Skaningowy Mikroskop Elektronowy (SEM) z systemem Spektroskopii Rentgenowskiej z Dyspersją Energii (EDS)

Jan Michalik

Katedra Fizyki Ciała Stałego
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Wykorzystano wyniki otrzymane podczas pomiarów:

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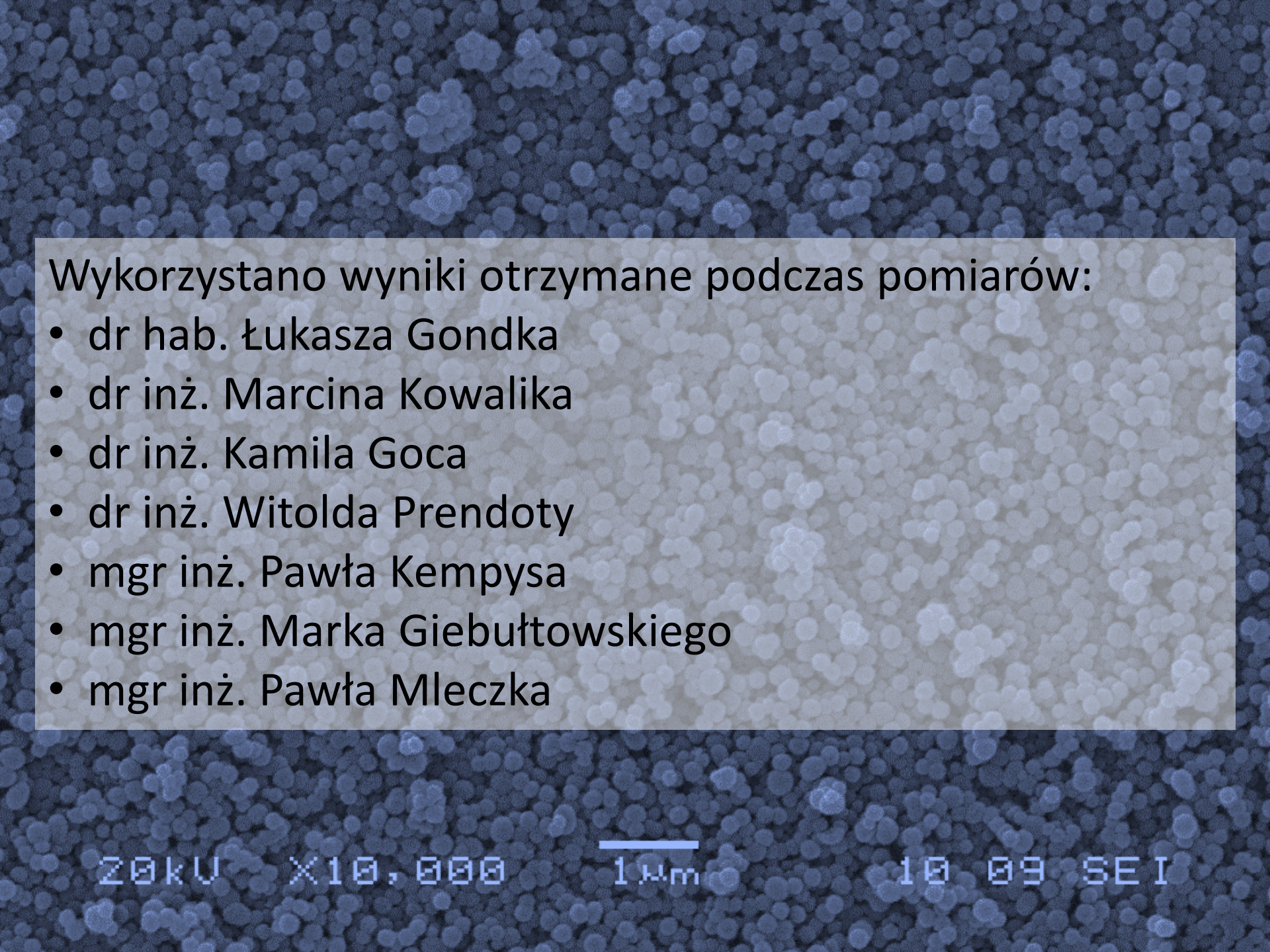
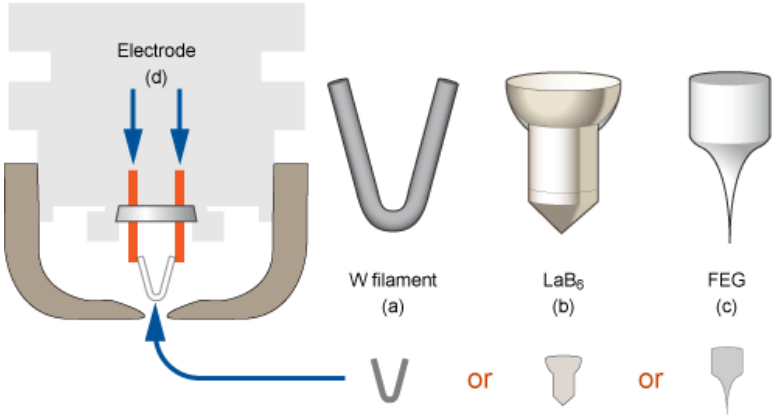
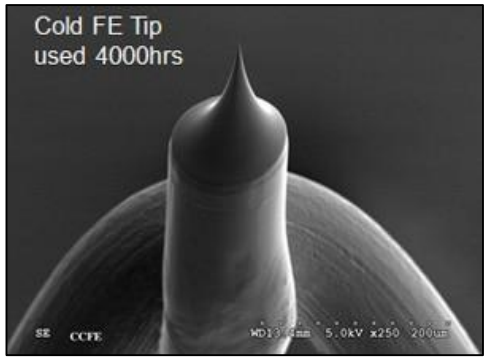
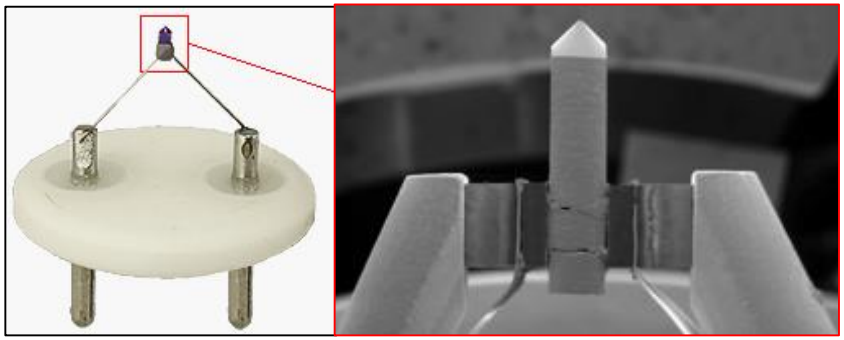
- dr inż. Marcina Kowalika
- dr inż. Kamila Goca
- dr inż. Witolda Prendoty
- mgr inż. Pawła Kempysa
- mgr inż. Marka Giebułtowskiego
- mgr inż. Pawła Mleczka

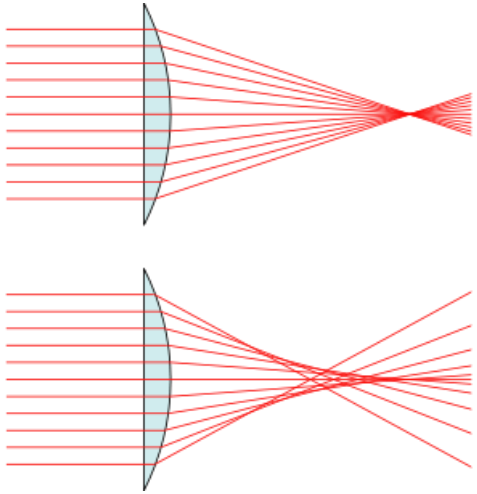






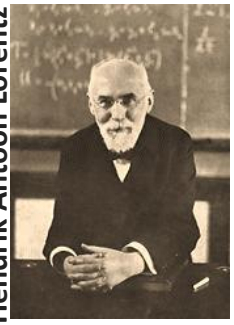


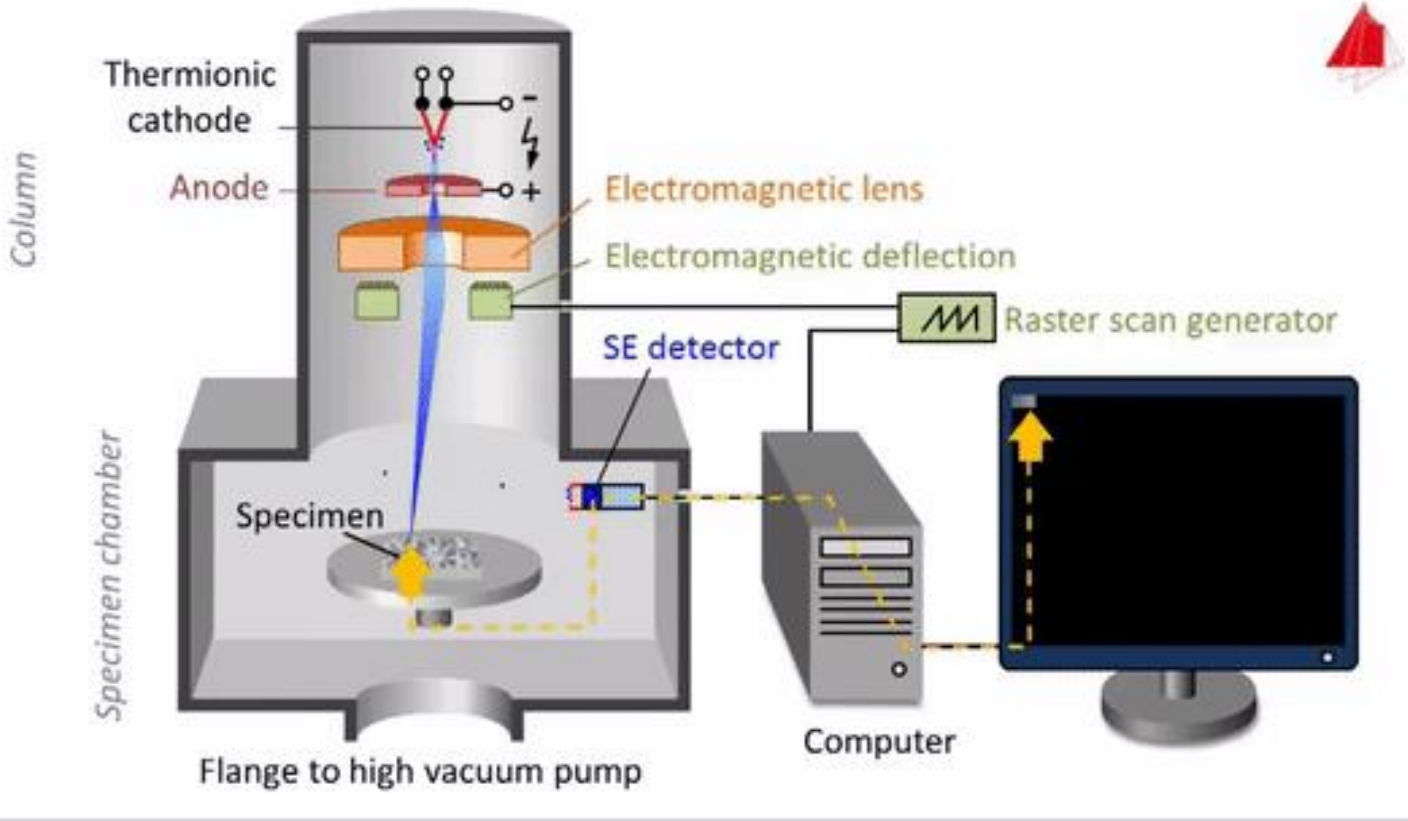
Source	Brightness	Stability(%)	Size	Energy spread	Vacuum
W	$3X10^5$	~1	50μm	3.0(eV)	10^{-5} (τ)
LaB_6	$3x10^6$	~2	5μm	1.5	10^{-6}
C-FEG	10^9	~5	5nm	0.3	10^{-10}
T-FEG	10^9	<1	20nm	0.7	10^{-9}

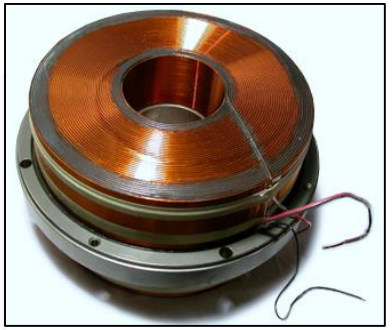


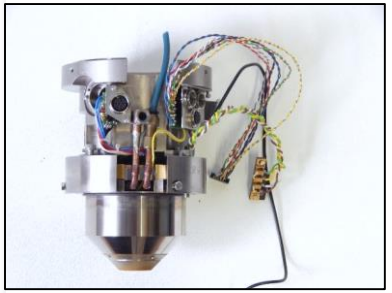
Mikroskopia skaningowa jest metodą rastrową - rozdzielczość zależy więc także od:

- wielkości skanowanego obszaru;
- rozdzielczości systemu generującego skan;
- rozdzielczości systemu zbierającego / przetwarzającego obraz.

