Scanning Enhancement of STM-tungsten Probes by Applying Colloidal Graphite Coatings

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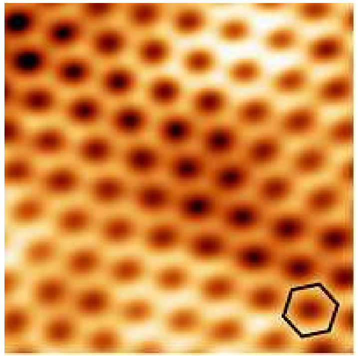
Introduction

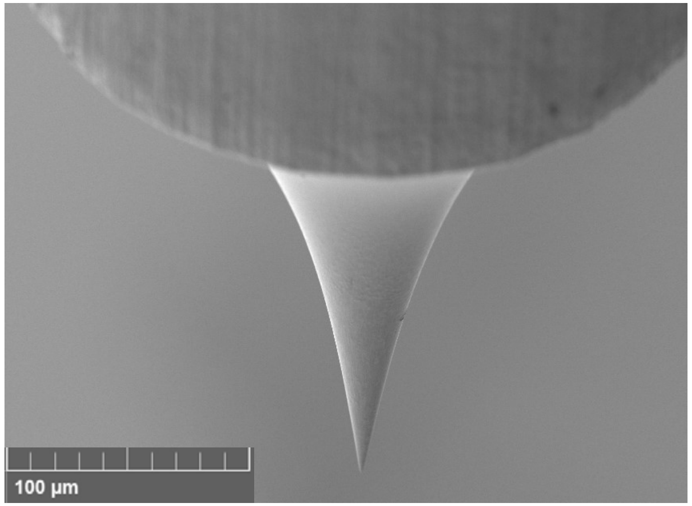
Scanning tunneling microscopy (STM) is an atomic level high-resolution surface analytical technique.



STM of Graphene

STM is a vacuum tunneling technique that uses a good conductive metallic sharp tip (tungsten, platinum/iridium, iridium, …) to scan the topography of a conductive sample surface.

Tungsten nano cold field emission tips is one of the most used probes in STM.



Tungsten cold field emission STM probe.

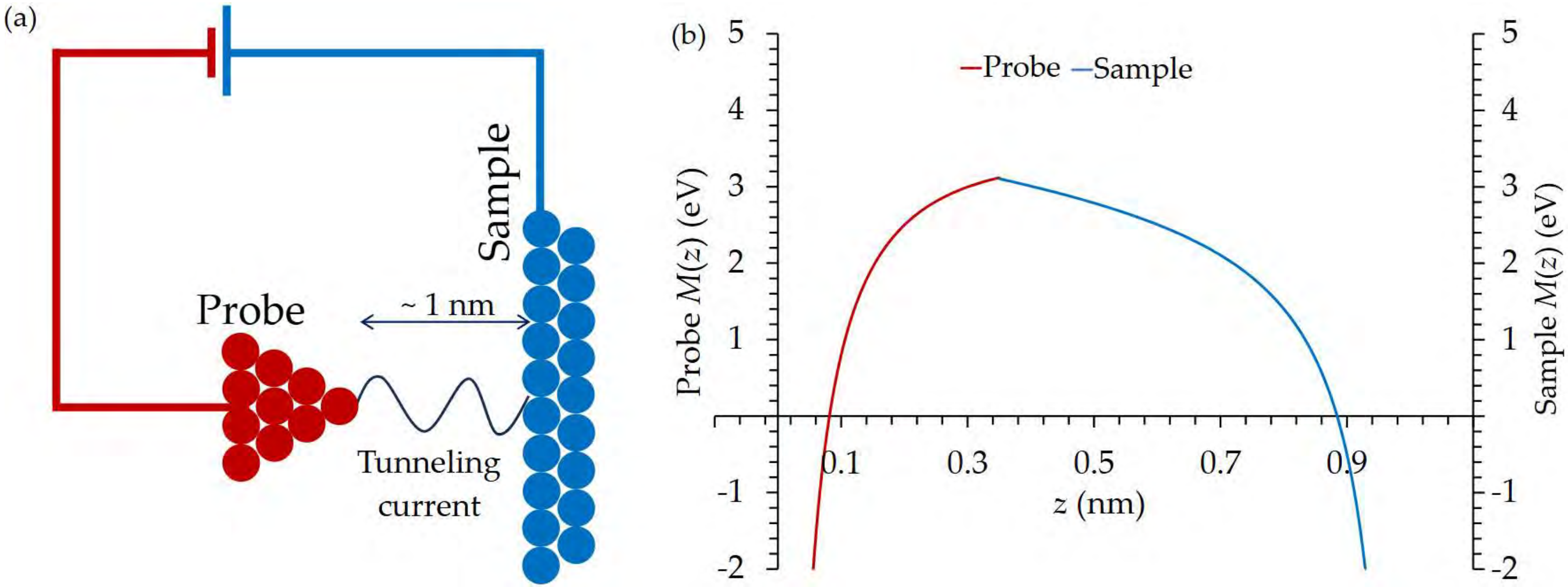
However, tungsten STM-probes have some limitations:

1- Requires ultra-high vacuum conditions.

2- Requires in-situ cleaning before a scanning process.

