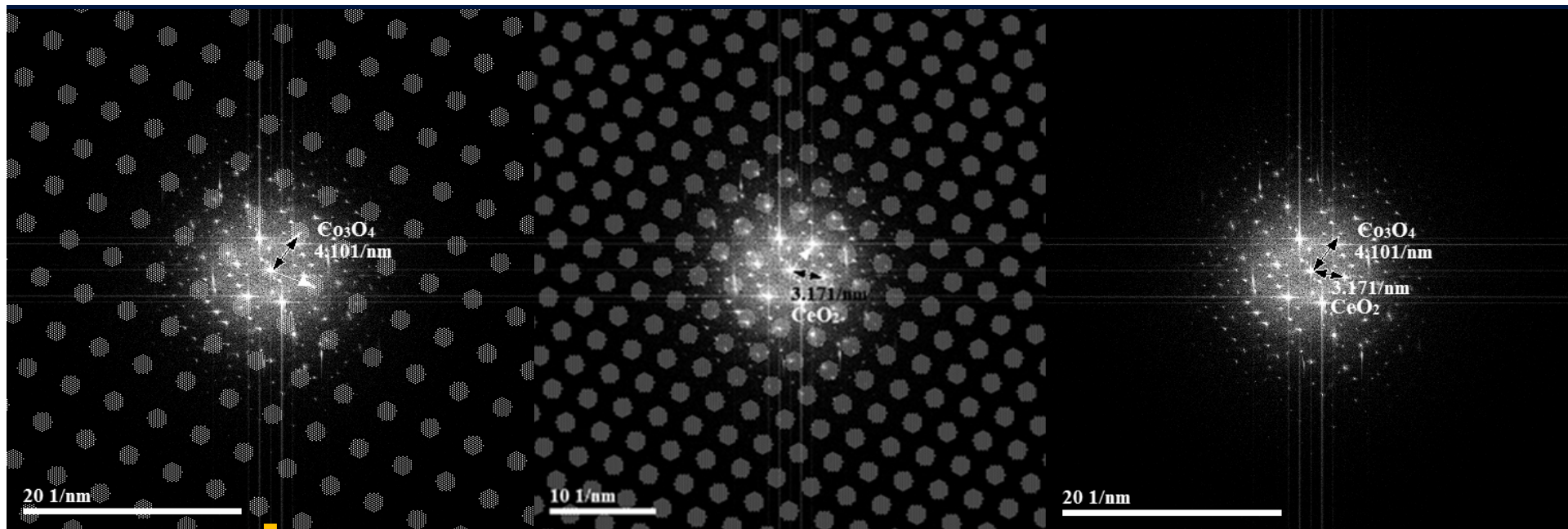
# Rozkład wielkości cząstek PdZn



# Katalizator $\text{KCoO}_x/\text{CeO}_2$