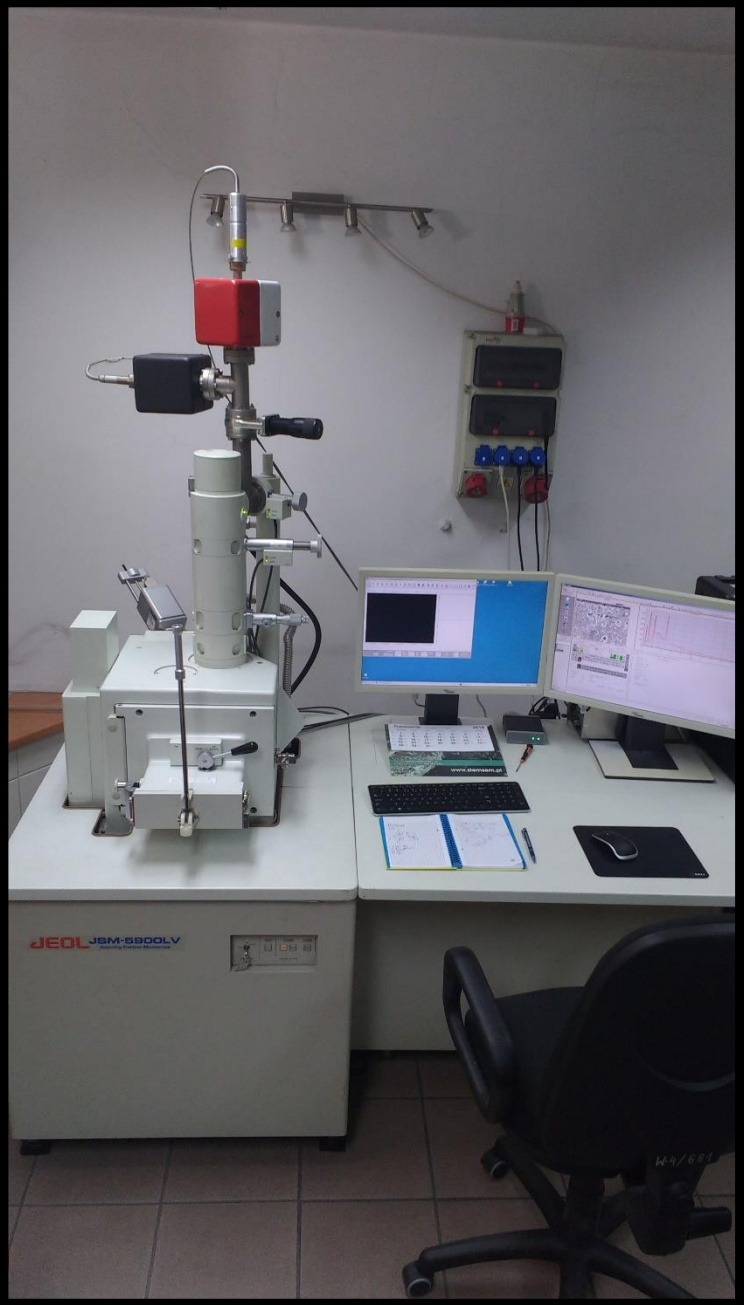

Hendrik Antoon Lorentz

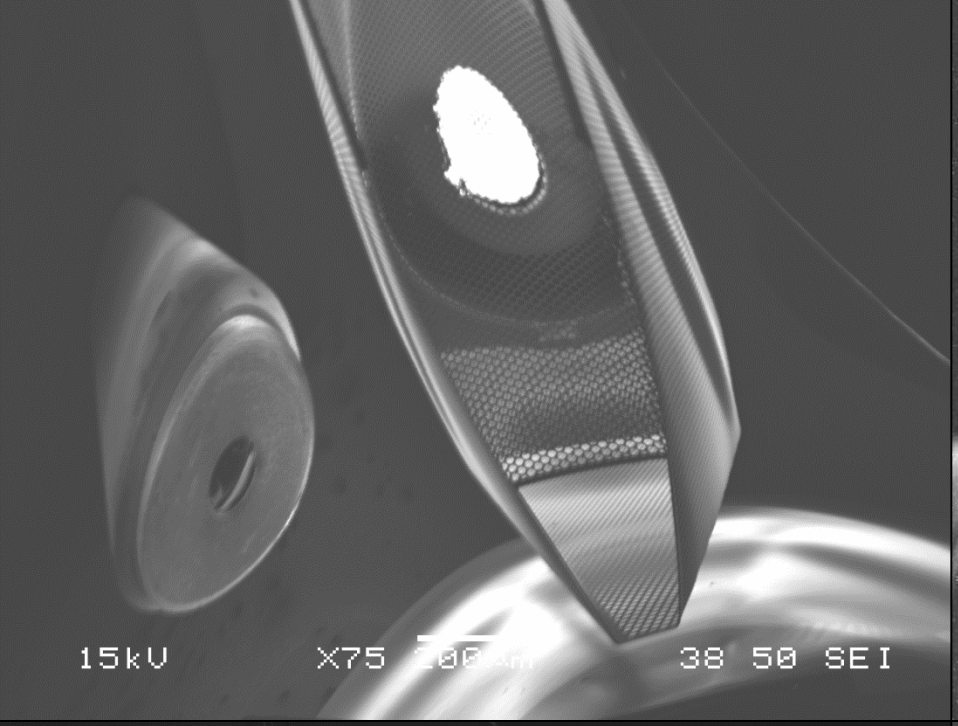


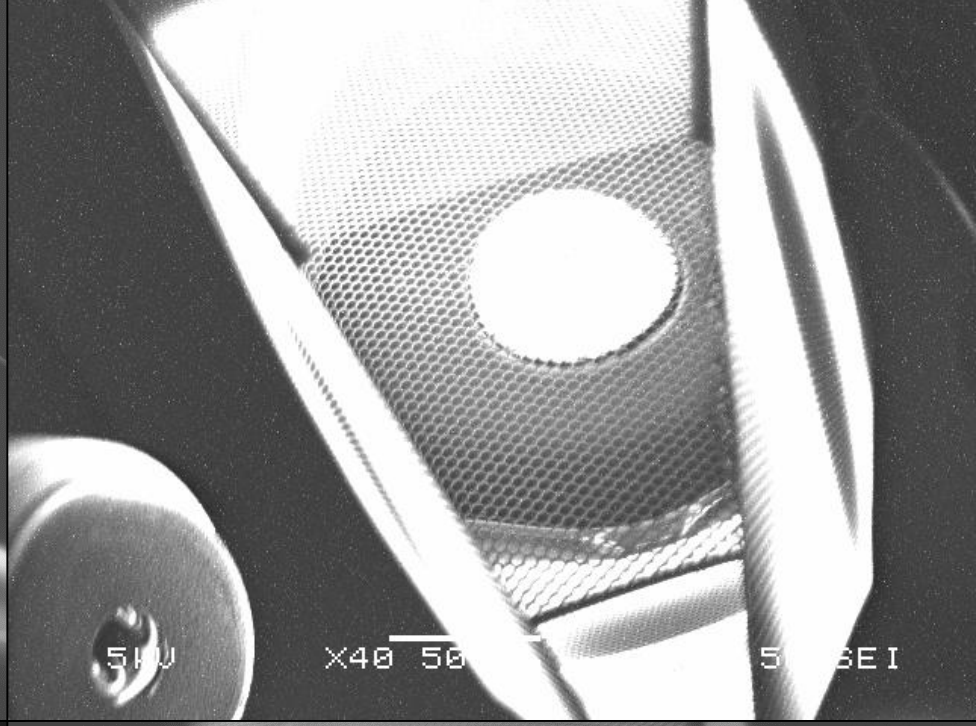


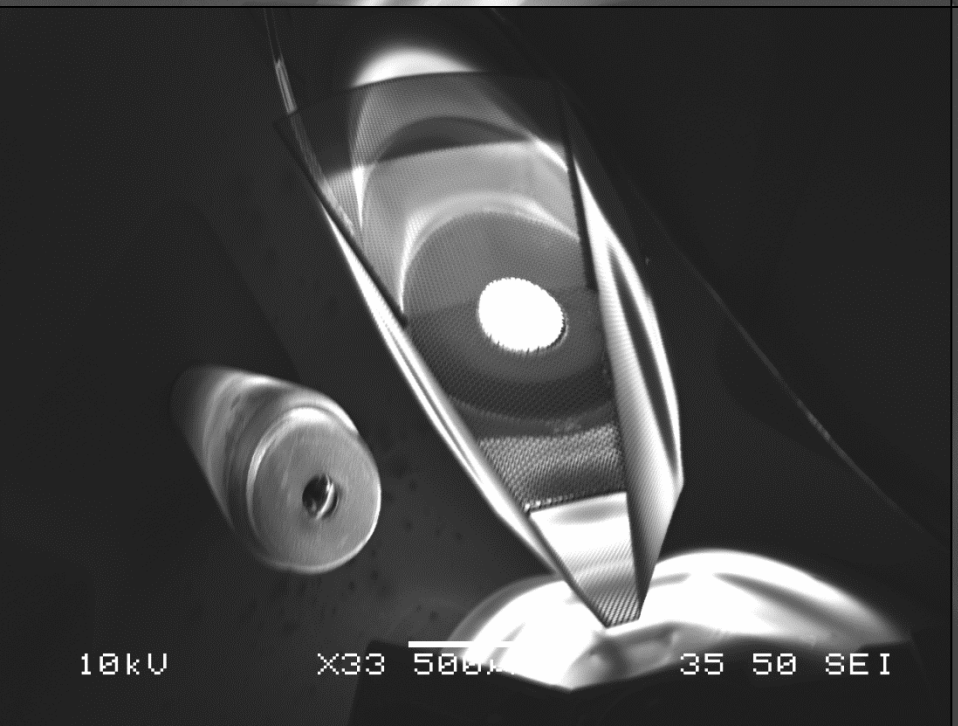


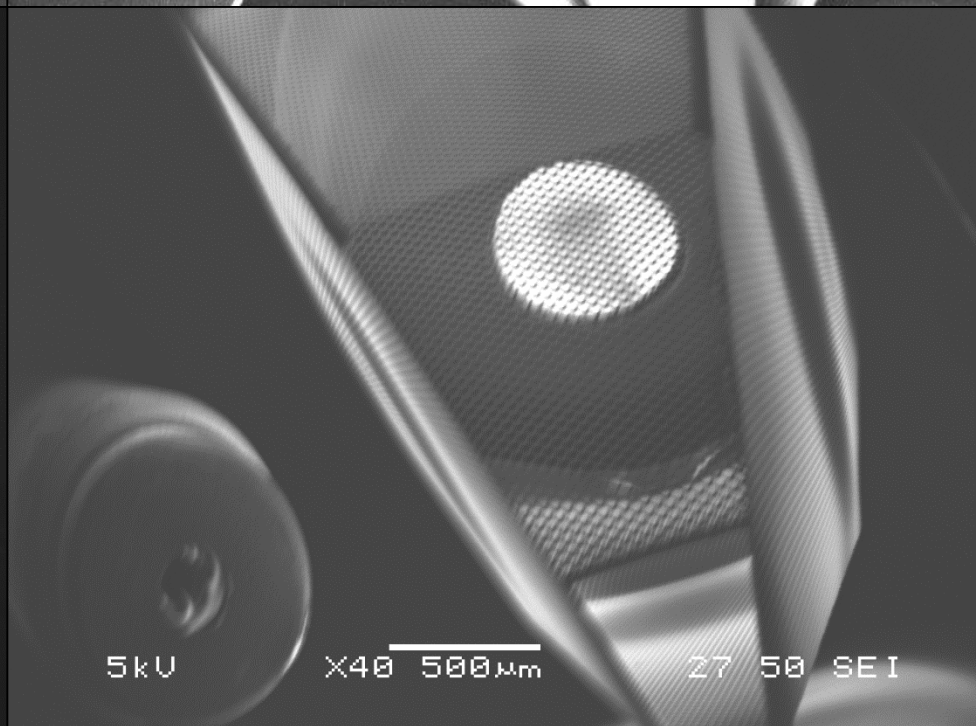
Skaningowy Mikroskop Elektronowy (SEM) z systemem Spektroskopii Rentgenowskiej z Dyspersją Energii (EDS)



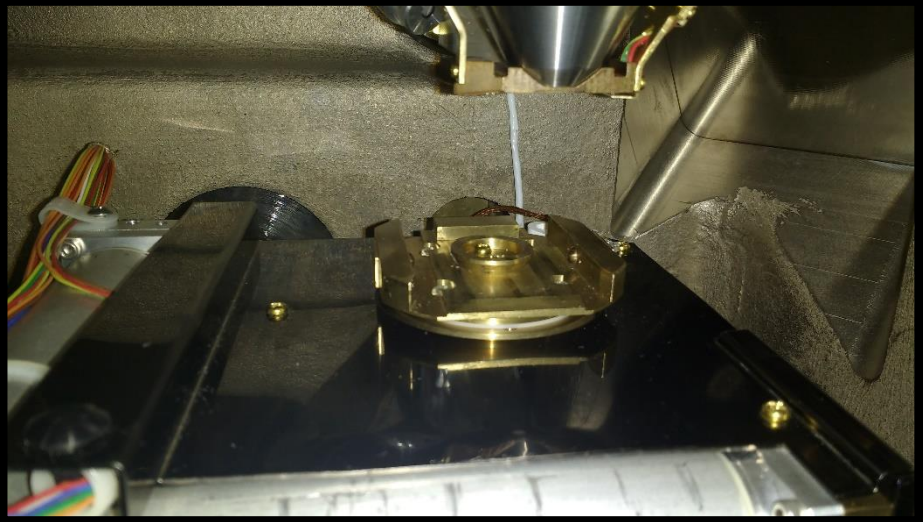

15kV X75 38 50 SEI

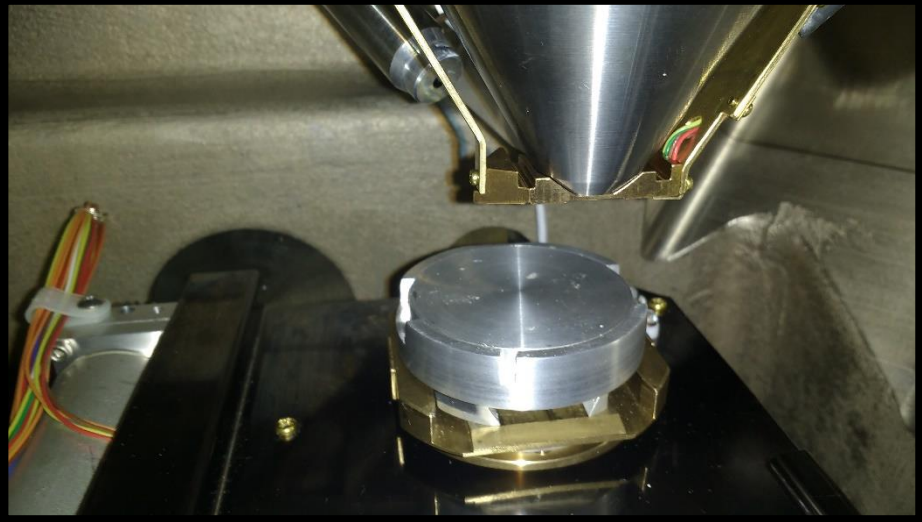

X40 50

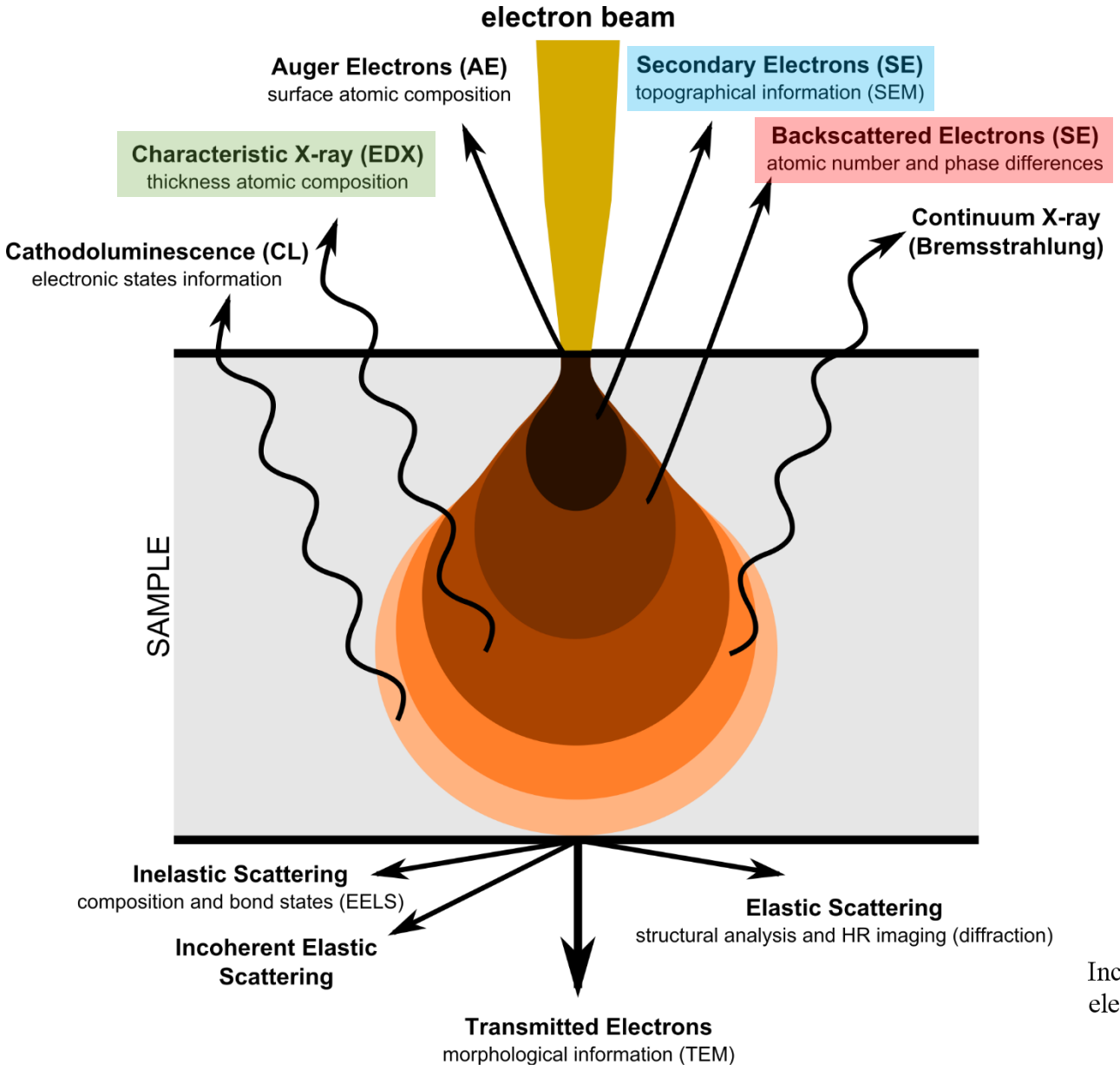

10kV X33 35 50 SEI

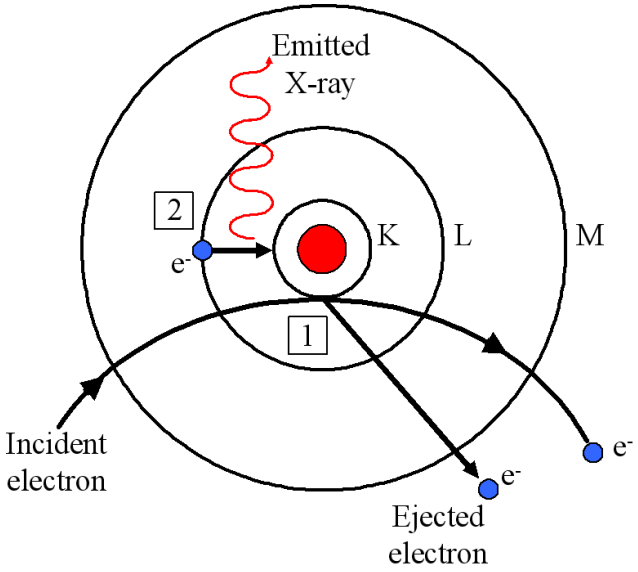

5kV X40 500µm 27 50 SEI

Skaningowy Mikroskop Elektronowy (SEM) z systemem Spektroskopii Rentgenowskiej z Dyspersją Energii (EDS)

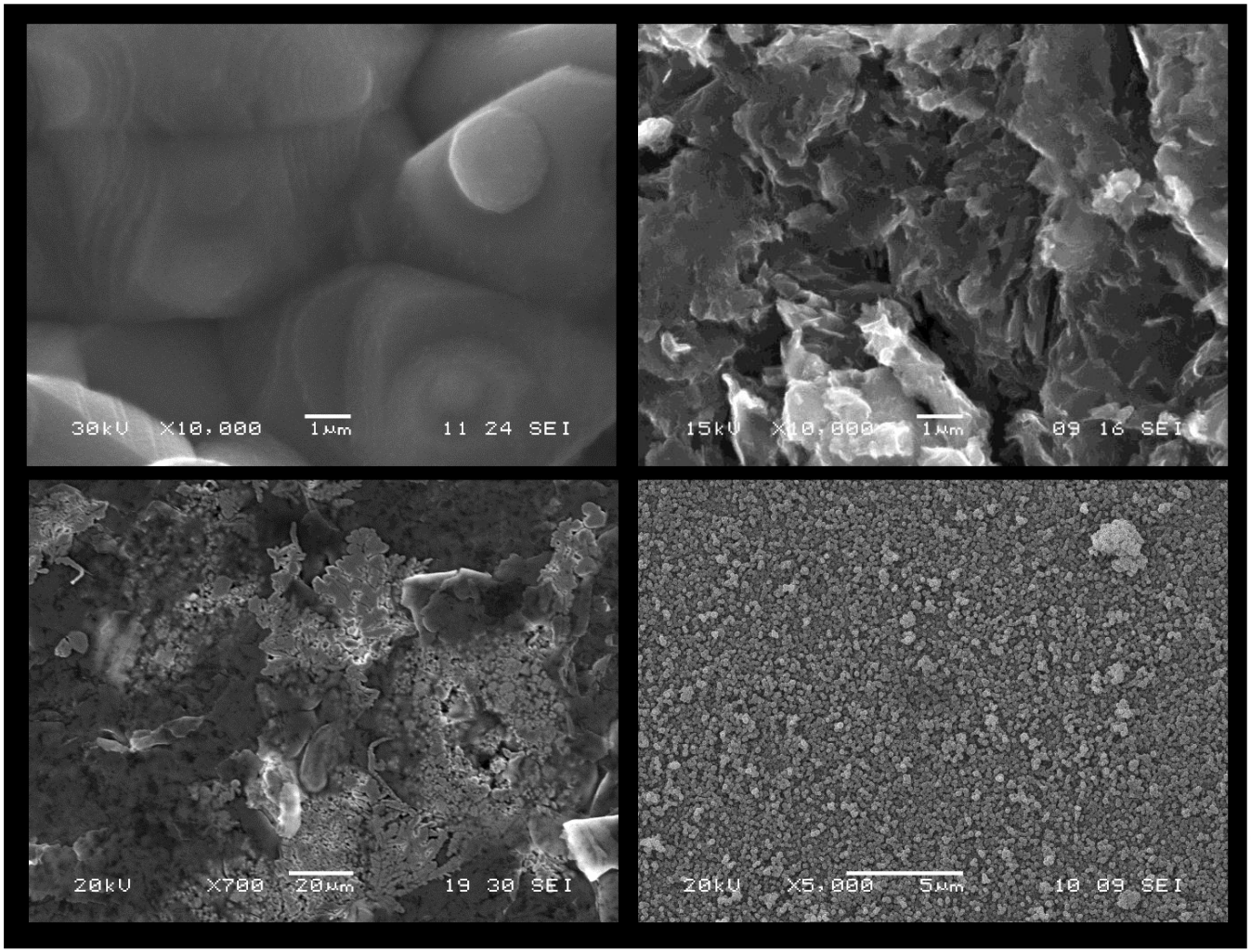


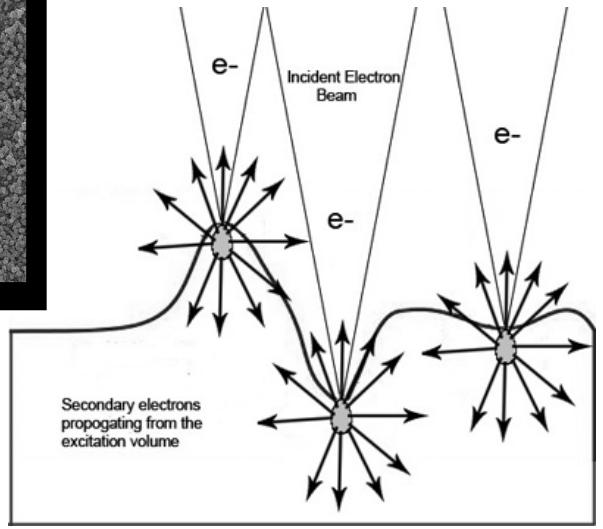



electron beam
Auger Electrons (AE)
surface atomic composition
Secondary Electrons (SE)
topographical information (SEM)
Characteristic X-ray (EDX)
thickness atomic composition
Backscattered Electrons (SE)
atomic number and phase differences
Continuum X-ray
(Bremsstrahlung)
Cathodoluminescence (CL)
electronic states information
SAMPLE
Inelastic Scattering
composition and bond states (EELS)
Incoherent Elastic
Scattering
Elastic Scattering
structural analysis and HR imaging (diffraction)
Transmitted Electrons
morphological information (TEM)