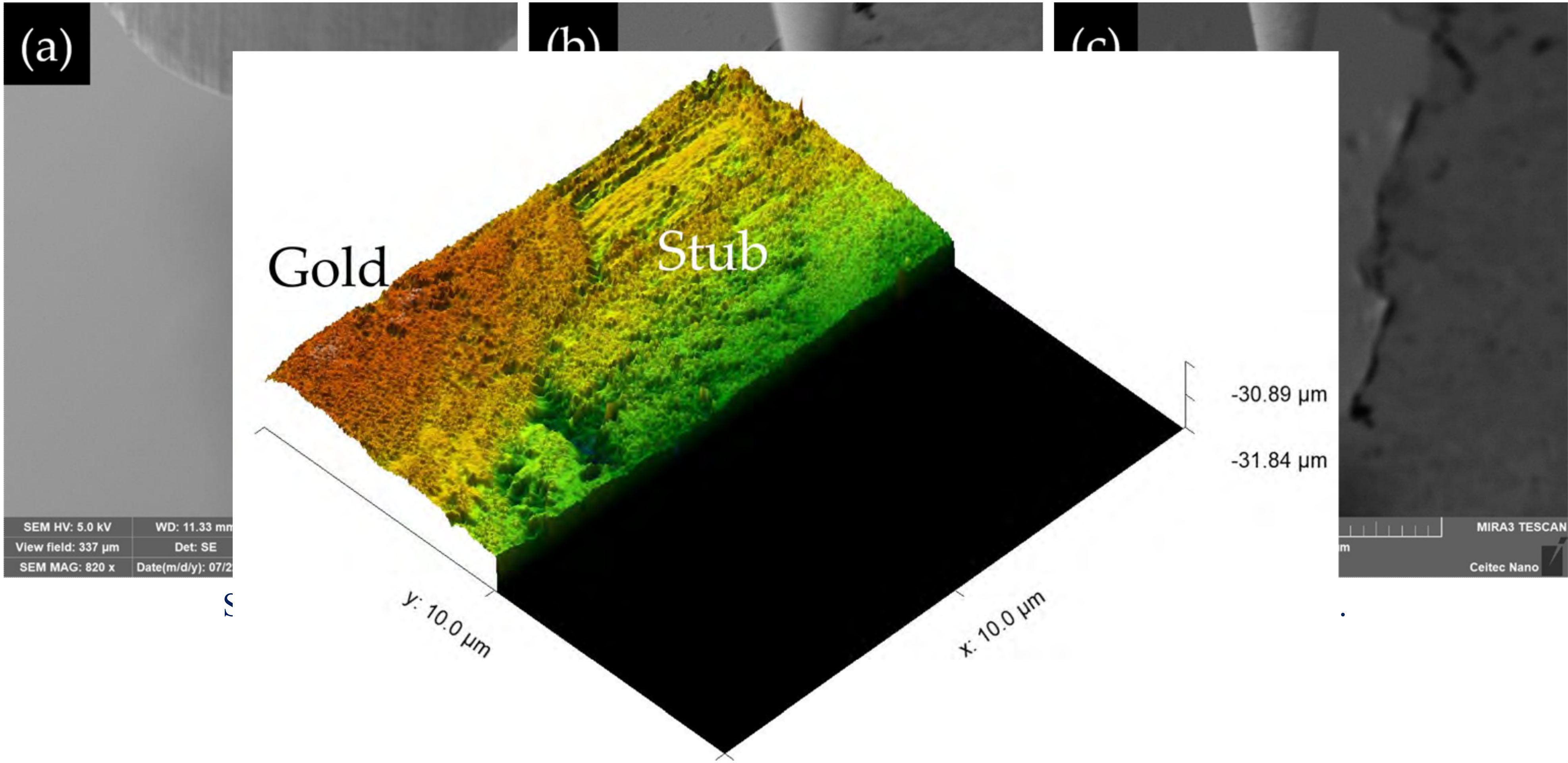
3- Sensitive against adsorbates and is quickly oxidized.

Introduction



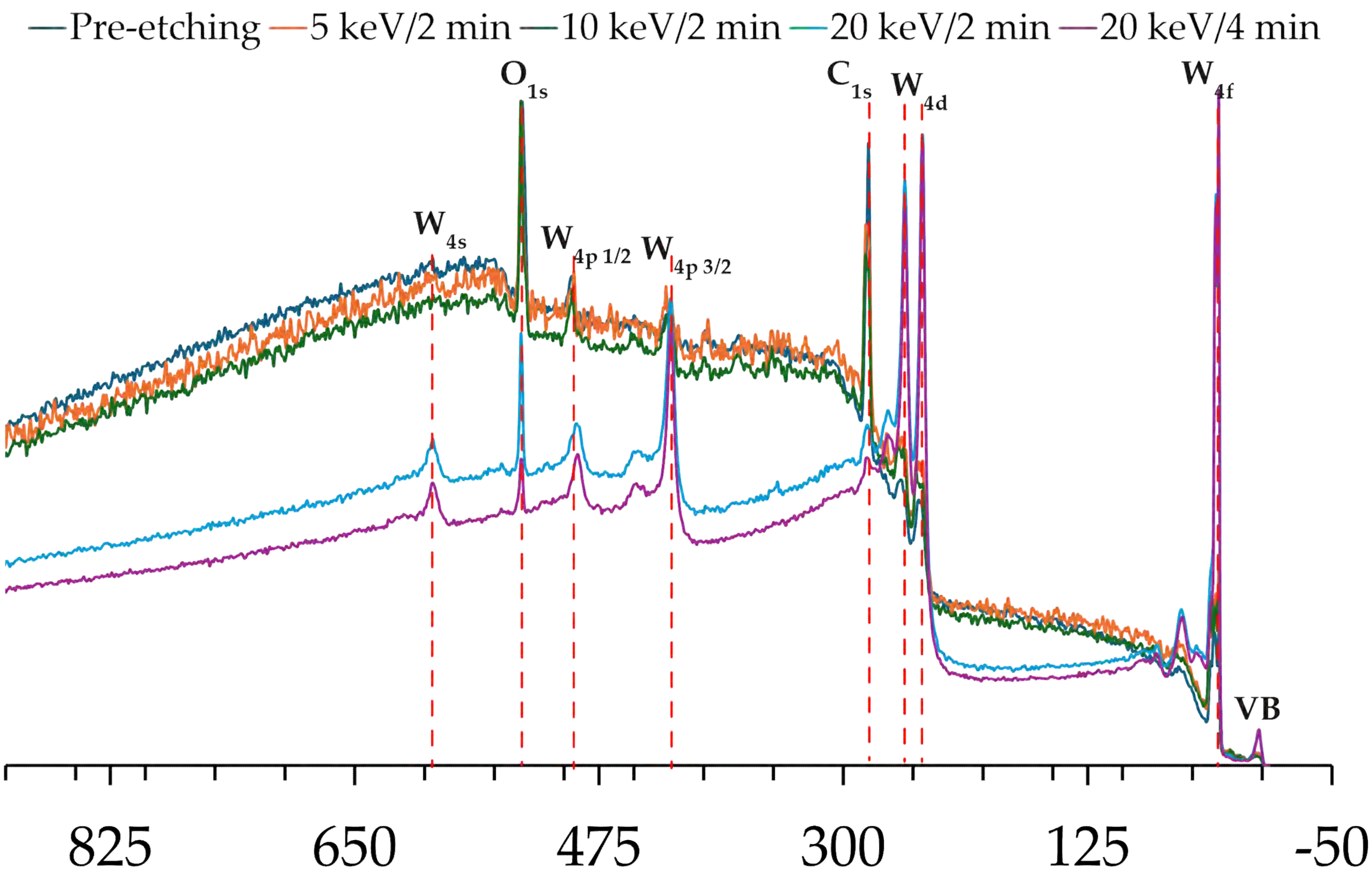
First approximation for the tunneling Schottky-Nordheim potential energy barrier between the sample and probe