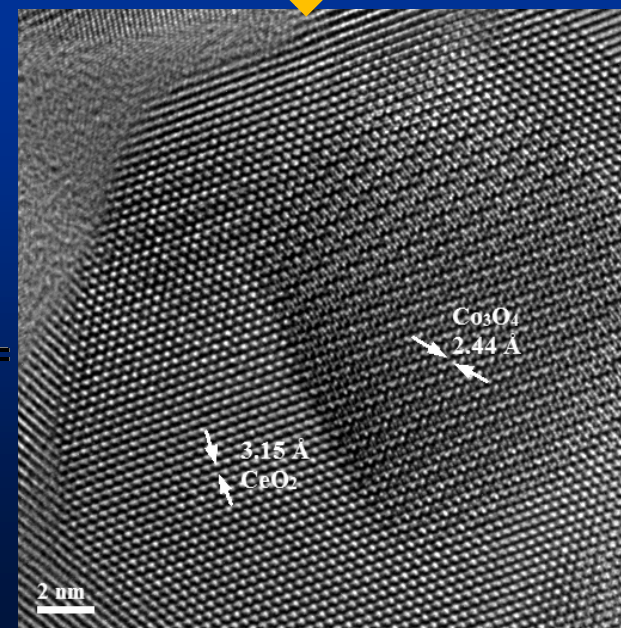
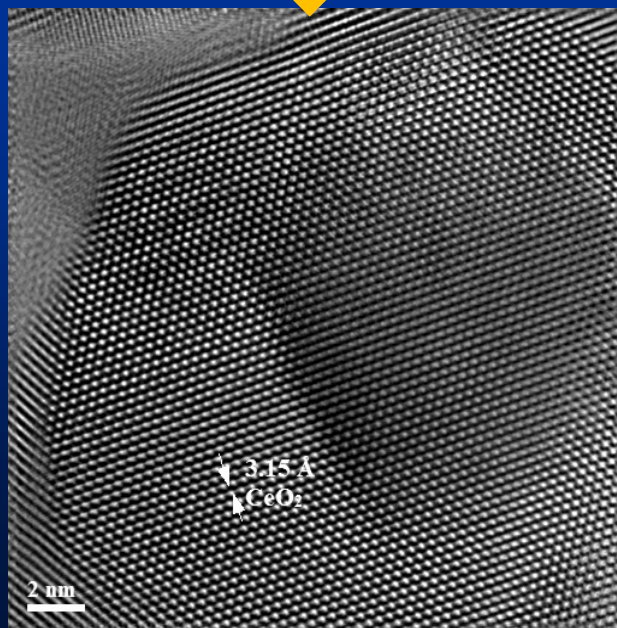
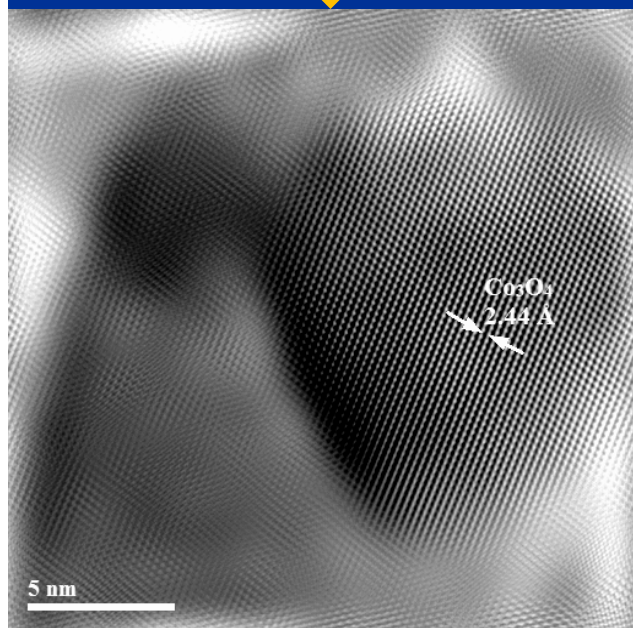