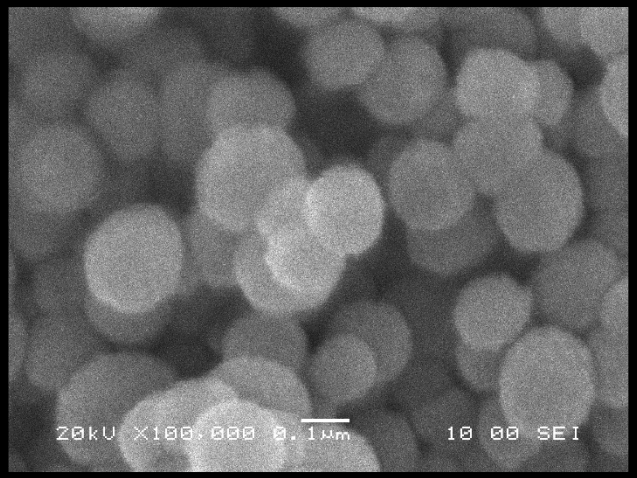

Emitted
X-ray
2
K
L
M
e-
1
Incident
electron
e-
e-
Ejected
electron

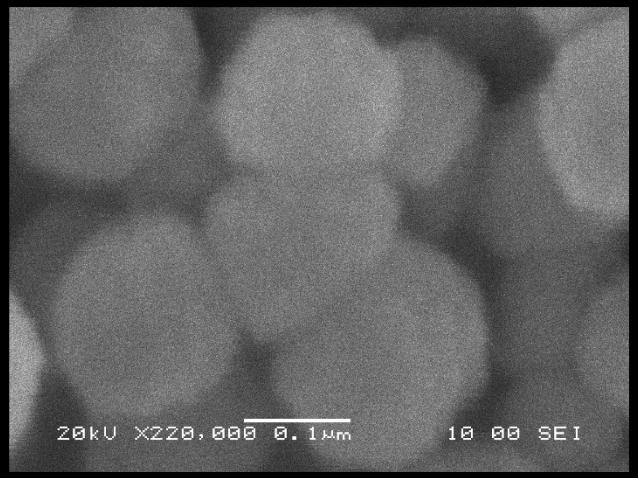
Detekcja Elektronów Wtórnych (SE) w trybie wysokiej próżni (HV)

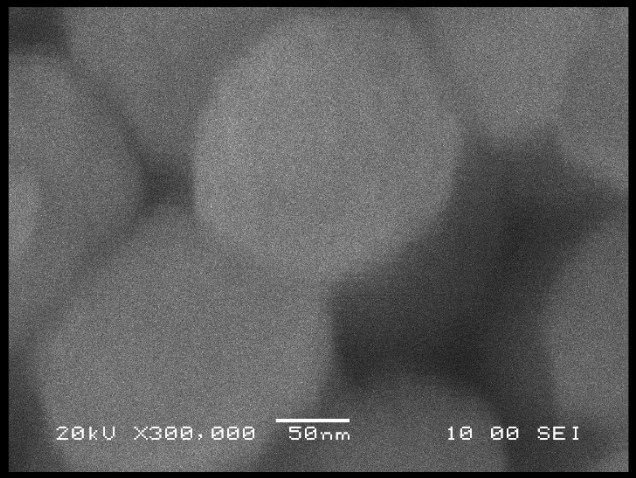


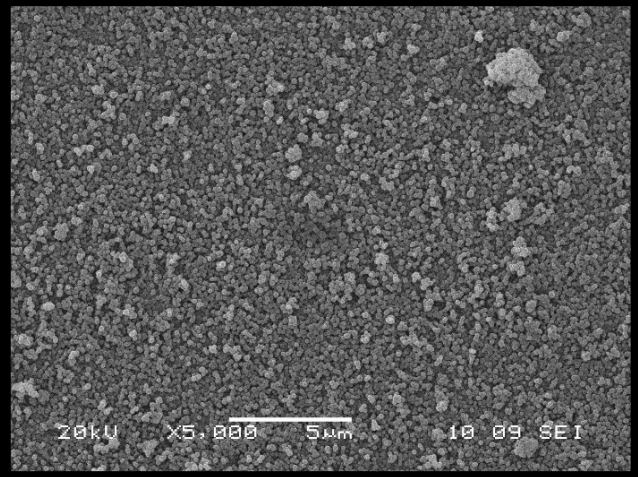


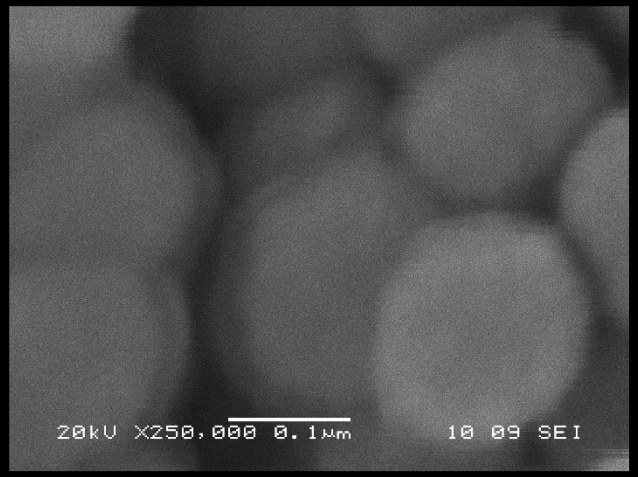
Detekcja Elektronów Wtórnych (SE) w trybie wysokiej próżni (HV)

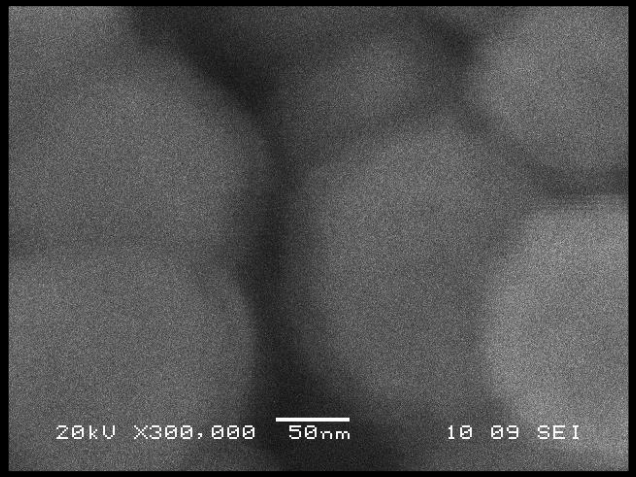






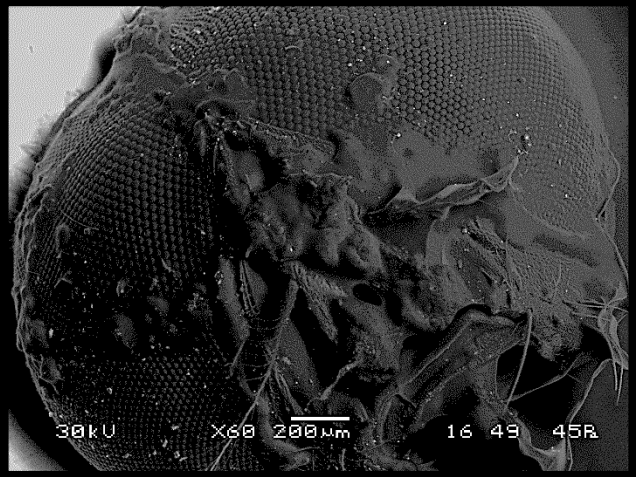


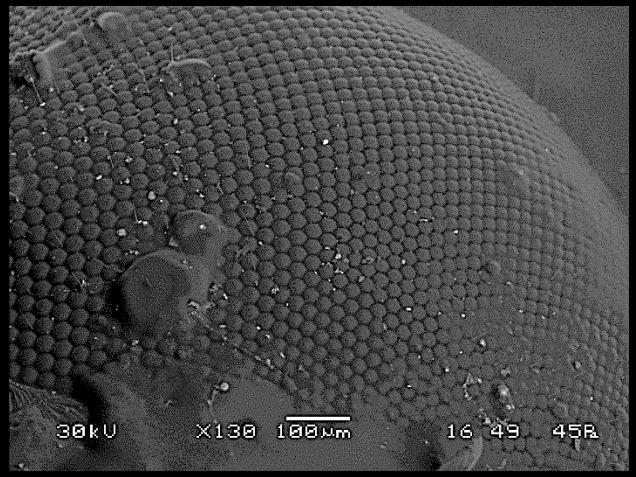


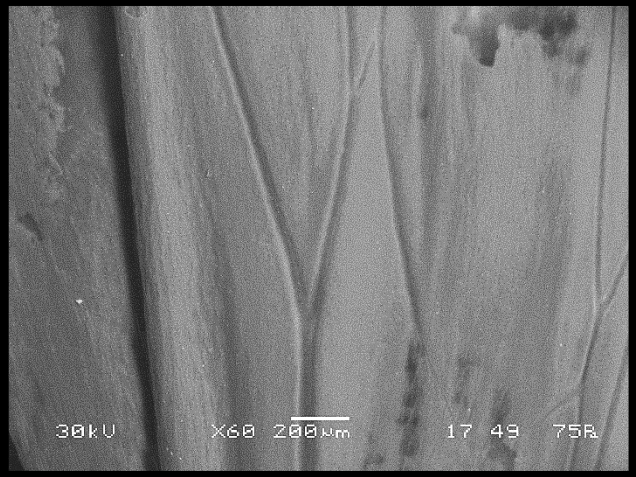


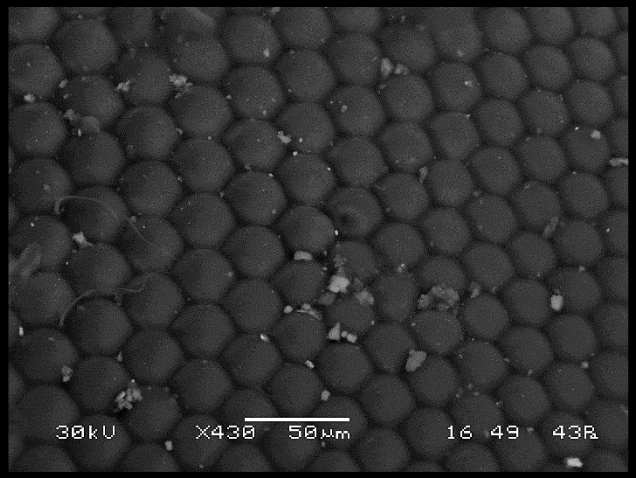
Kulki SiO_2 pokryte Au

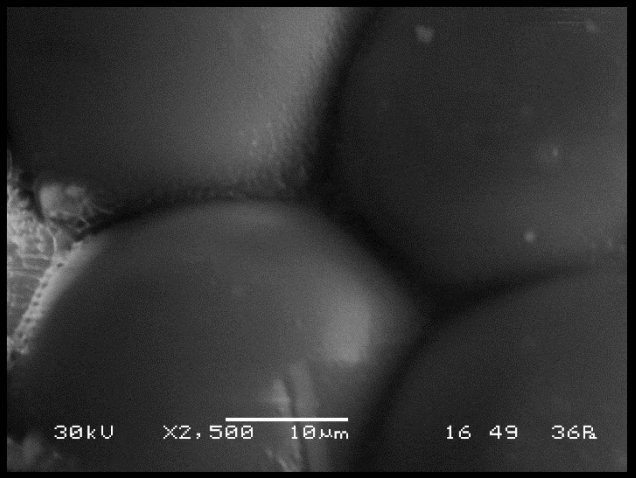
Detekcja Elektronów Wtórnych (SE) w trybie niskiej próżni (LV)