STM from uncoated W cathodes in SEM chamber



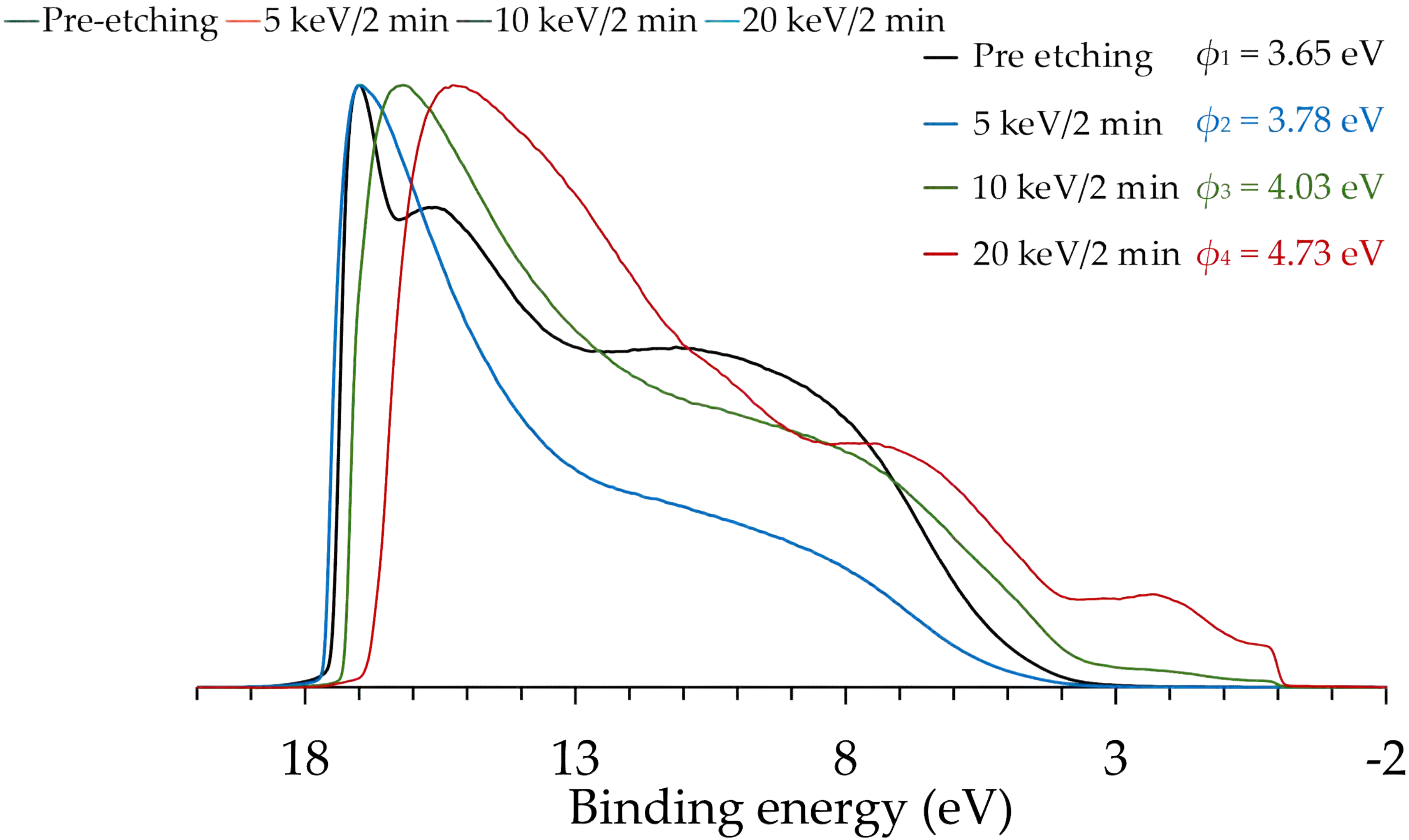
Result od the STM scan attempt using a tungsten cold field emission tip ($P = 10^{-2}$ Pa).

Limited surface conductivity of W



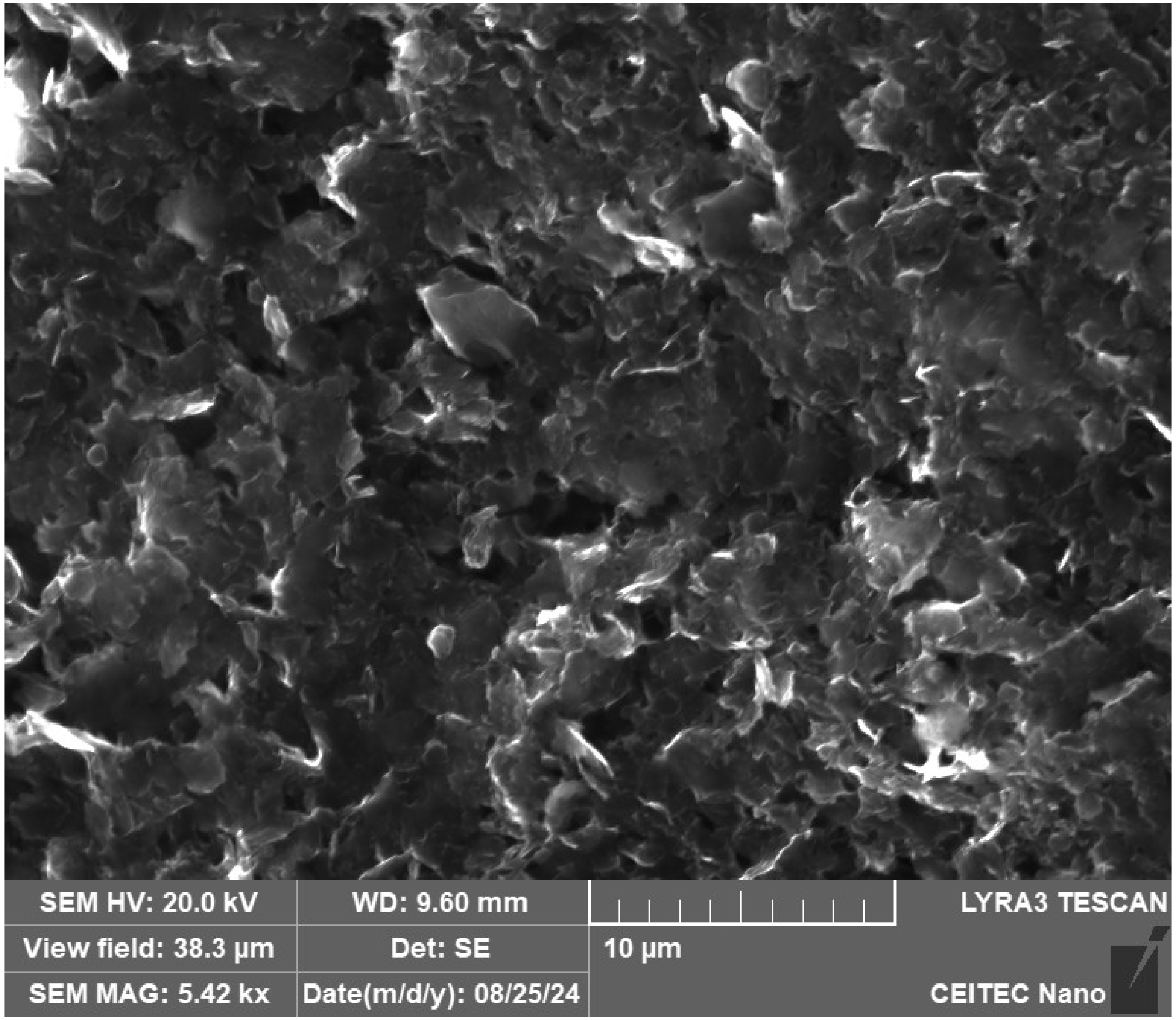
XPS spectra of cleaned tungsten after different Ar500+ ion etching steps