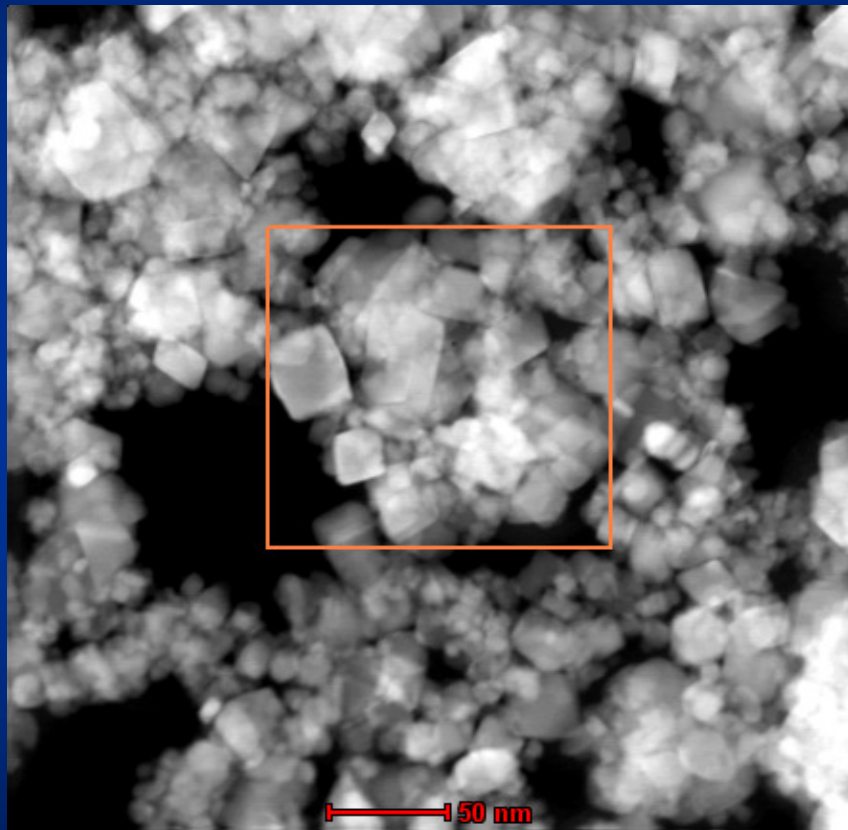


Co<sub>3</sub>O<sub>4</sub>

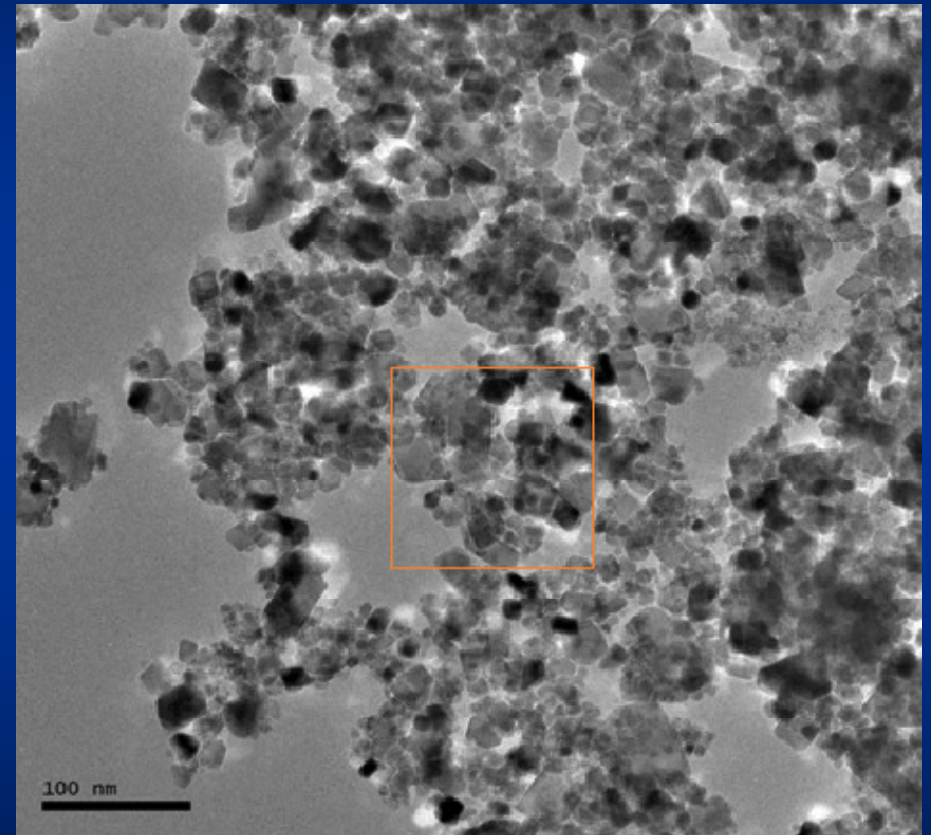
CeO<sub>2</sub>



# Katalizator $\text{KCoO}_x/\text{CeO}_2$



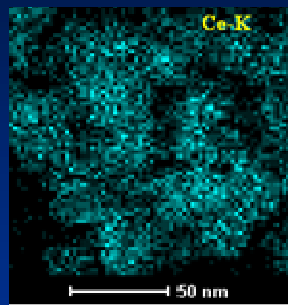
Zdjęcie STEM



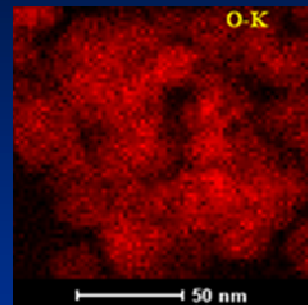
Zdjęcie TEM



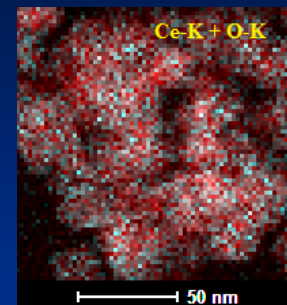
# Mapki 2D z wybranego obszaru



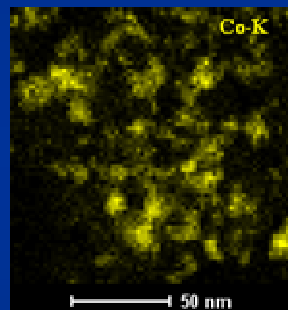
+



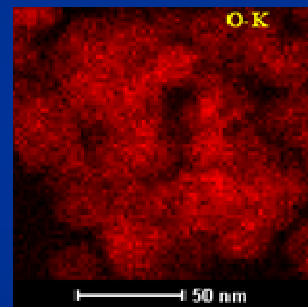
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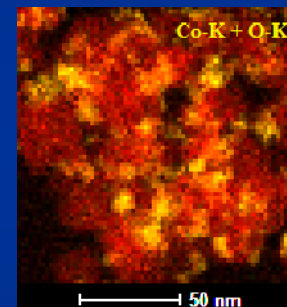
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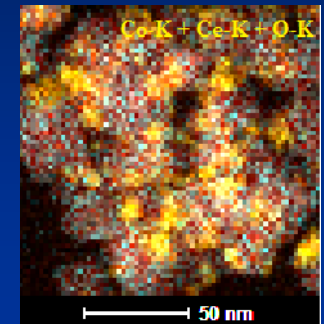
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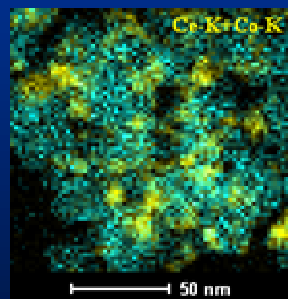
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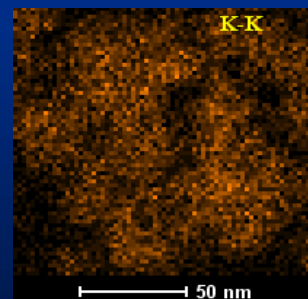