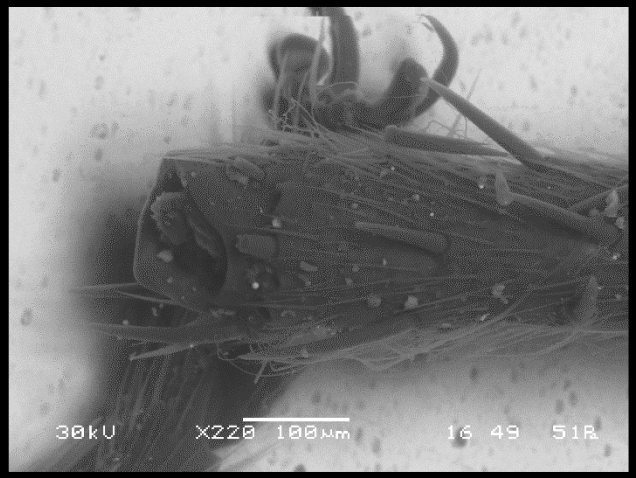




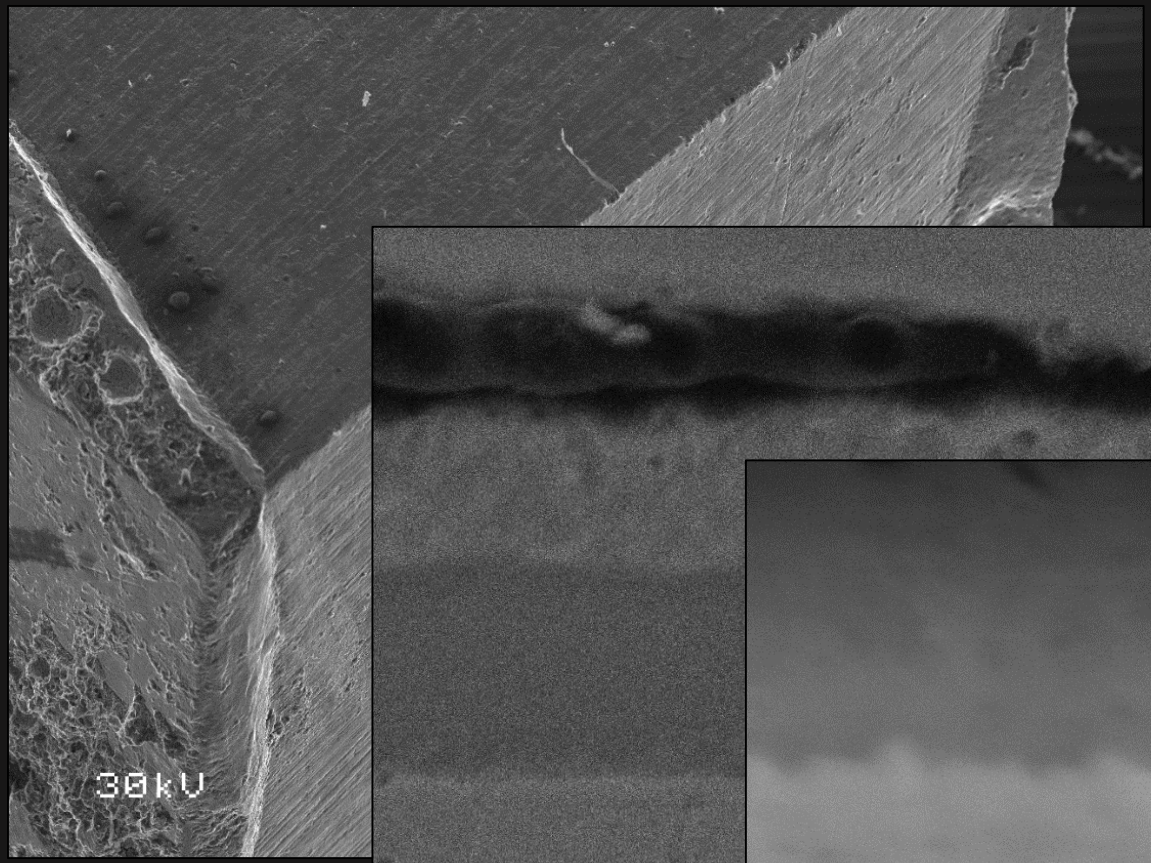


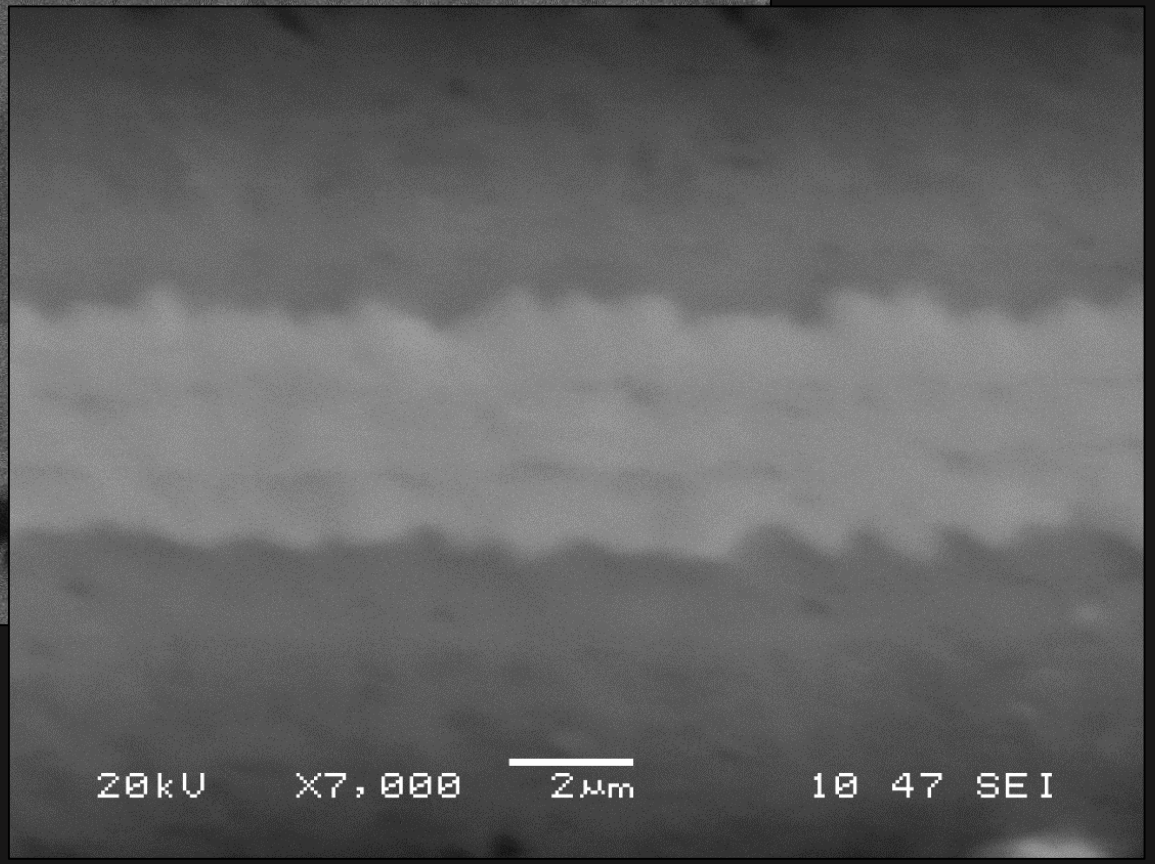






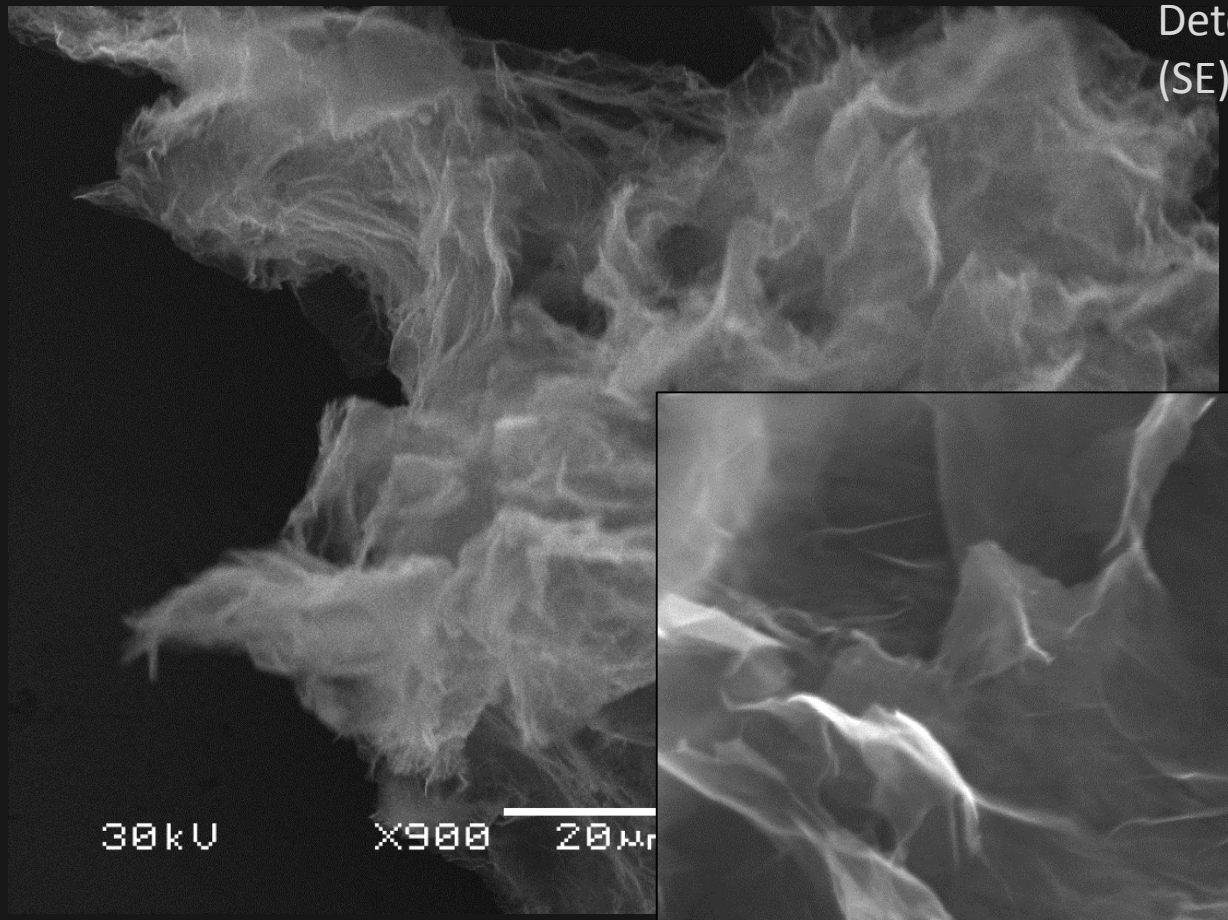
Detekcja Elektronów Wtórnych (SE) w trybie wysokiej próżni (HV)

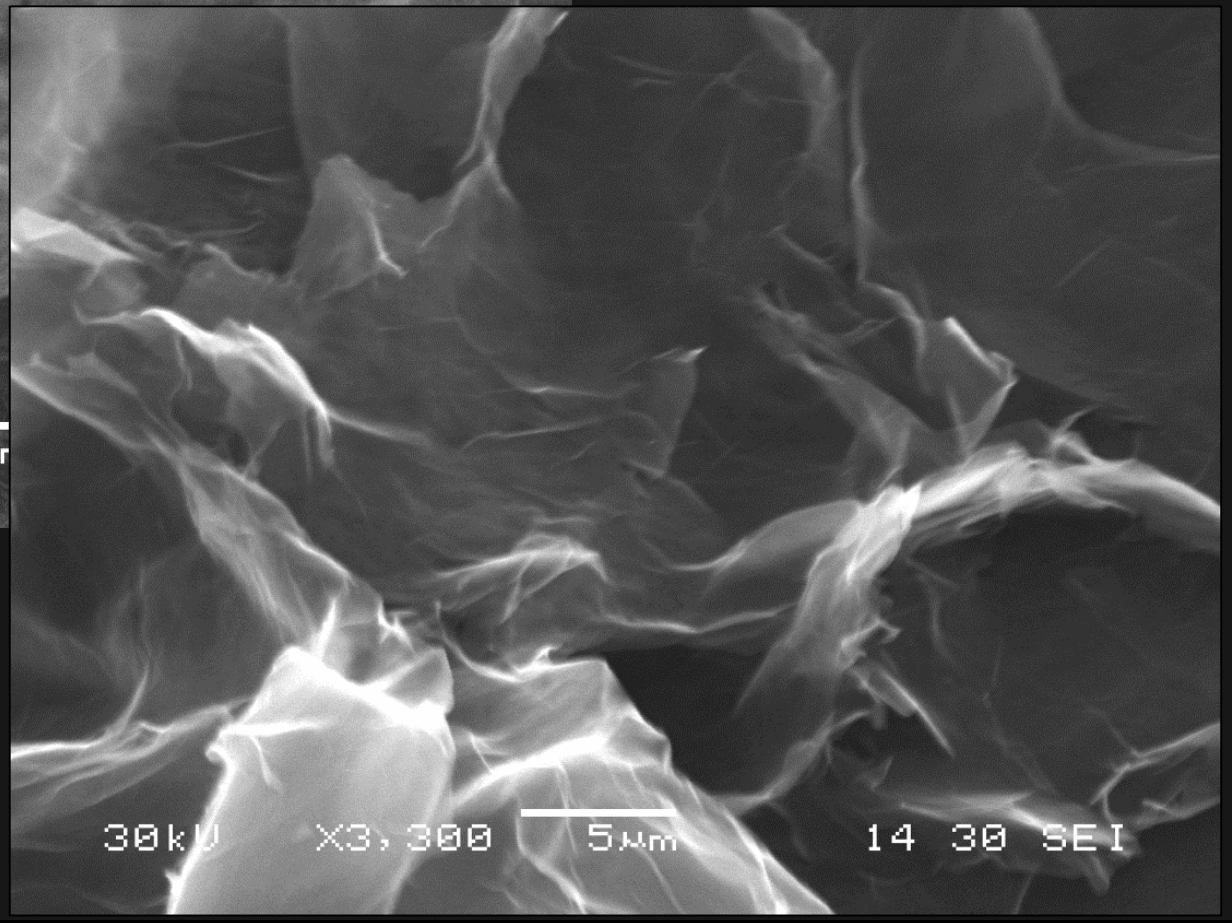




Anizotropowy spiek
Zgrzewane taśmy Ti-Ni

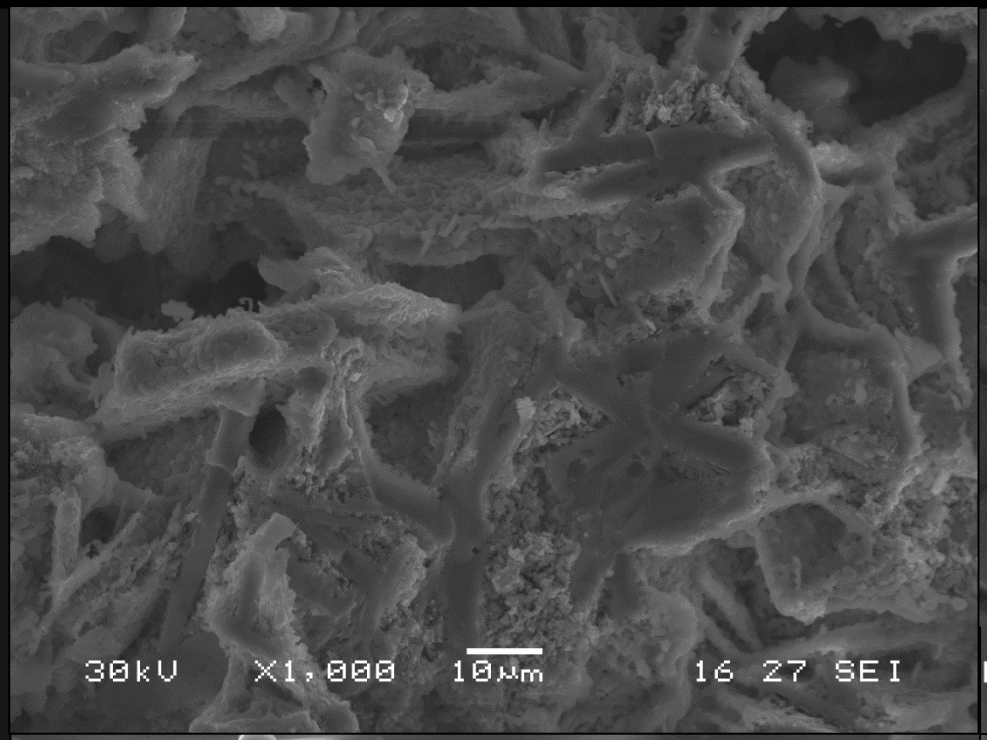
Detekcja Elektronów Wtórnych (SE) w trybie wysokiej próżni (HV)

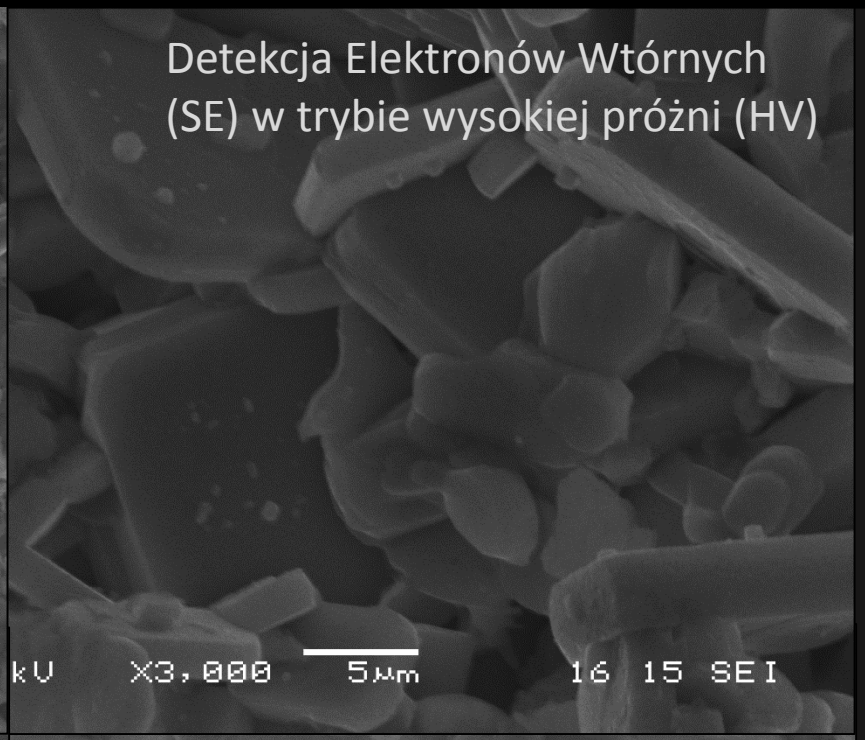


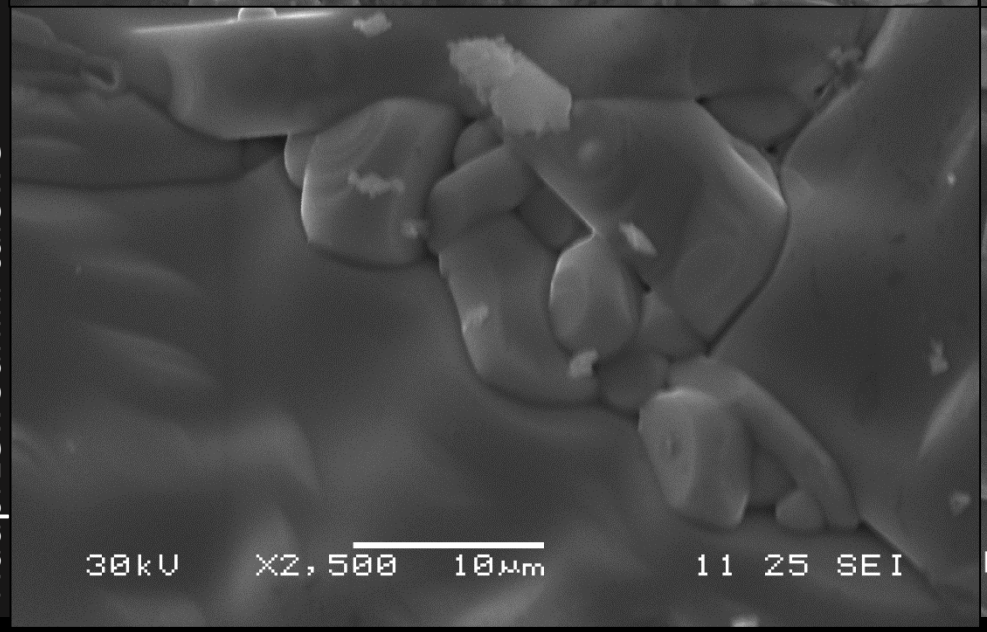


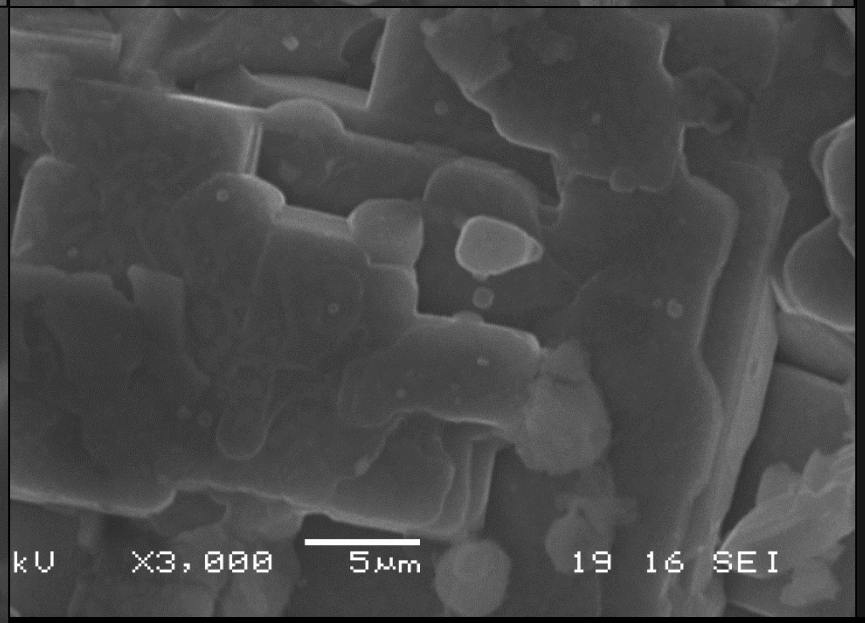
Elektrochemicznie eksfoliowany grafit / tlenek grafitu / nanografit / wielowarstwowy tlenek grafenu

Detekcja Elektronów Wtórnych (SE) w trybie wysokiej próżni (HV)