Limited surface conductivity of W



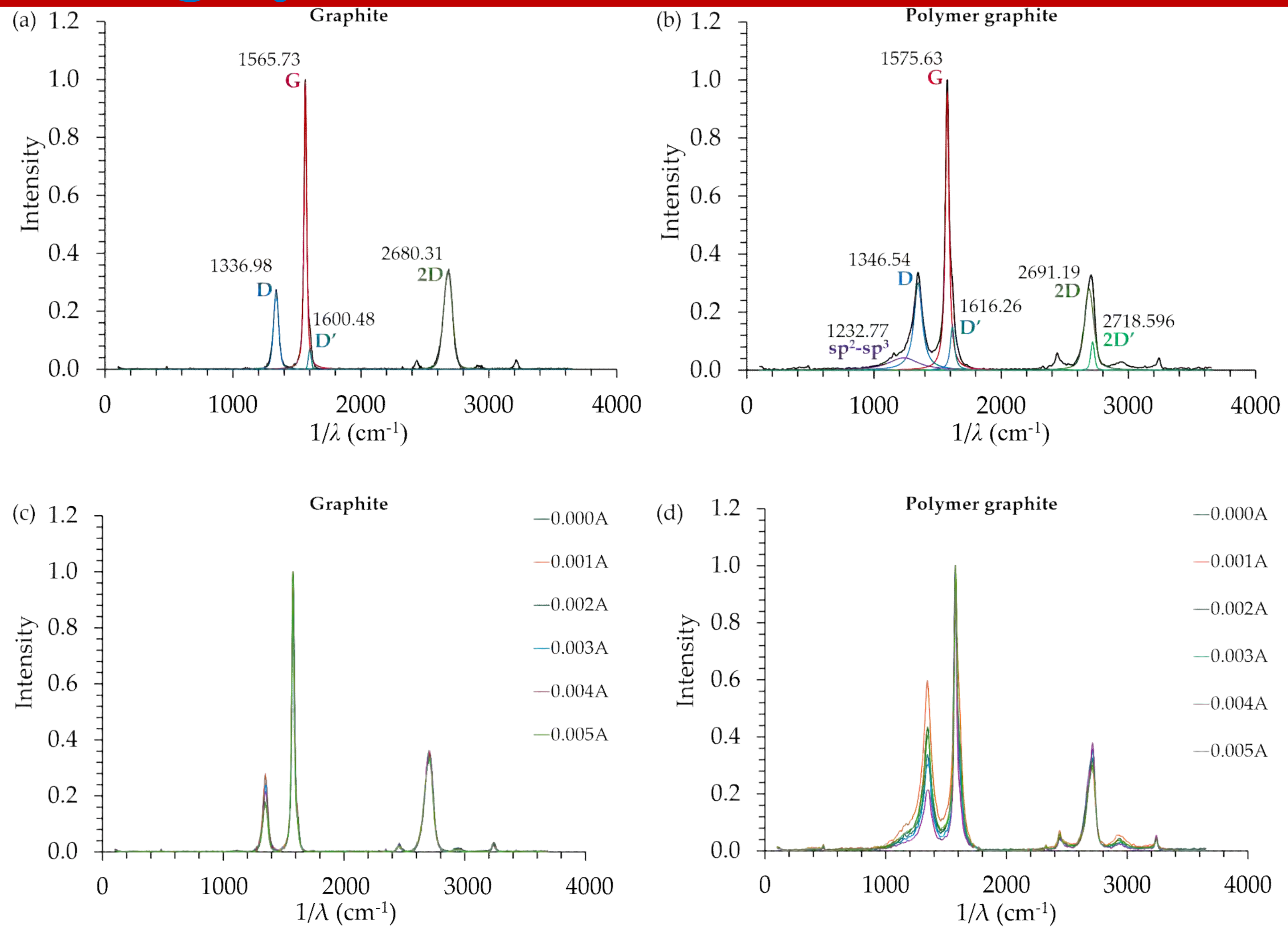
UPS spectra of cleaned tungsten after different Ar500+ ion etching steps

Why colloidal graphite?



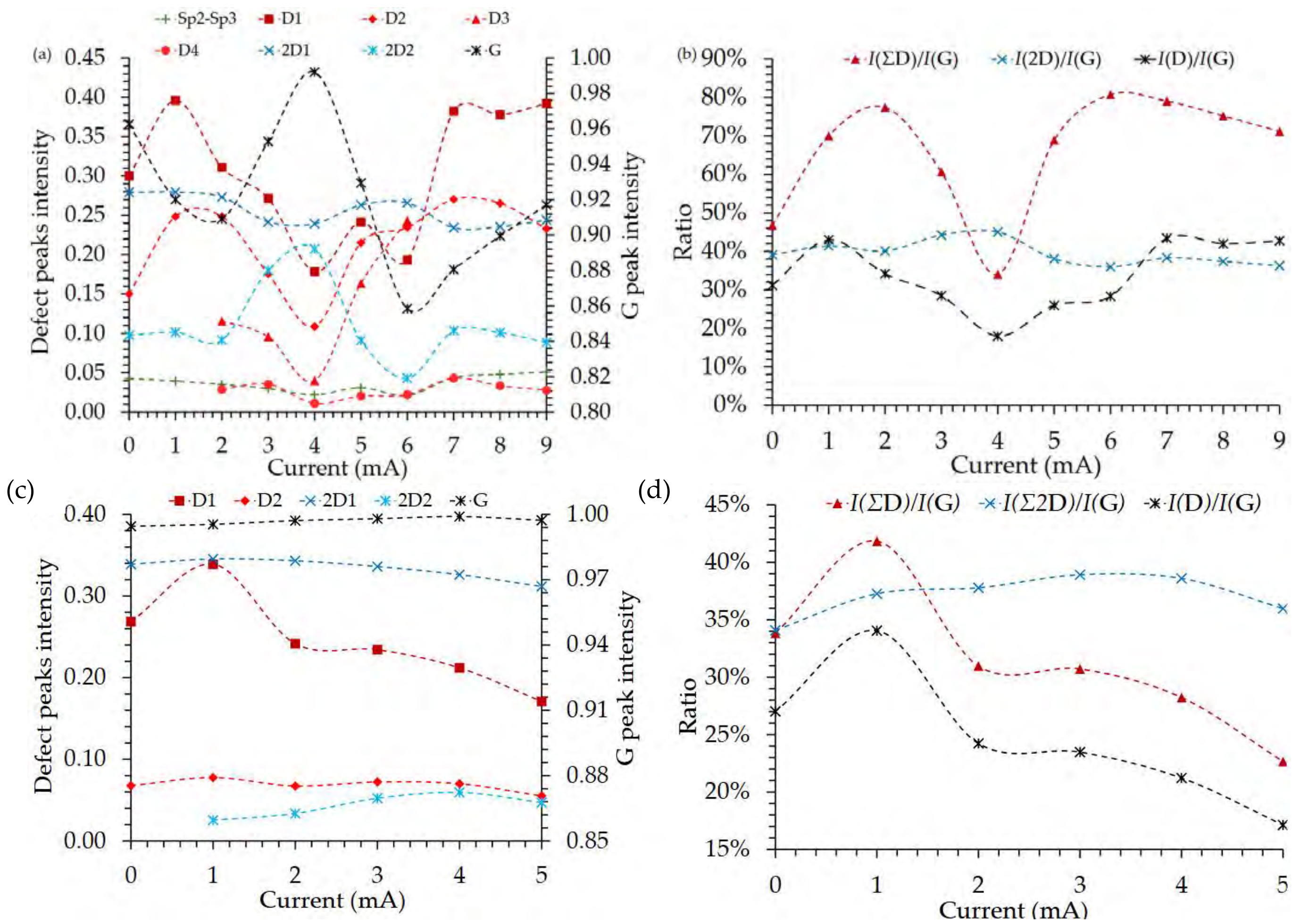
SEM of colloidal graphite surface deposited on glass

Why colloidal graphite?