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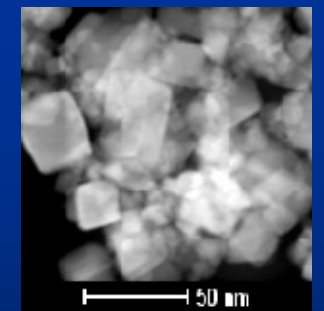
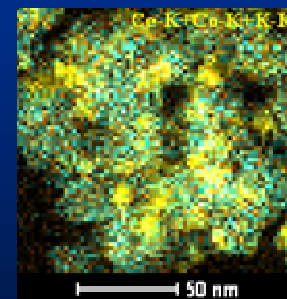
=



+



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**Fragment  
mapowanej  
próbki**

## Podsumowanie:

- » Mikroskopia elektronowa pozwala na osiągnięcie bardzo dużych powiększeń i obserwowanie obiektów w skali atomowej
- » Możliwe zastosowania do szerokiej gamy materiałów, od roślin i wirusów po półprzewodniki i kompozyty
- » Dzięki metodom spektroskopowym takim jak EDS można określić skład i rozłożenie pierwiastków w danej próbce oraz oszacować jakie związki chemiczne budują materiał
- » Dyfrakcja elektronów oraz zastosowanie w obrazowaniu FFT pozwala na zbadanie właściwości krystalograficznych badanego materiału