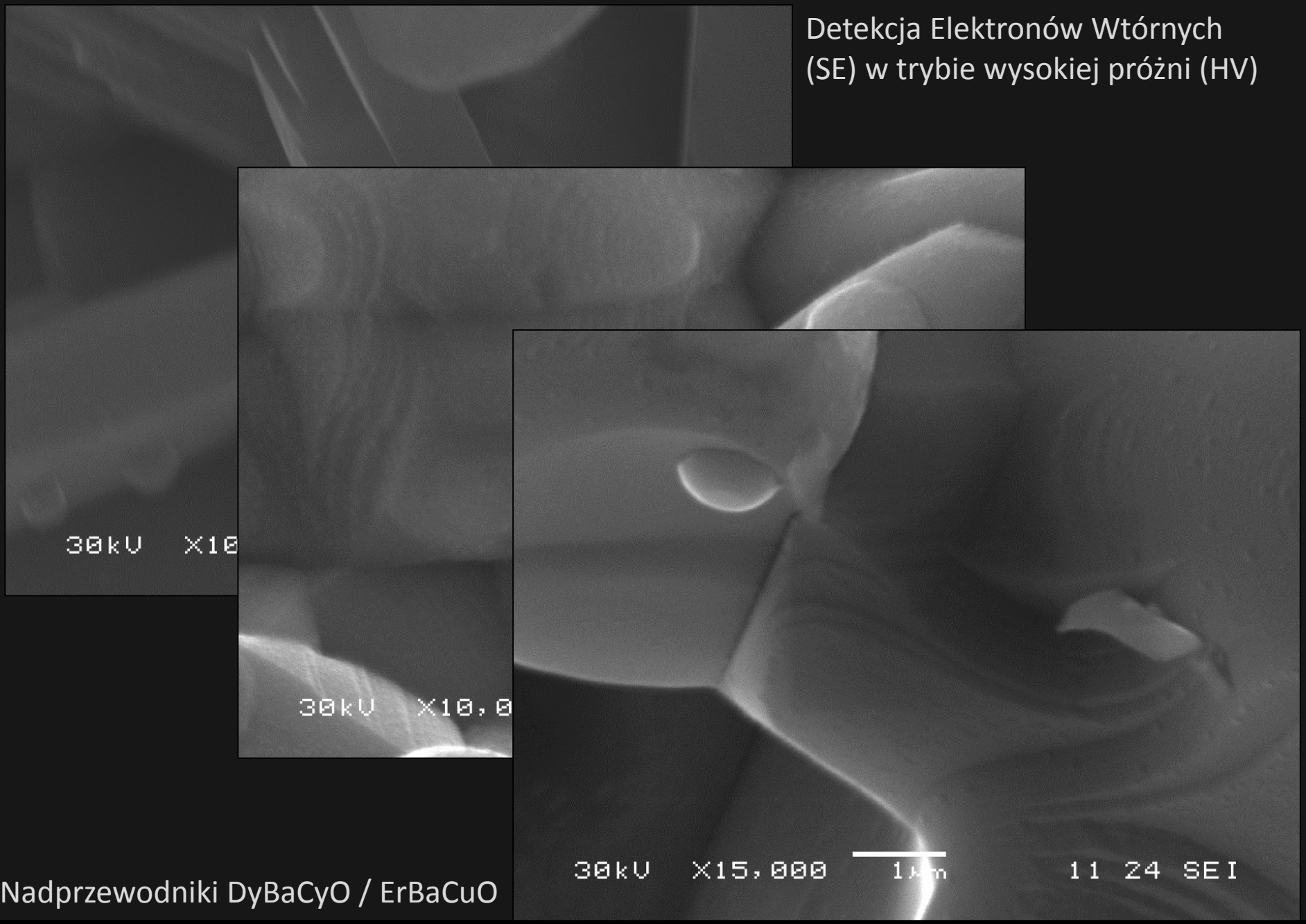






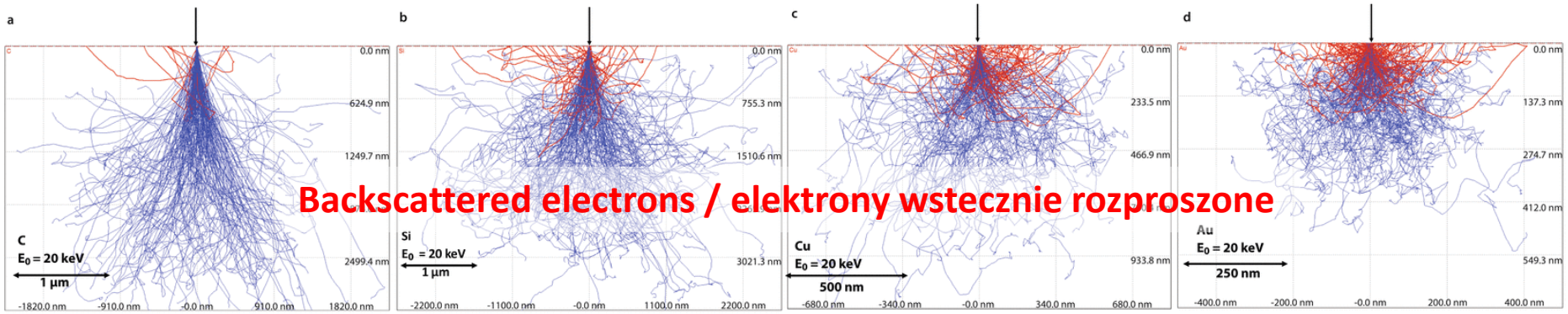
Nadprzewodniki talowe

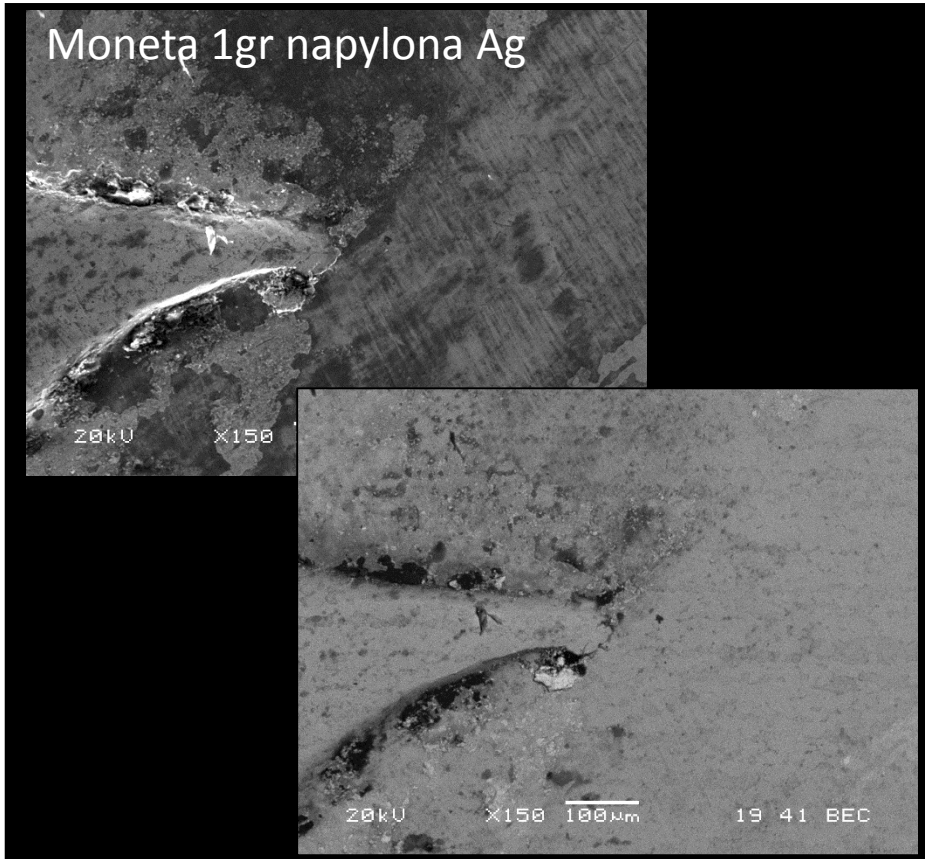
Detekcja Elektronów Wtórnych (SE) w trybie wysokiej próżni (HV)

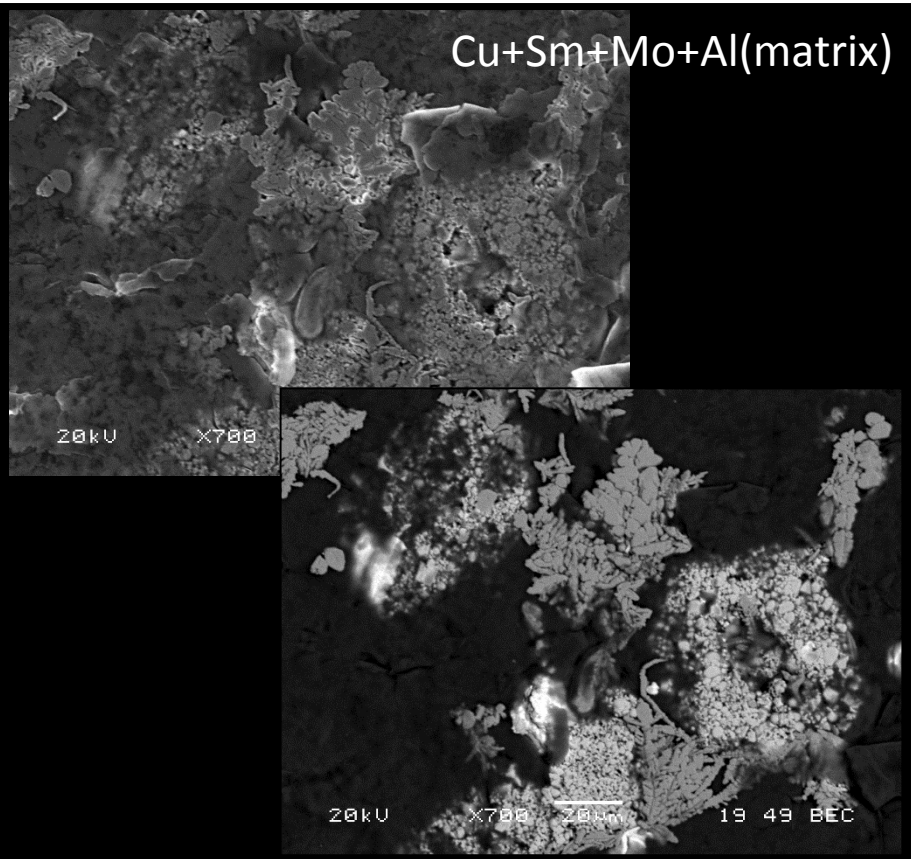


Nadprzewodniki DyBaCyO / ErBaCuO

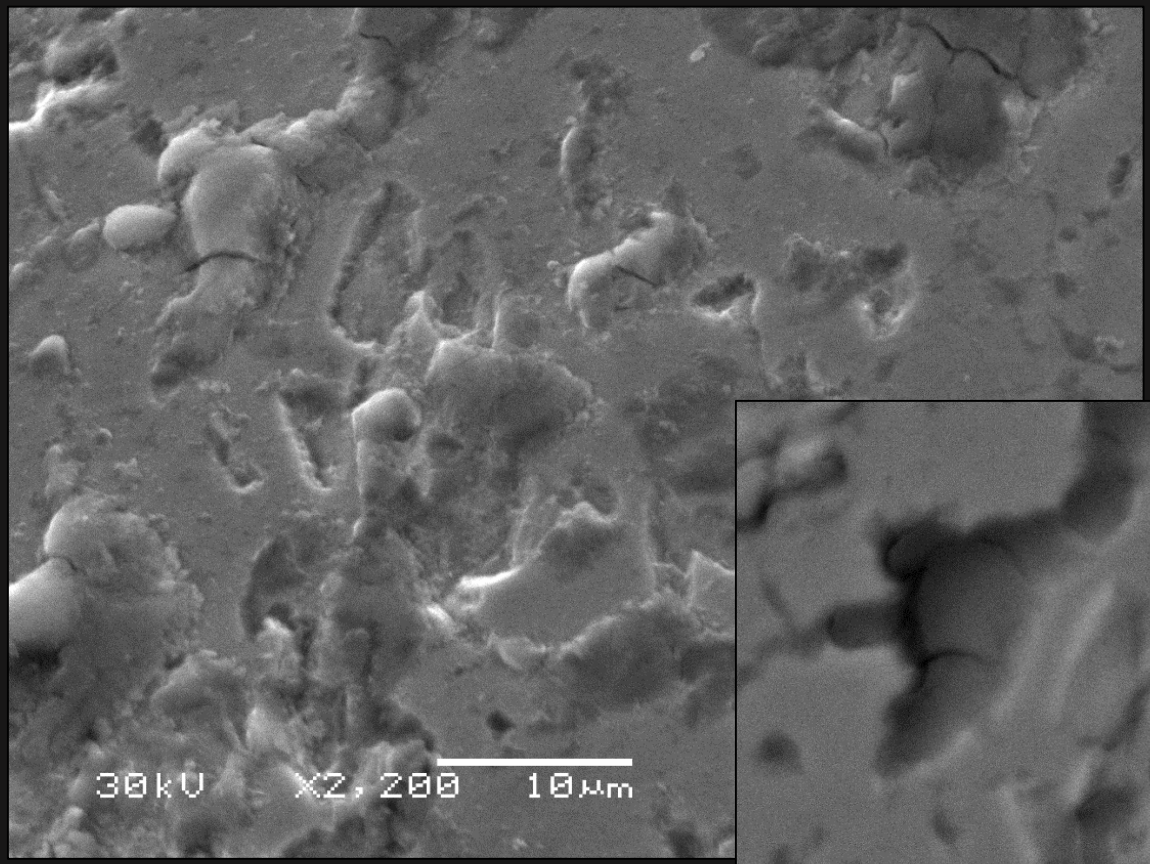
Detekcja Elektronów Wstecznie Rozproszonych (BSE) w trybie wysokiej próżni (HV)

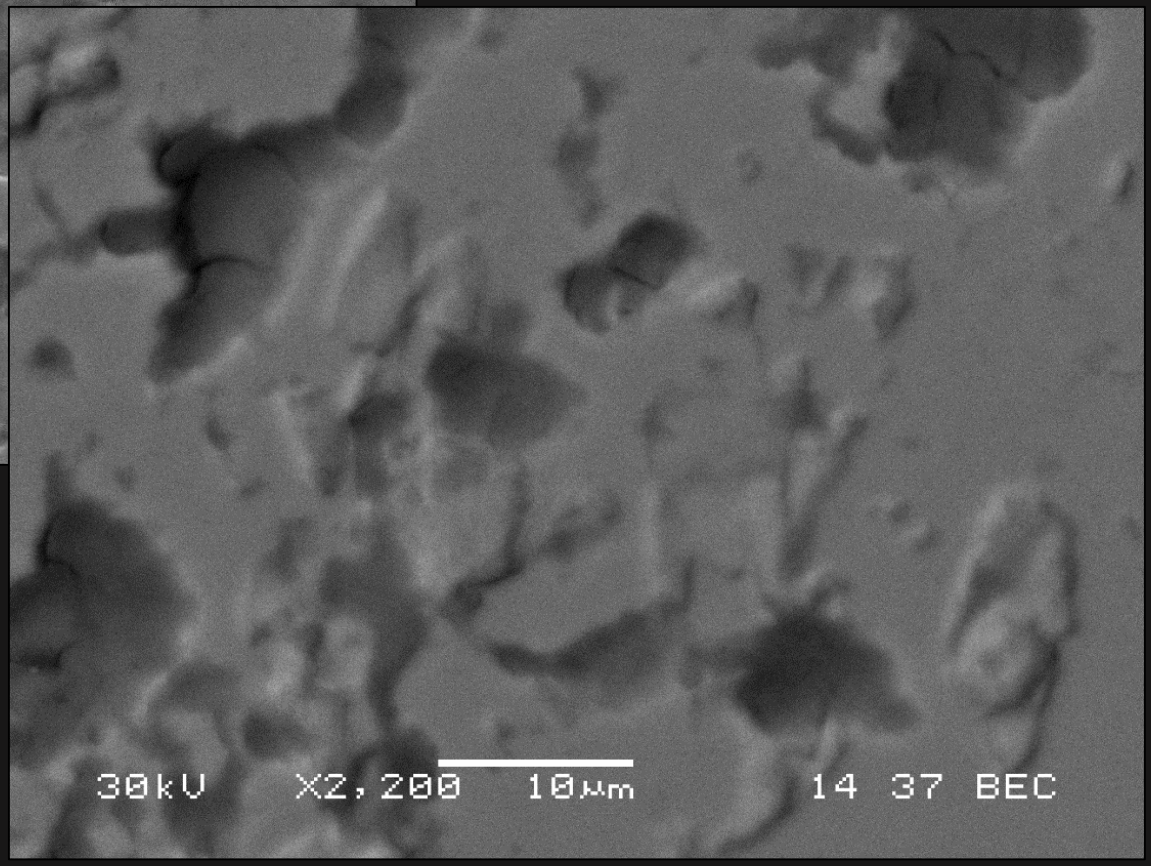






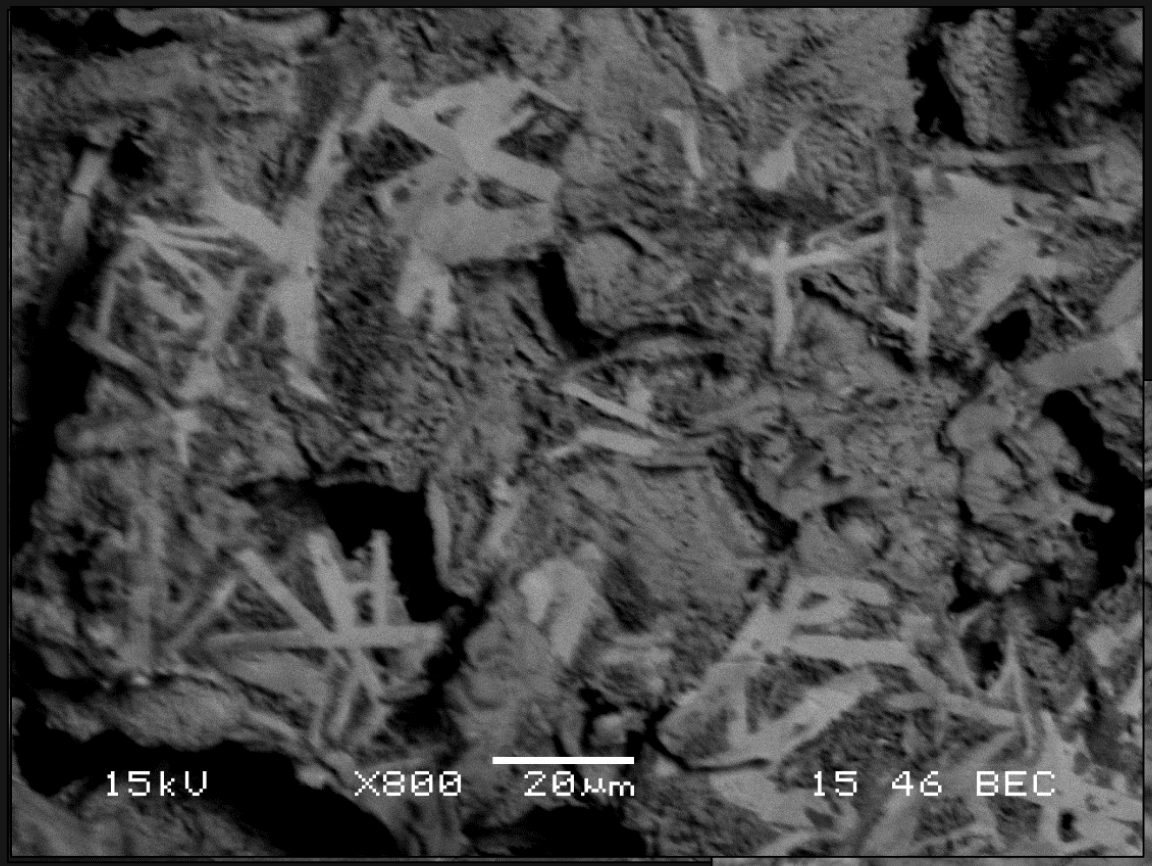
Detekcja Elektronów Wstecznie Rozproszonych (BSE) w trybie wysokiej próżni (HV)