Raman spectroscopy for a graphite sample surface compared to amorphous polymer graphite

Why colloidal graphite?



Raman spectroscopy peaks analysis for polymer graphite (a and b) and for colloidal graphite (c and d)

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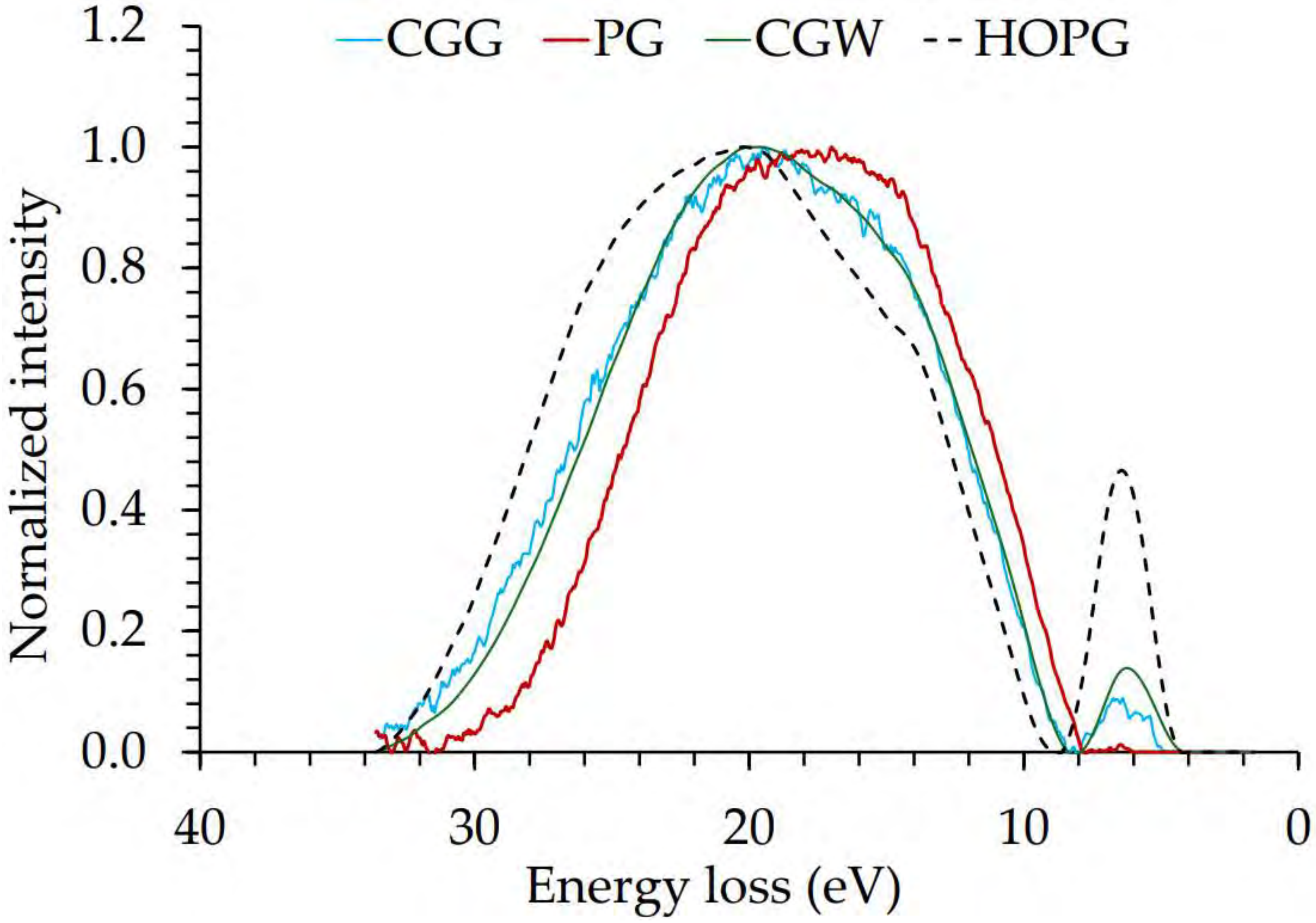
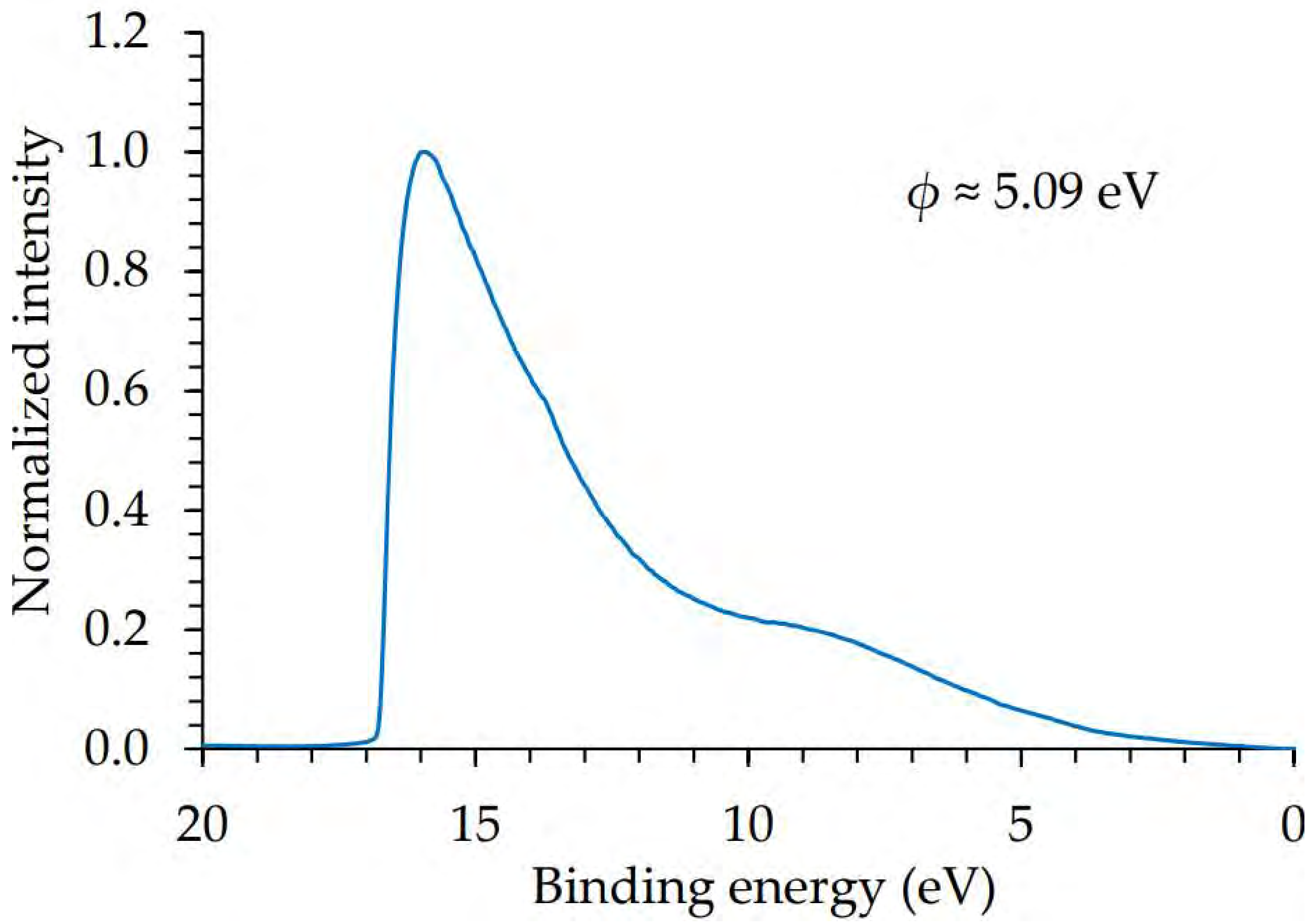
Why colloidal graphite?



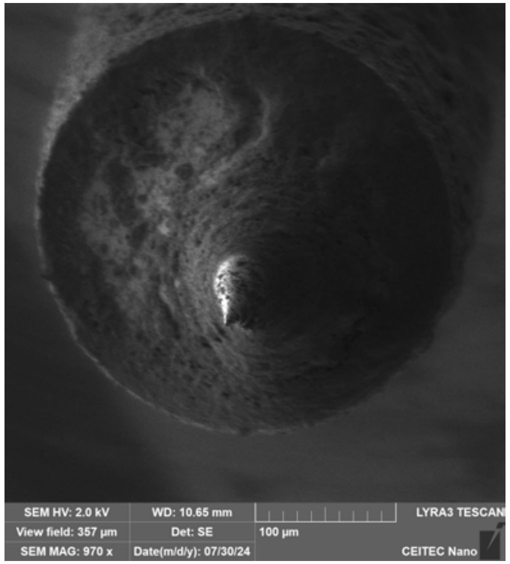
Reflected electron energy loss for colloidal and polymer graphite along with HOPG

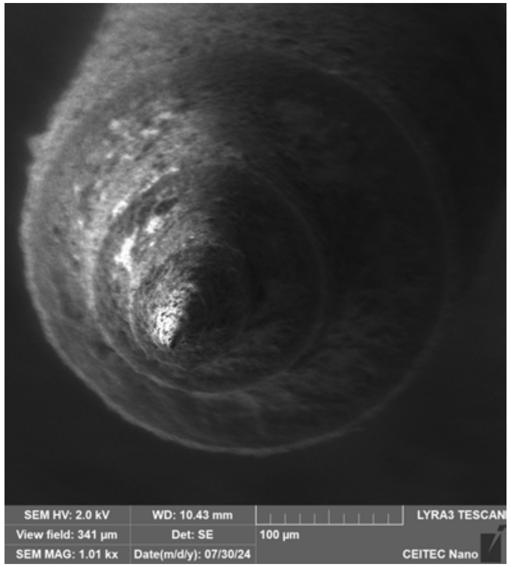
Why colloidal graphite?