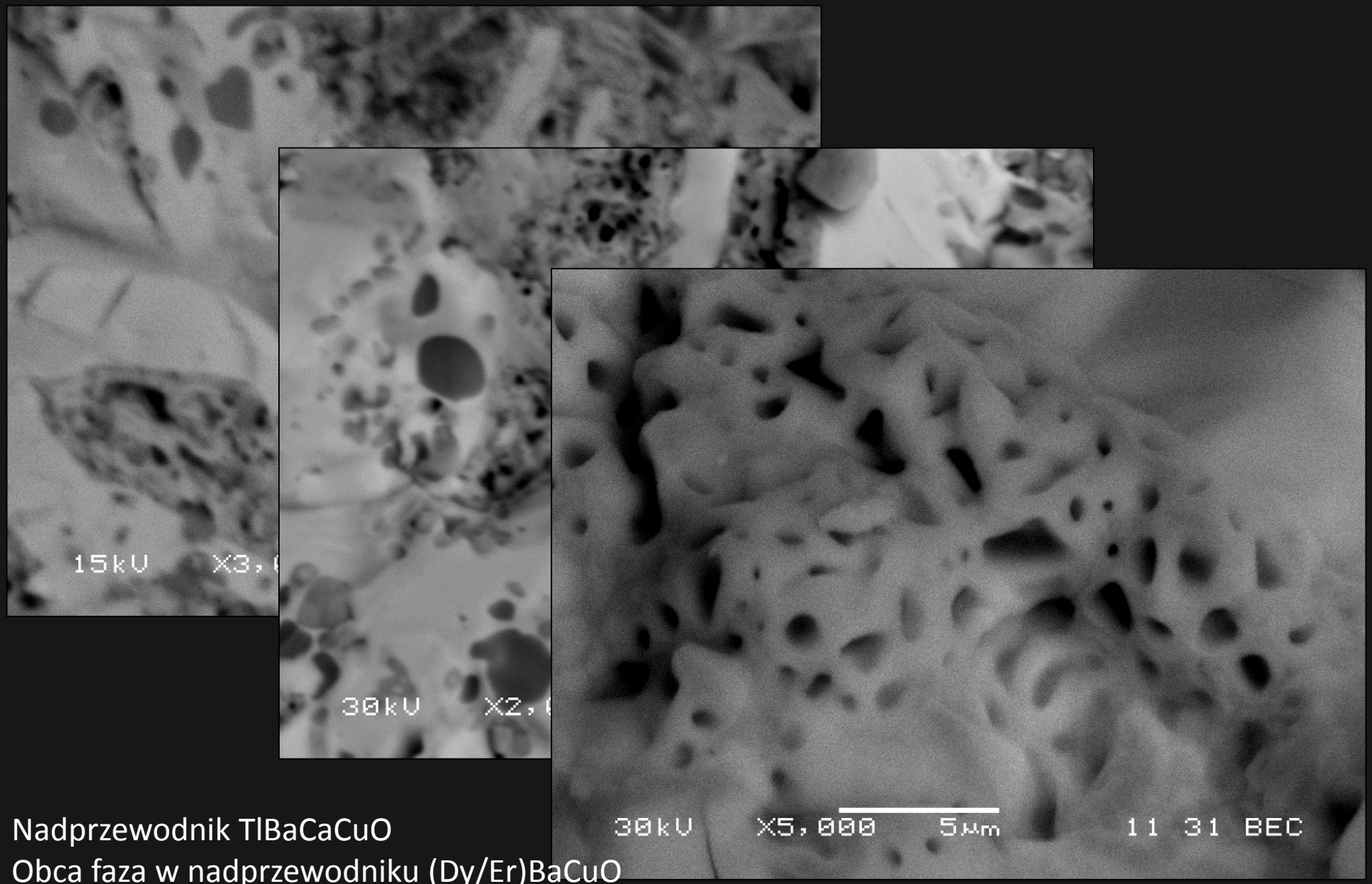
Taśma molibdenowa

Detekcja Elektronów Wstecznie Rozproszonych (BSE) w trybie wysokiej próżni (HV)



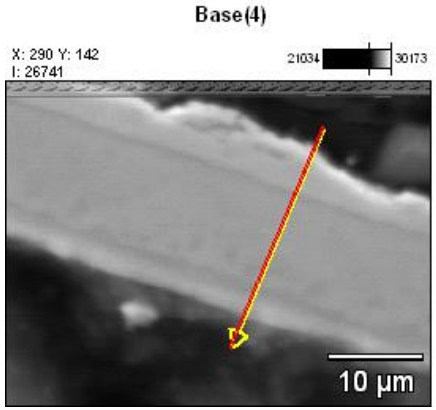
Nadprzewodnik TlBaCaCuO

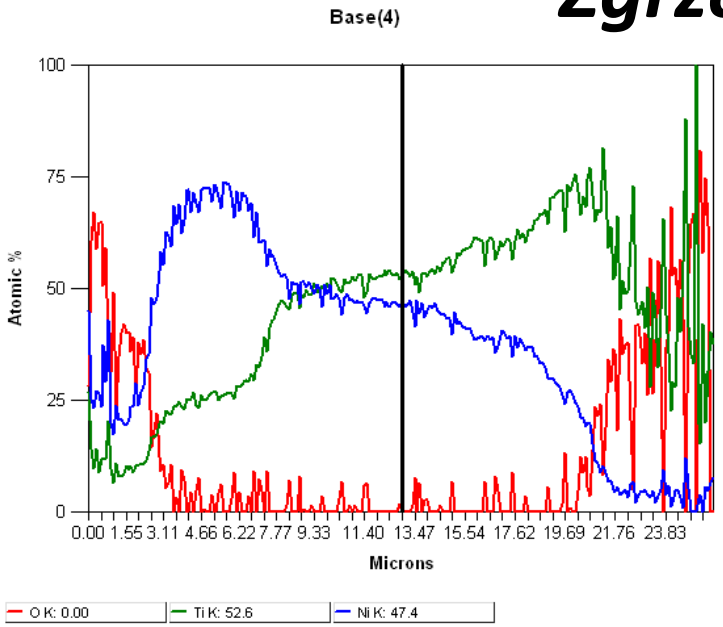
Detekcja Elektronów Wstecznie Rozproszonych (BSE) w trybie wysokiej próżni (HV)

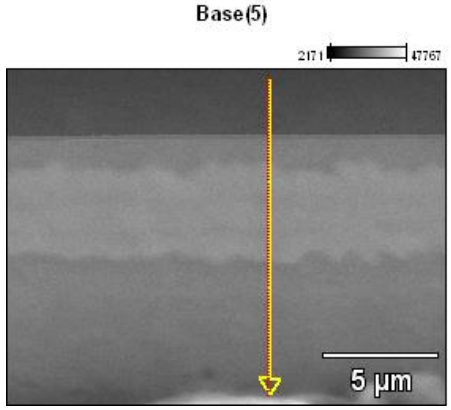


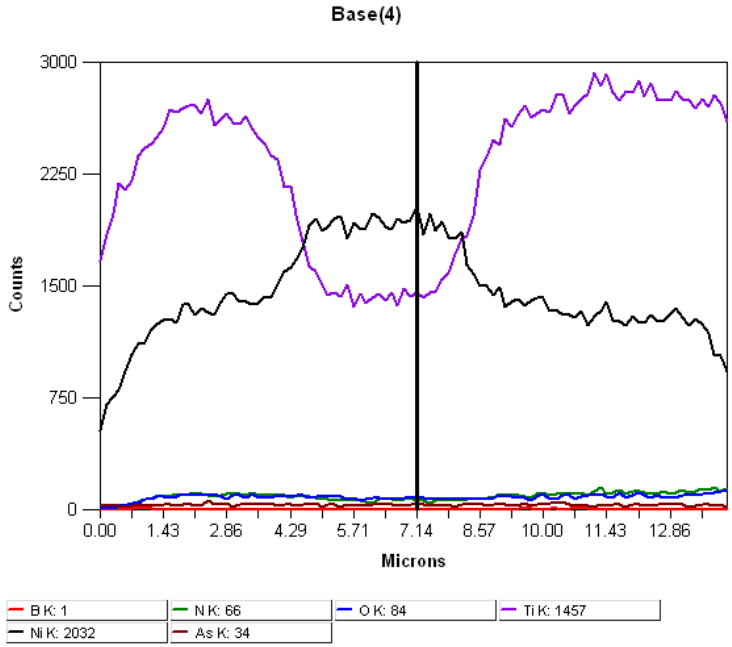
Nadprzewodnik TlBaCaCuO
Obca faza w nadprzewodniku (Dy/Er)BaCuO

Zgrzewane taśmy Ti-Ni



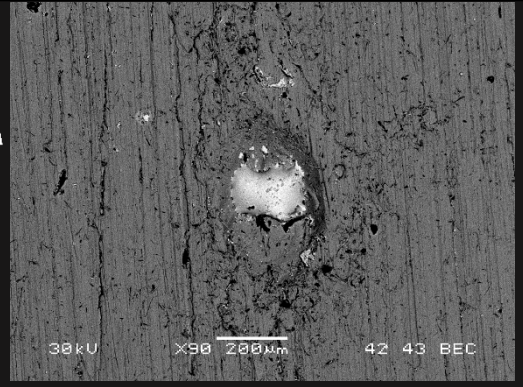


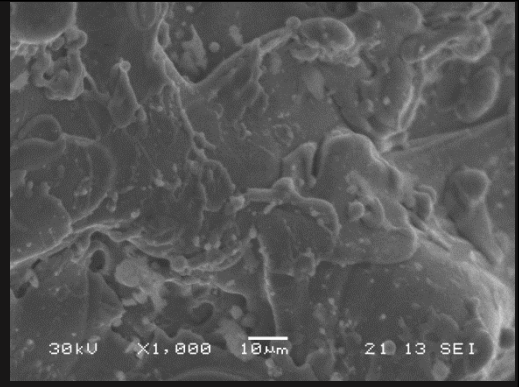


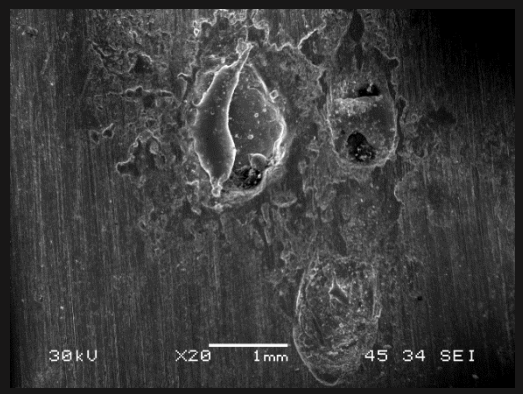


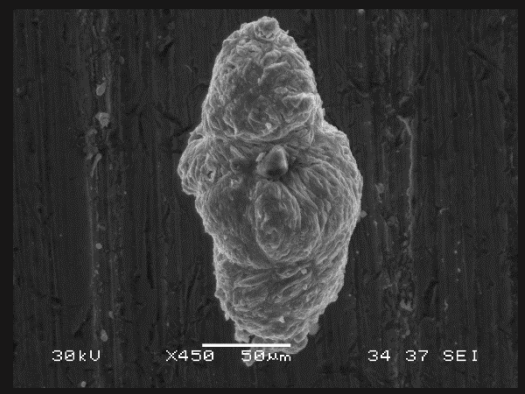
HYDRA

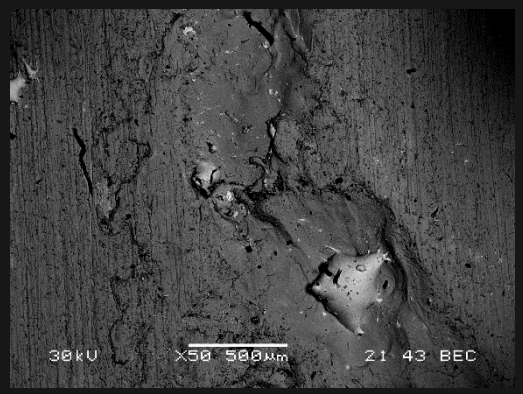
High Yield Dynamic Railgun Automaton

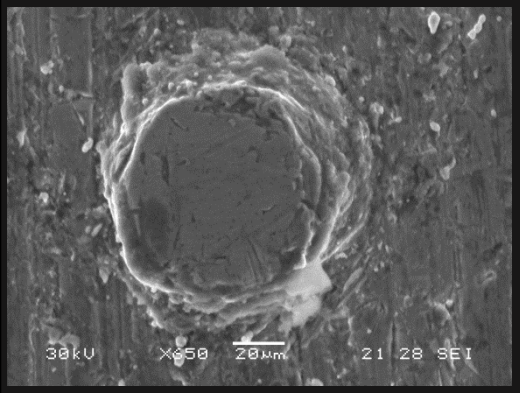


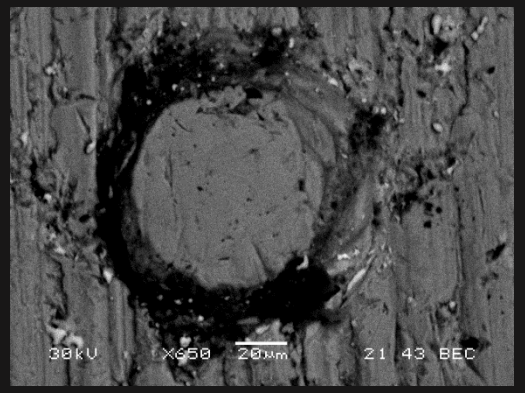


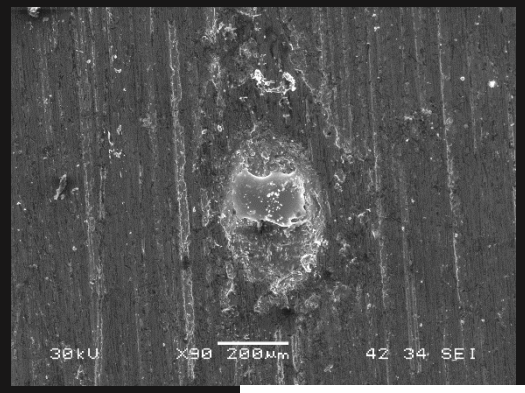


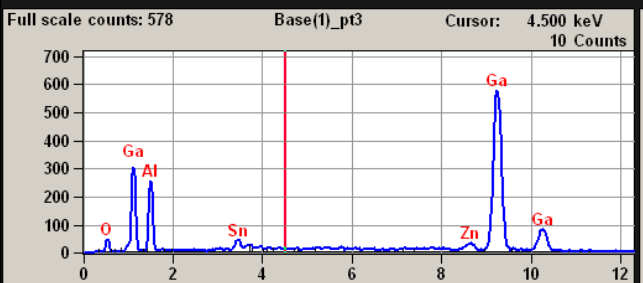


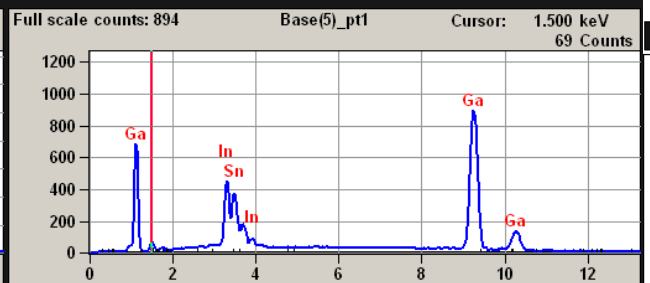


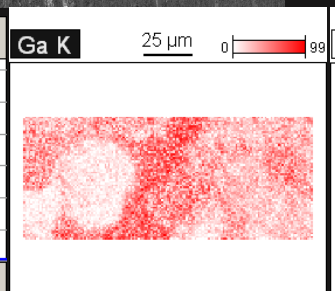


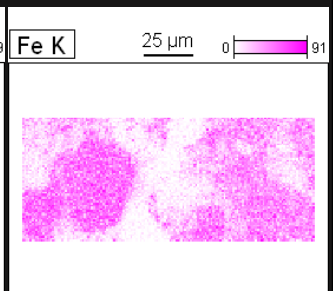


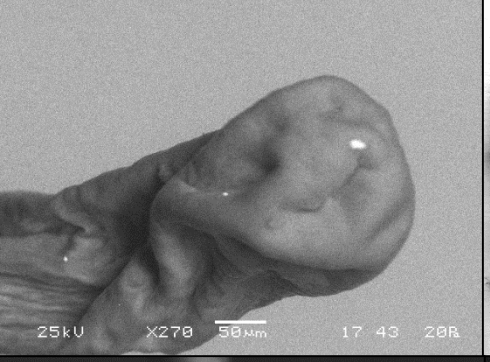


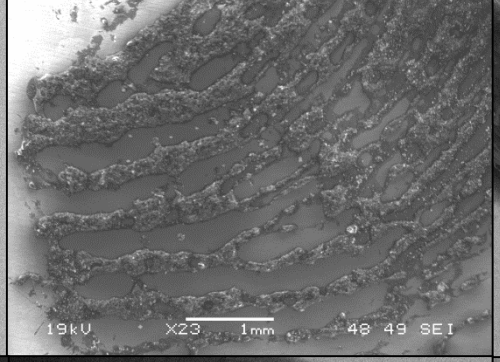


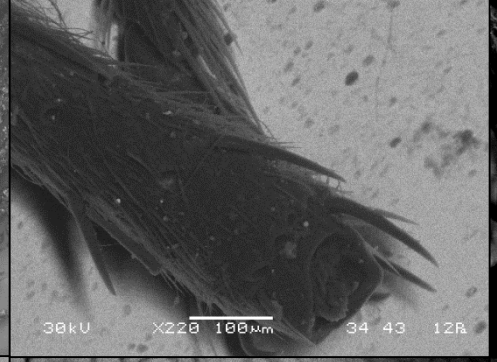







25kV X270 50µm 17 43 20R


19kV X23 1mm 48 49 SEI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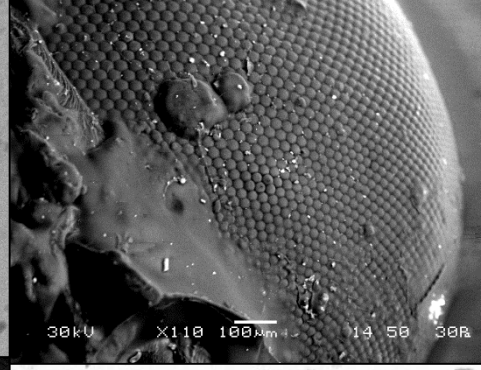
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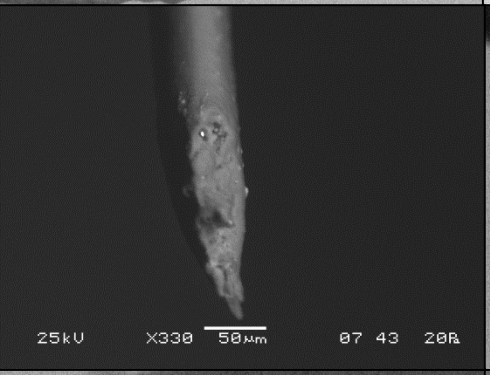
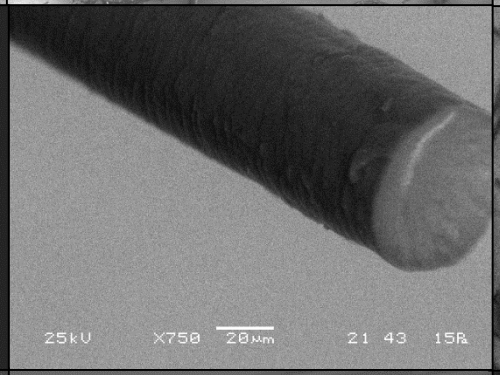
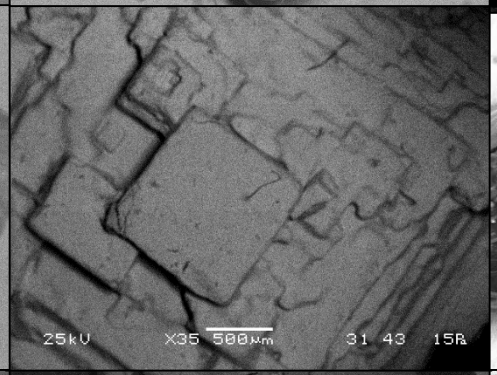

25kV X330 50µm 07 43 20R


25kV X750 20µm 21 43 15R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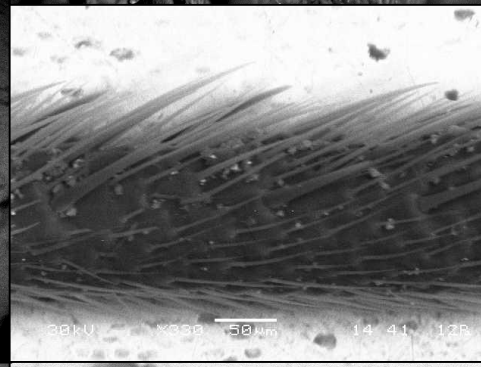
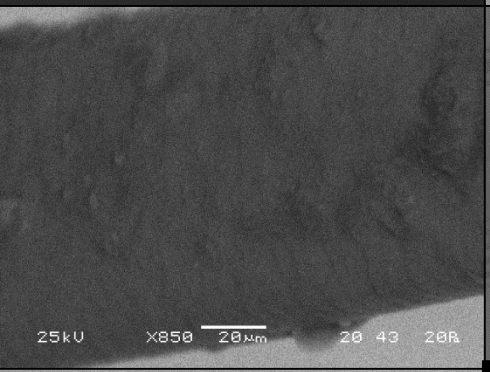

30kV X350 50µm 14 41 12R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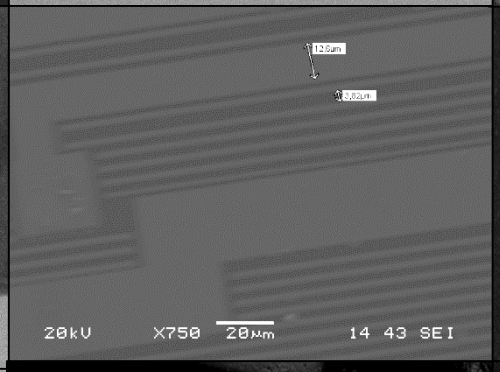
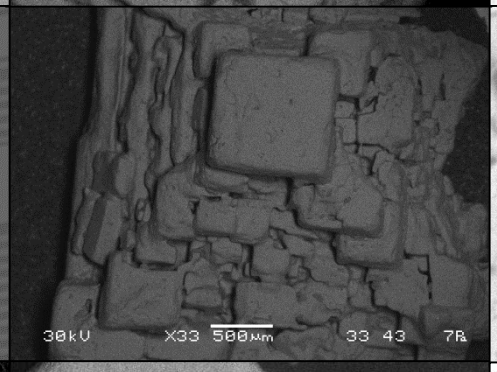

20kV X750 20µm 14 43 SEI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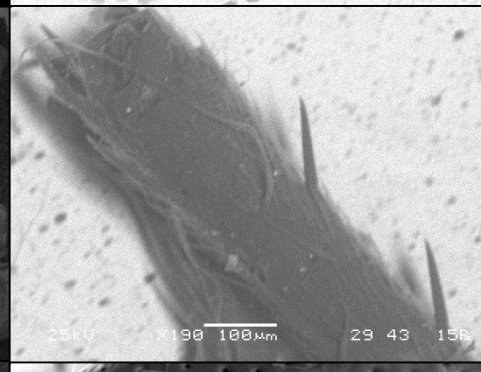
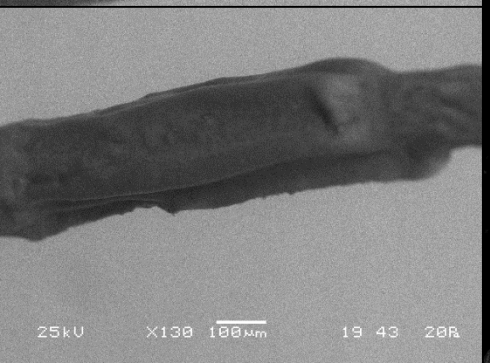

25kV X190 100µm 29 43 15R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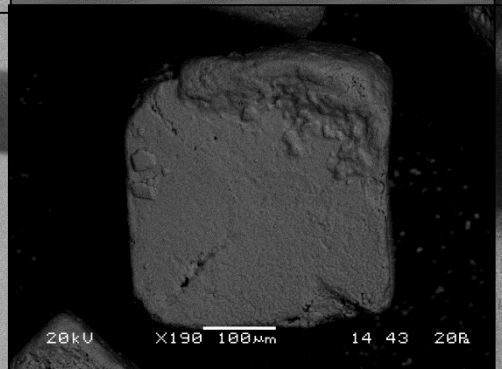
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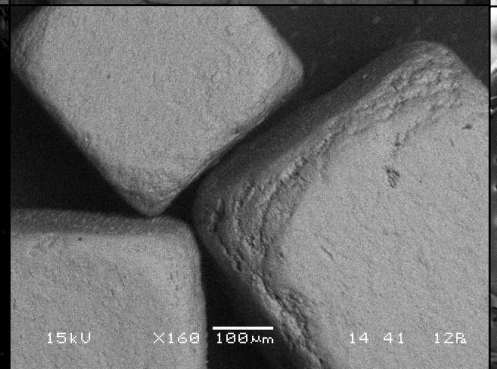
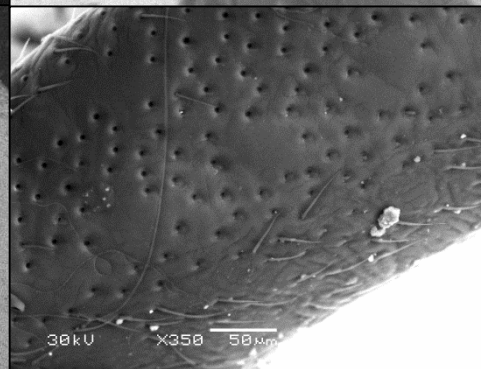

15kV X160 100µm 14 41 12R


30kV X350 50µm

AGH

Budowa i testowanie układu kontroli wiązki elektronów oraz implementacja oprogramowania sterującego procesami mikro- i nanofabrykacji indukowanej zogniskowaną wiązką elektronów

Autor: *Paweł Grzegorz Kempys*
Kierunek studiów: Informatyka Stosowana
Opiekun pracy: *dr inż. Jan Michalik*

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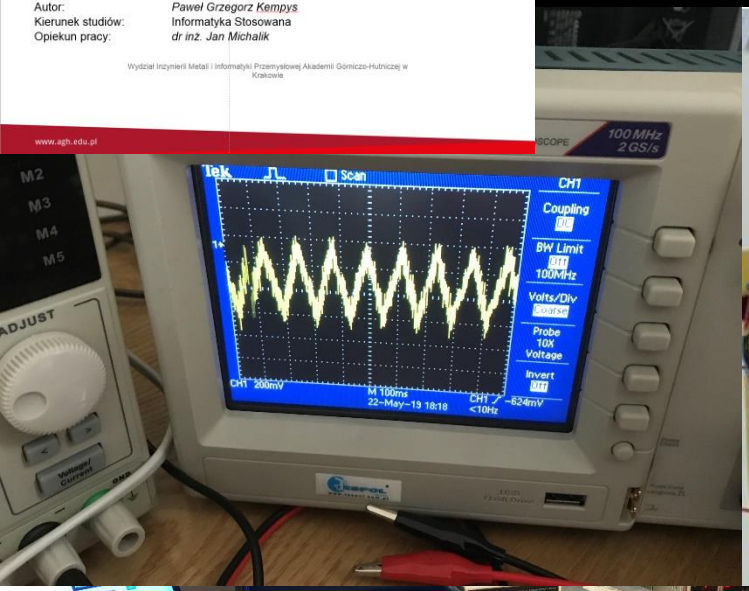
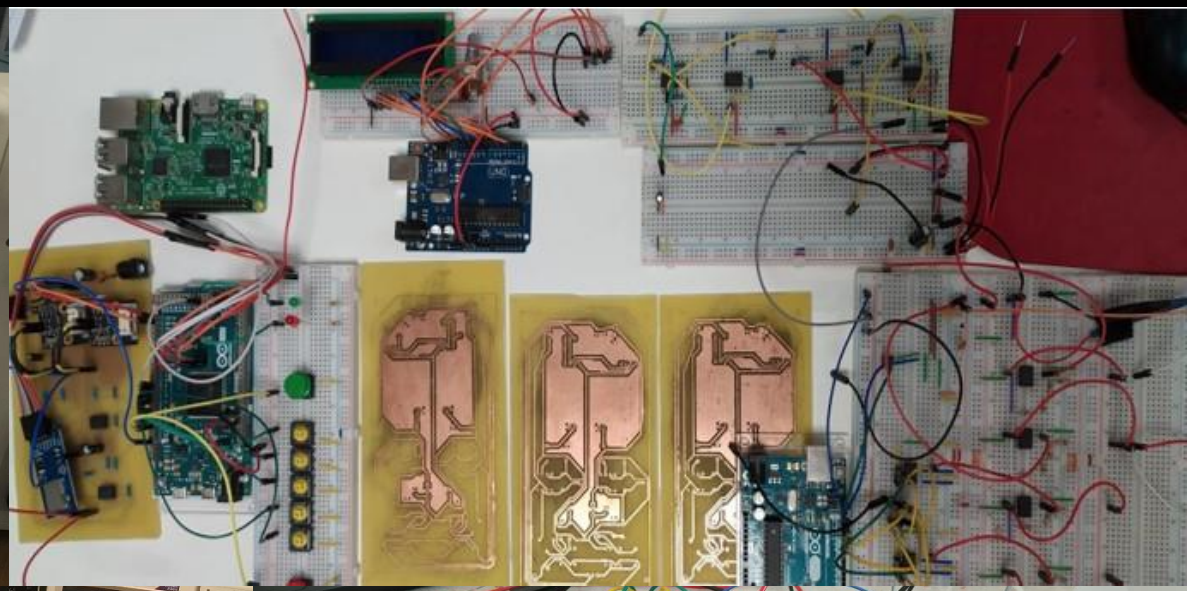
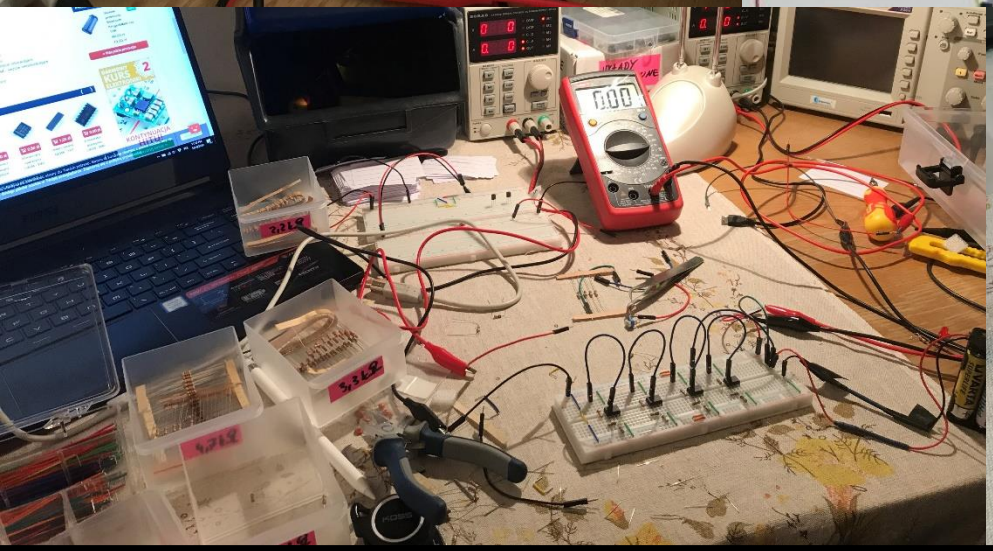
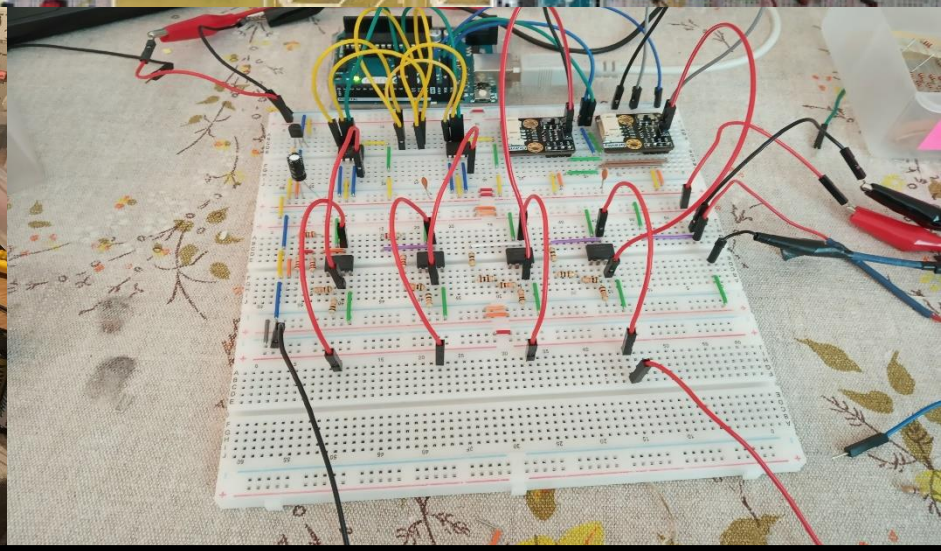
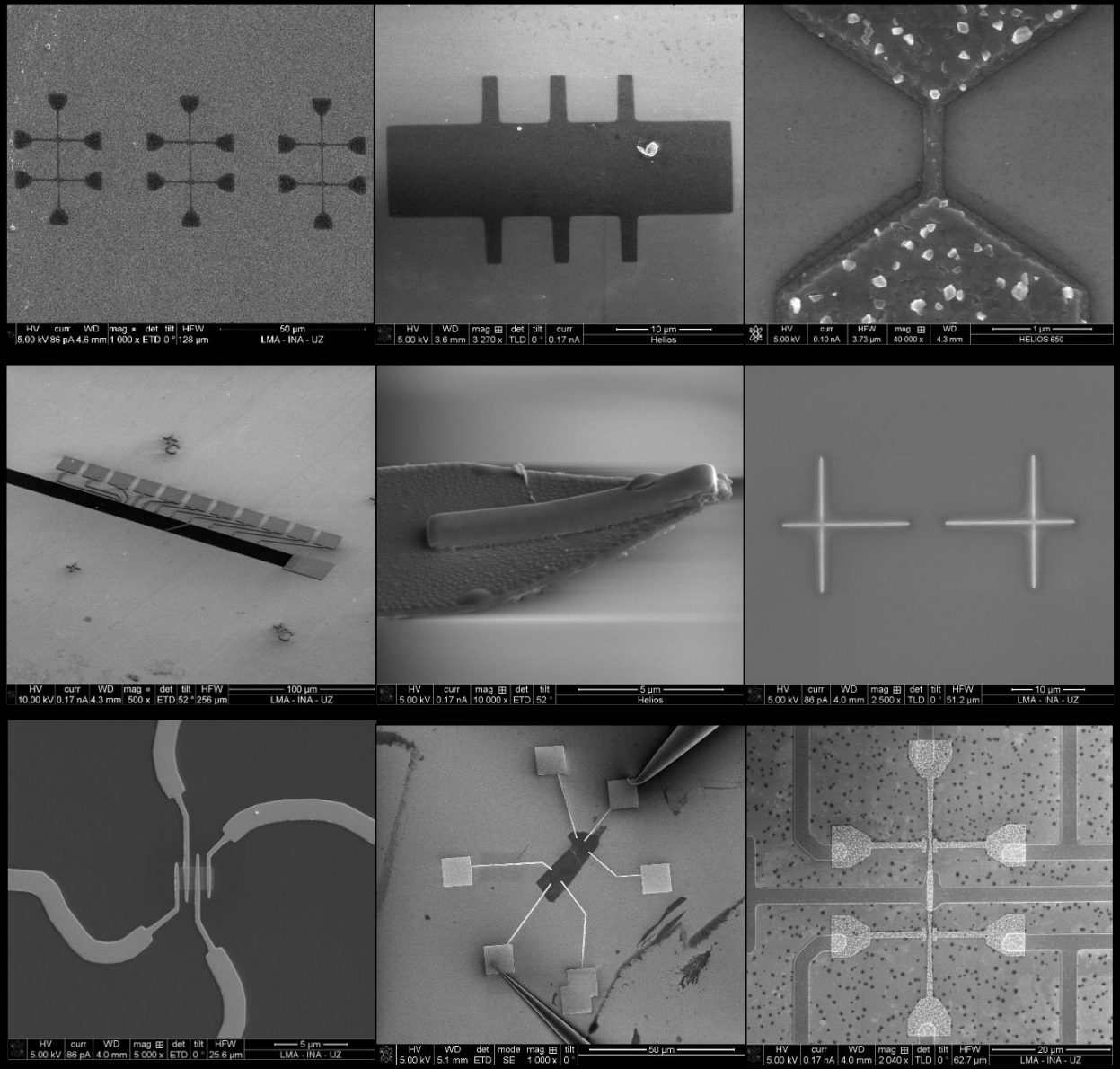