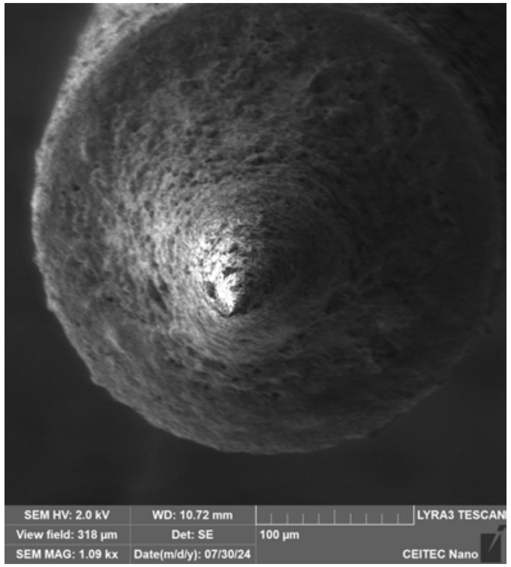


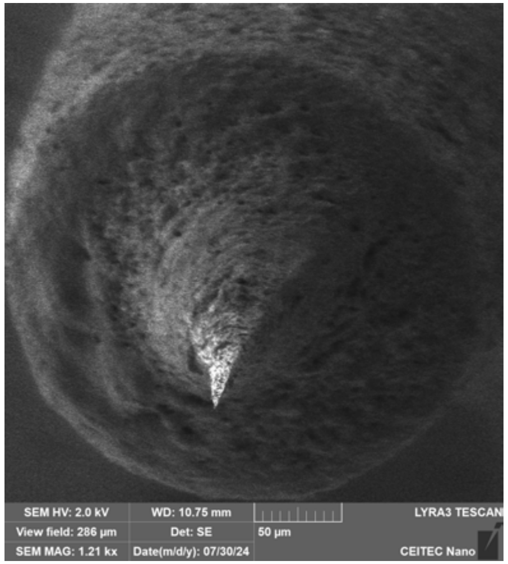
UPS spectrum of colloidal graphite

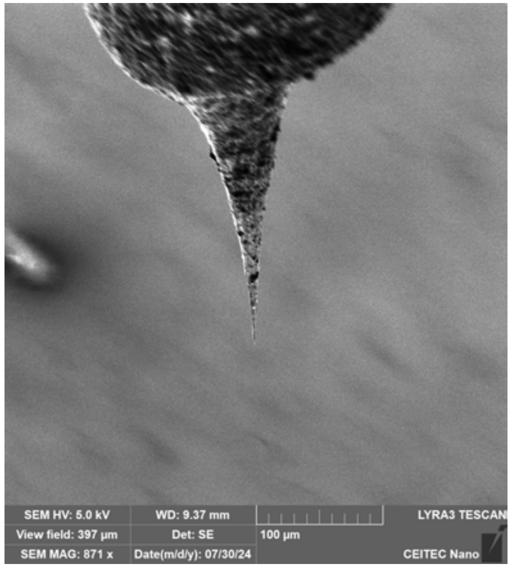
Samples prepared











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Sample prepared

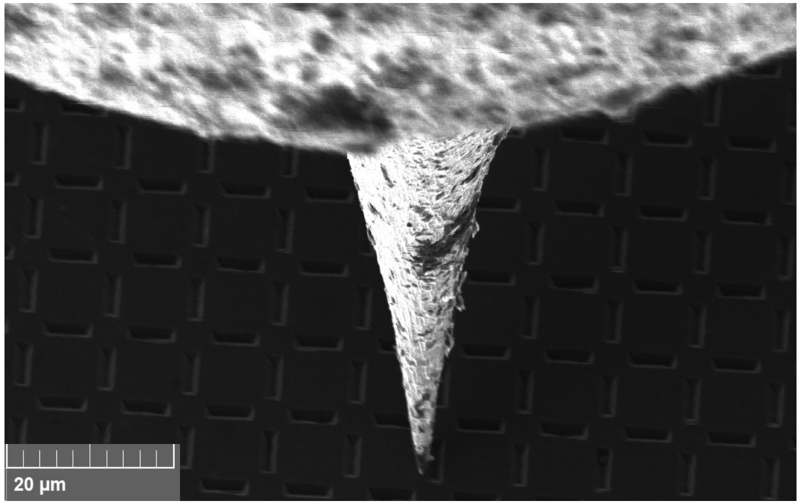
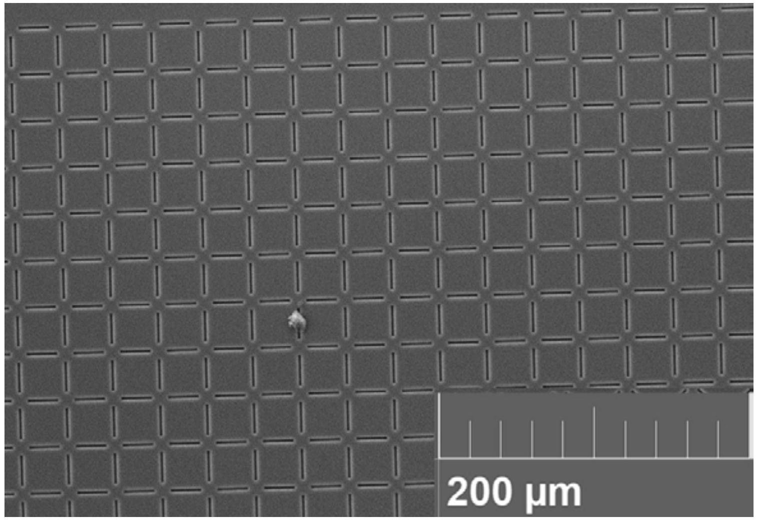


Fig.10. Tungsten-graphite cathode



SEM calibration sample

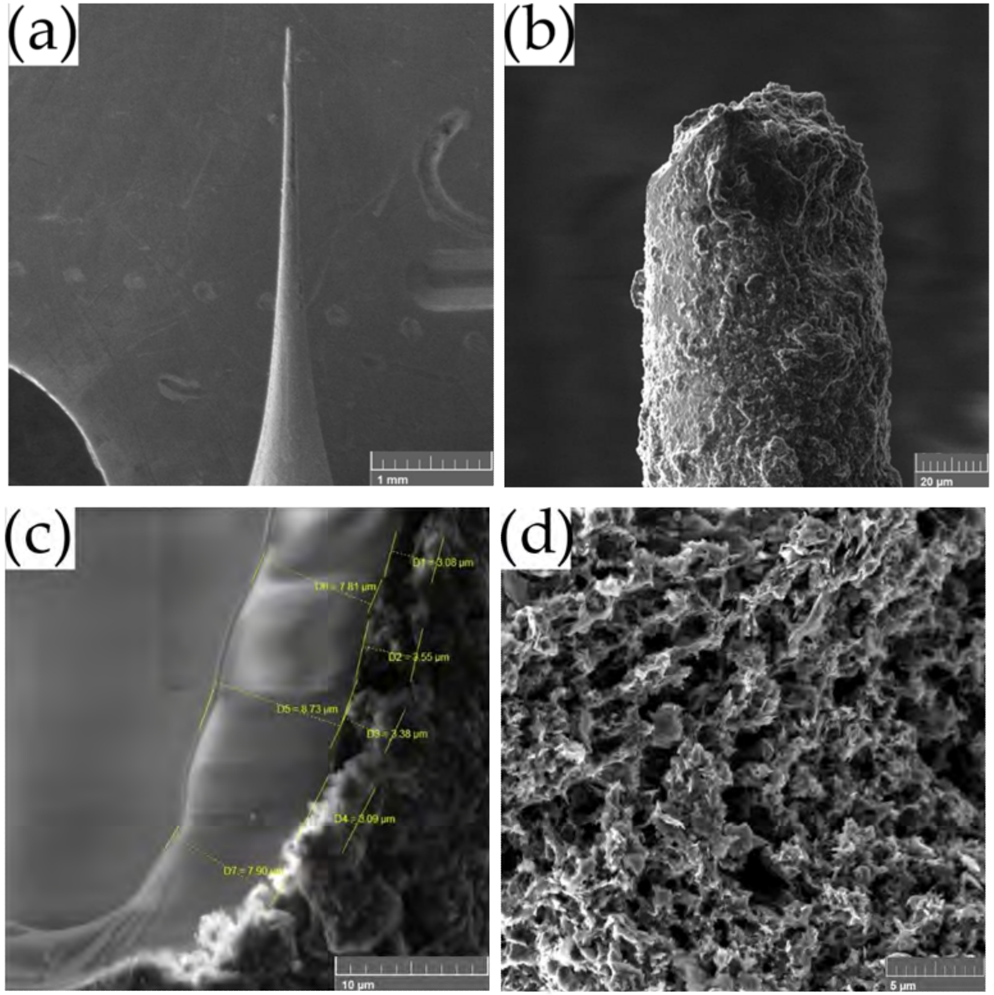
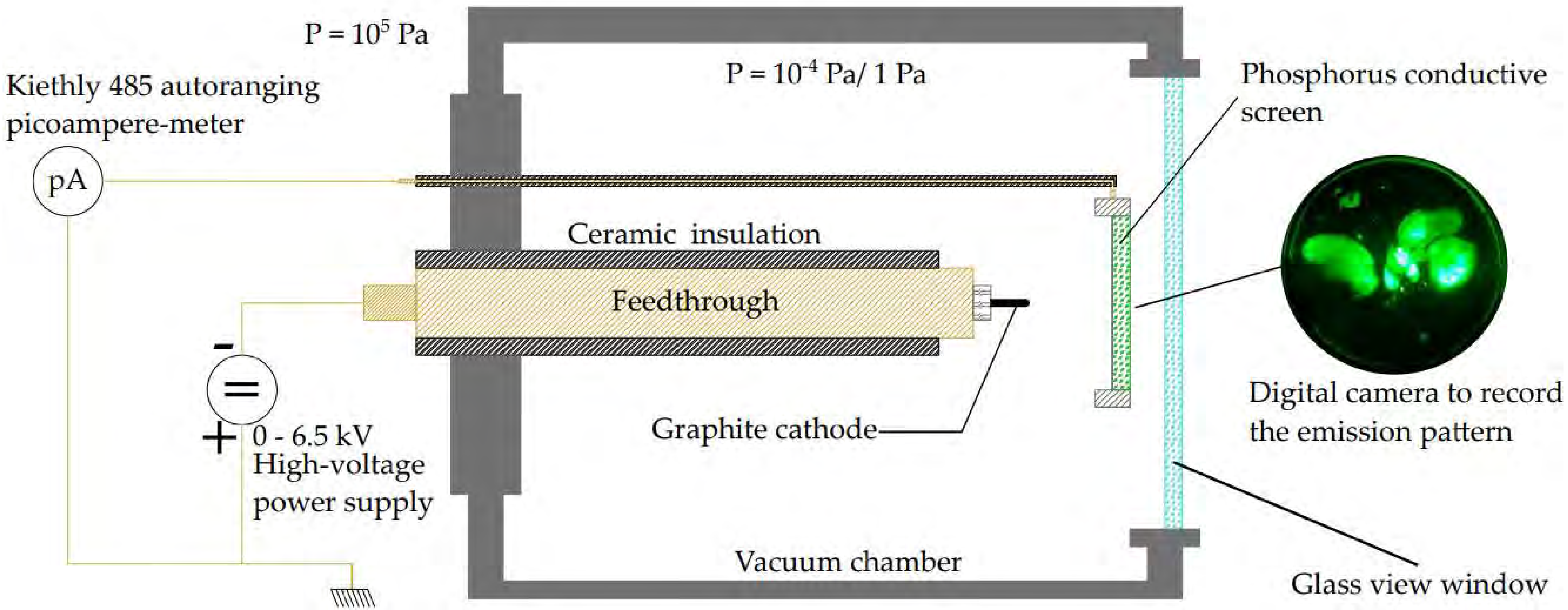