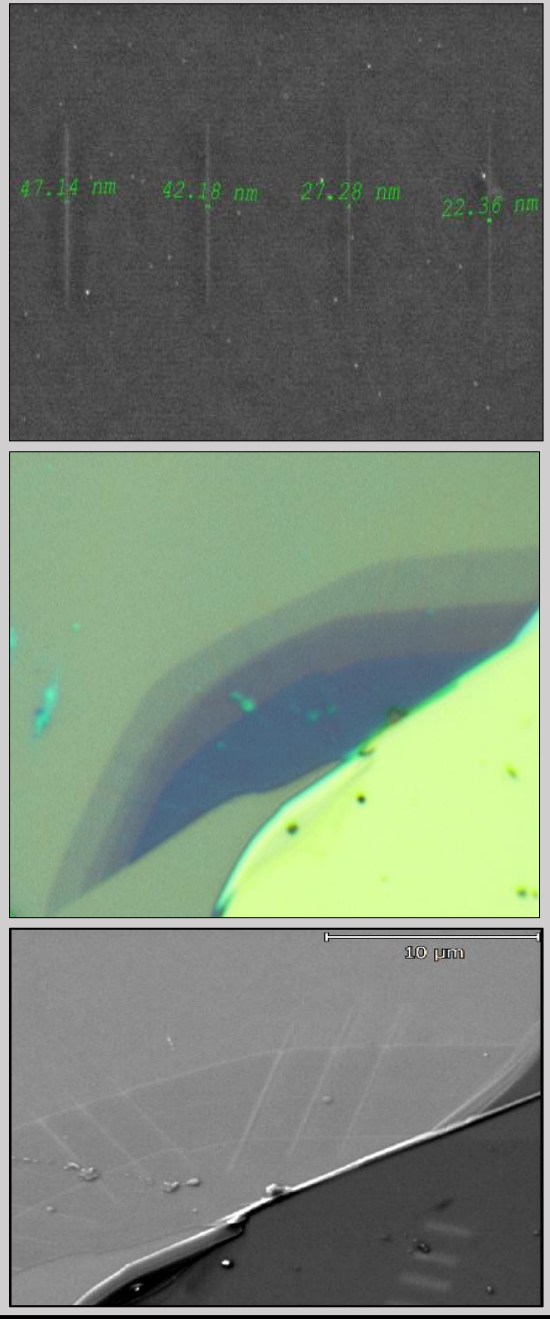






Skaningowy Mikroskop Elektronowy (SEM) z systemem Spektroskopii Rentgenowskiej z Dyspersją Energii (EDS)

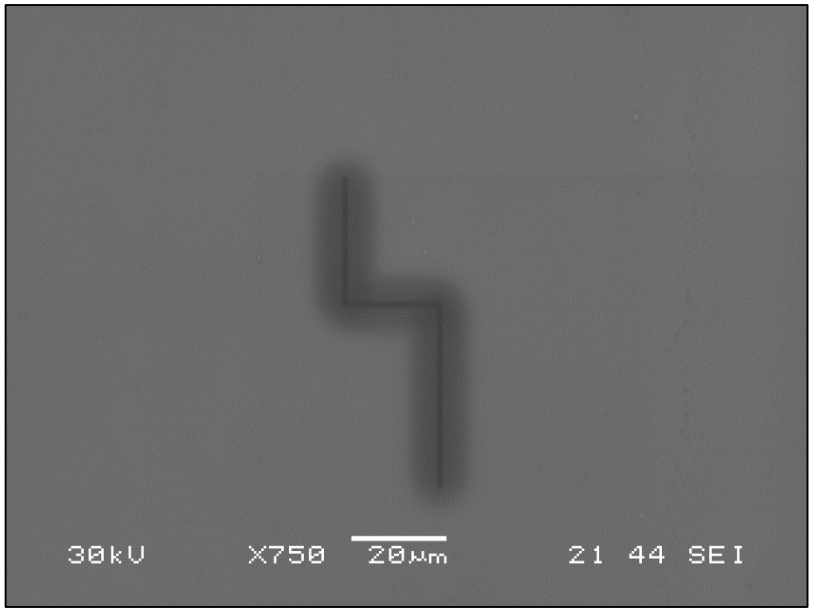


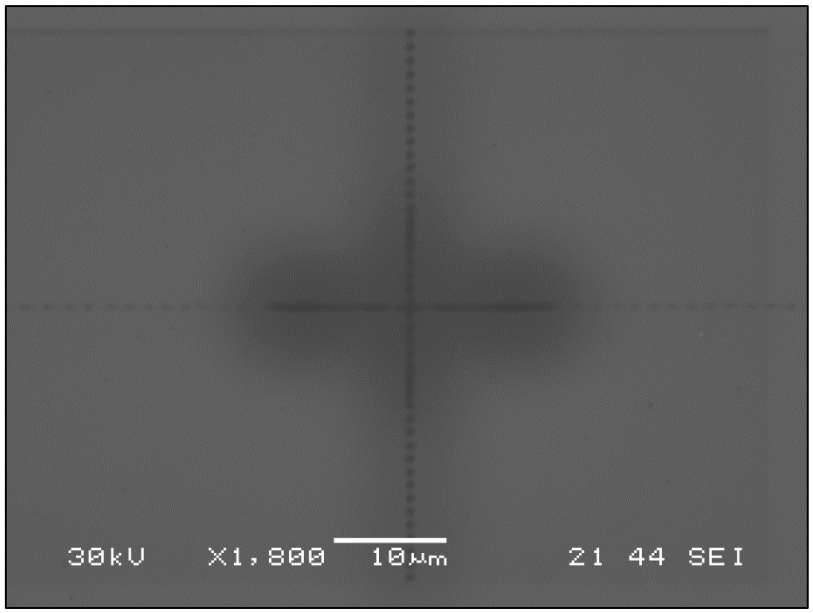


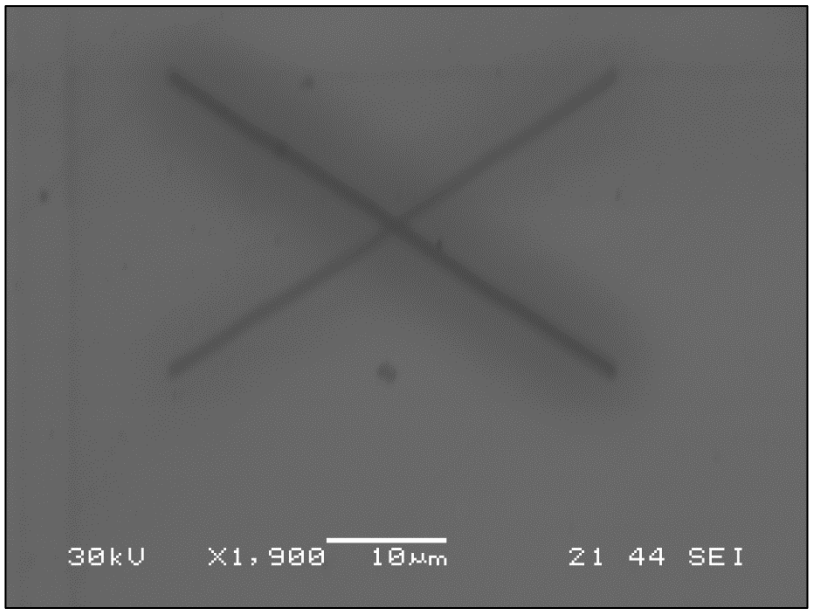
Etap III: Testy

Faza I testów:

- Układ nie był jeszcze skończony
- **Cel:** Sprawdzenie możliwości realizacji podstawowych założeń projektowych
- **Wynik:** Układ jest zdolny do precyzyjnej kontroli położenia wiązki elektronowej

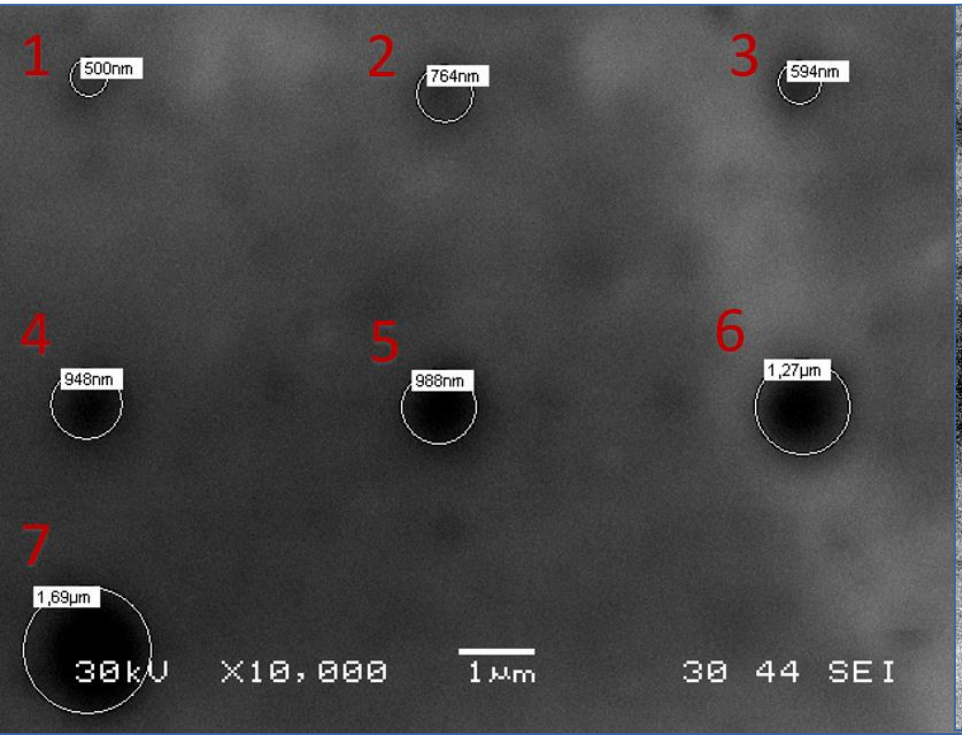


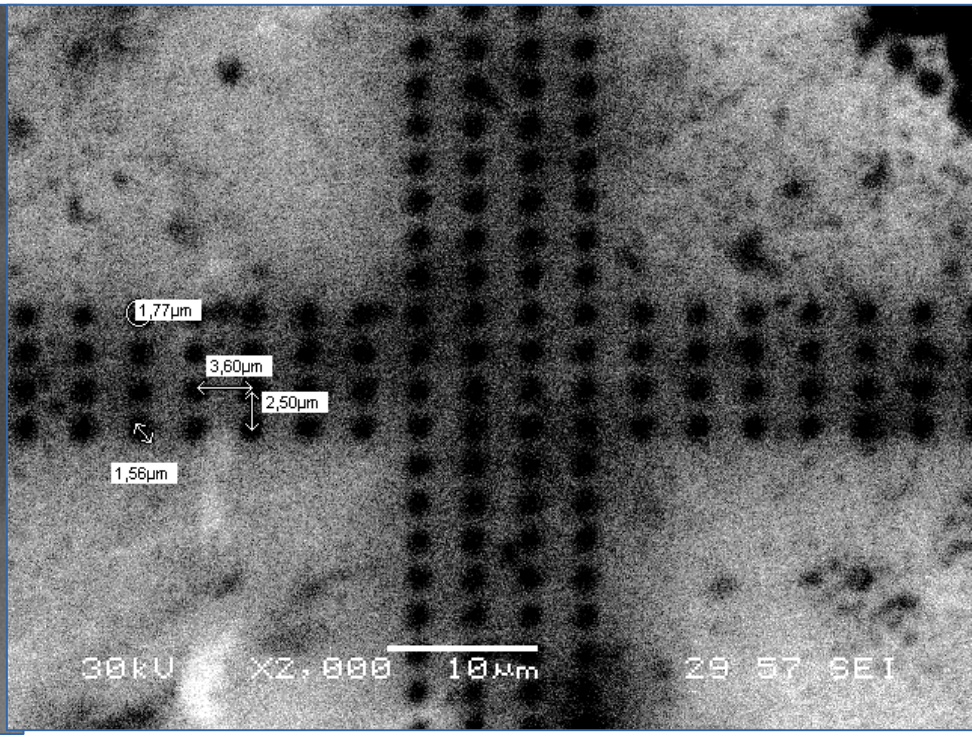




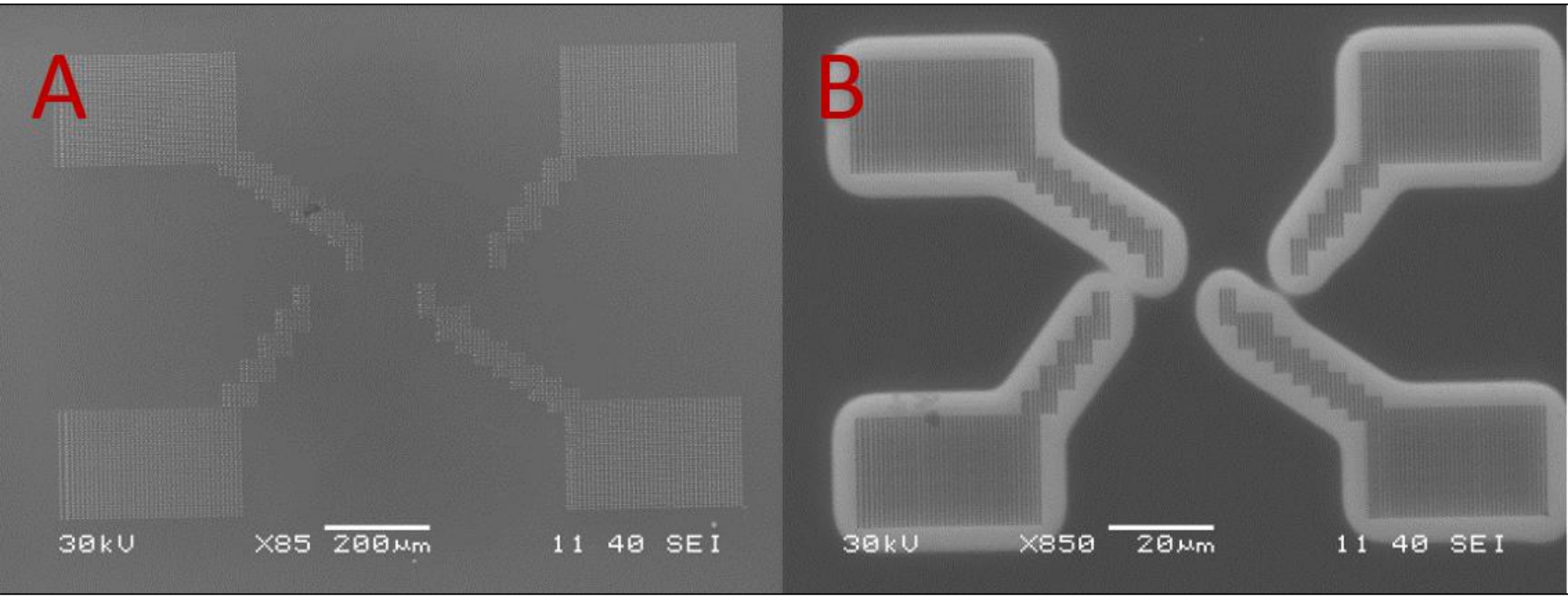
Faza II testów

- Układ elektroniczny przeniesiony na płytkę PCB
- Utworzono interfejs graficzny
- **Cel:** Wstępna ocena rozdzielczości procesu oraz wpływu czasu postoju wiązki na rozmiar utworzonego punktu

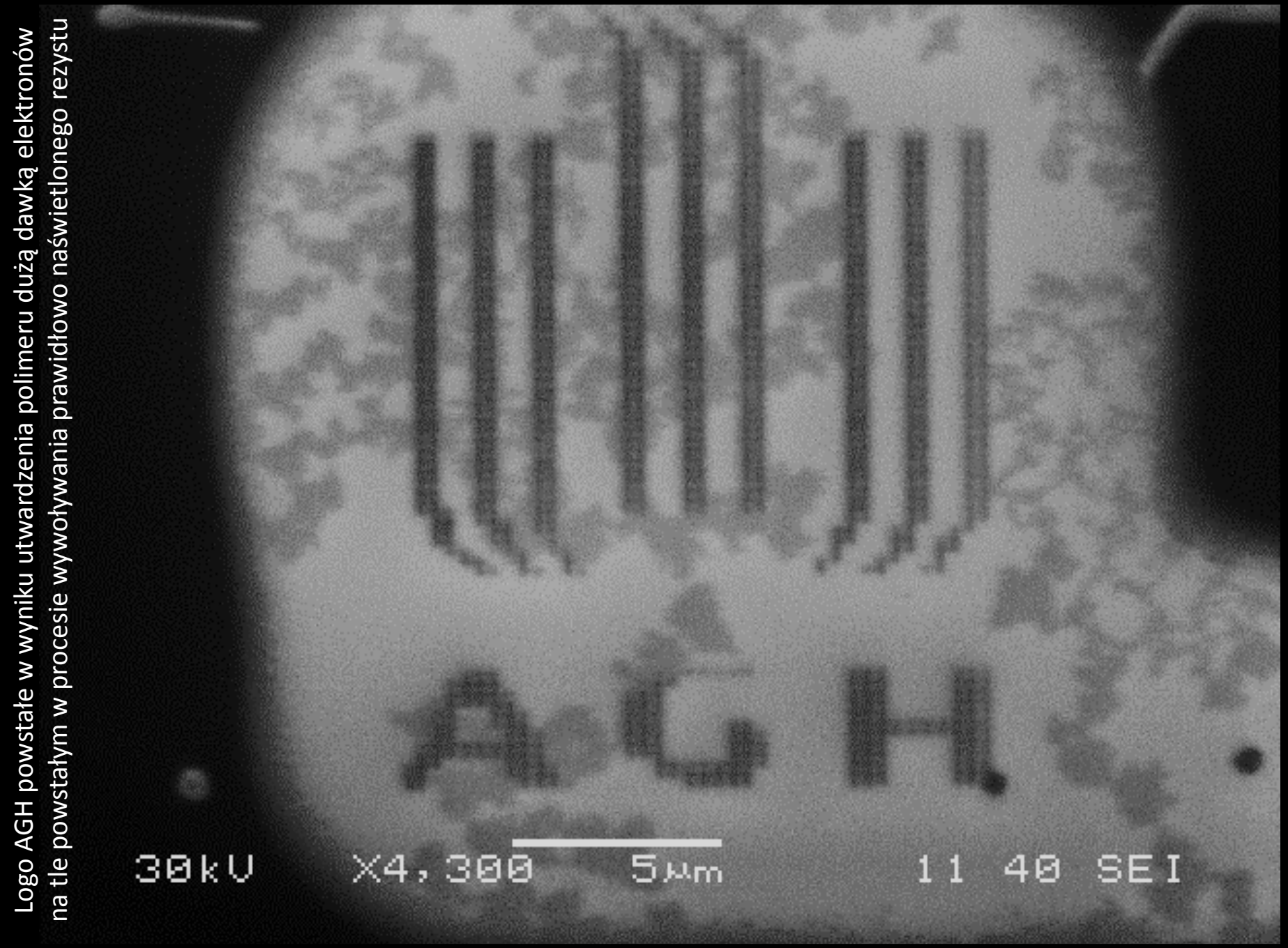




Faza III testów



Przejście z wersji pozytywowej (A) na negatywową (B) spowodowane m. in. zbyt długim czasem postoju wiązki (znacznie lepsze odwzorowanie geometrii wzoru w obszarach z nadmiarową dawką)



Logo AGH powstałe w wyniku utwardzenia polimeru dużą dawką elektronów na tle powstałym w procesie wywoływania prawidłowo naświetlonego rezystu