Fig.9. Glass-graphite cathode

Setup – FEM



Zero series resistor field emission microscope

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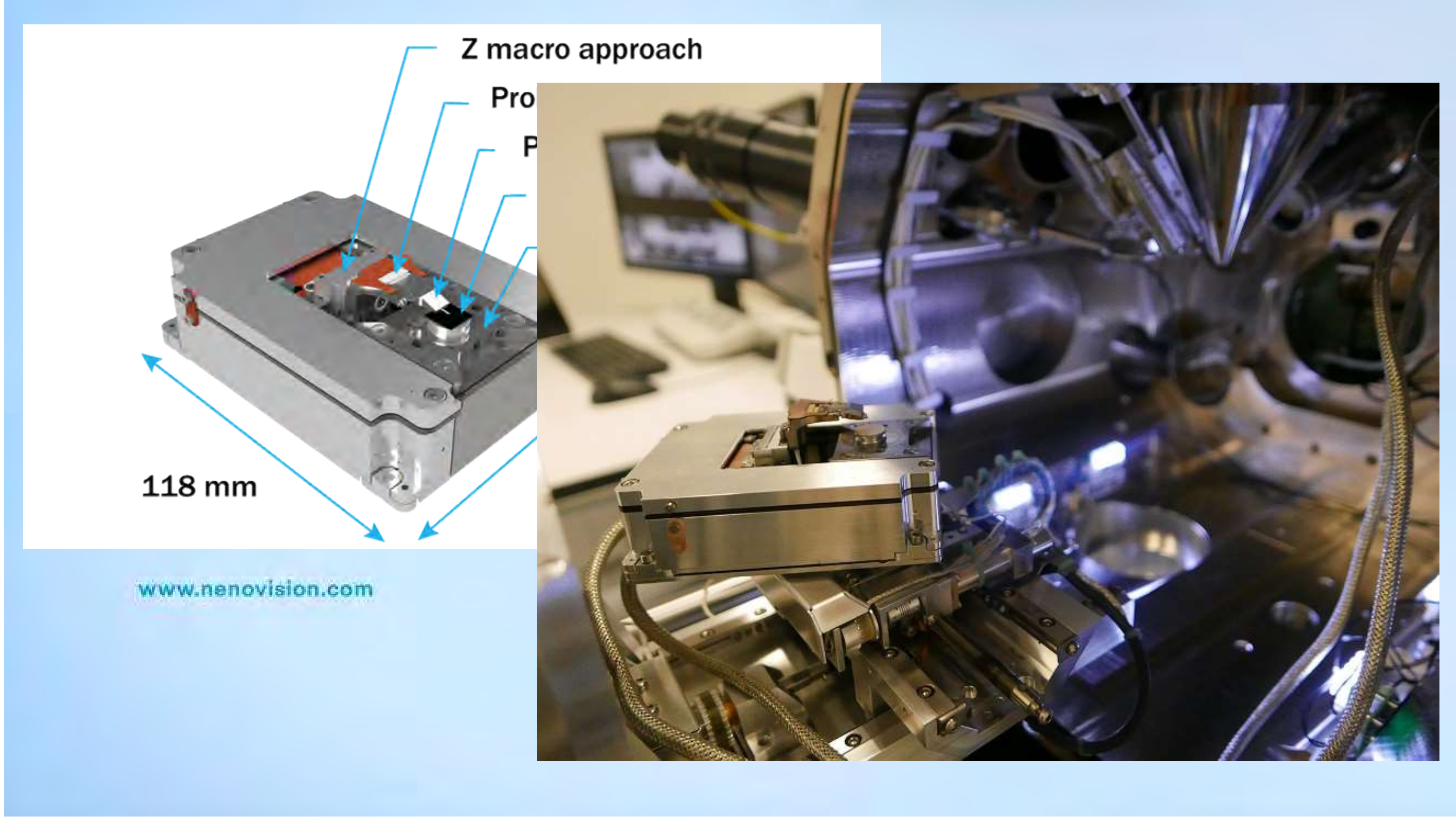
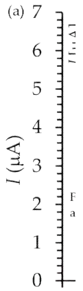
Setup – STM

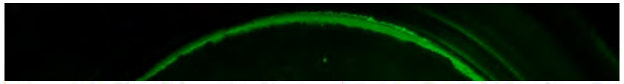


Nenovision litescope AFM in SEM

Field emission characteristics of glass-graphite cathodes



Field emission pattern at 2.37 kV (maximum current = 32 μA):



Field emission pattern at 3.36 kV (maximum current = 68 μA):

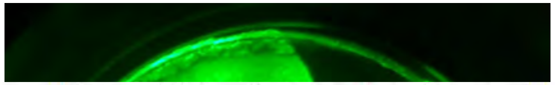
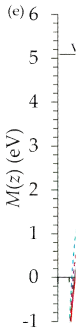
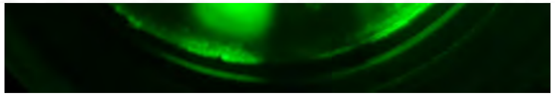


Table 4: Summary of the cold field emission characteristics for the tested samples. ΔM refers to the change in the SN-PEB height with respect to ϕ, and ΔW refers to the change in the SN-PEB width at the Fermi level.

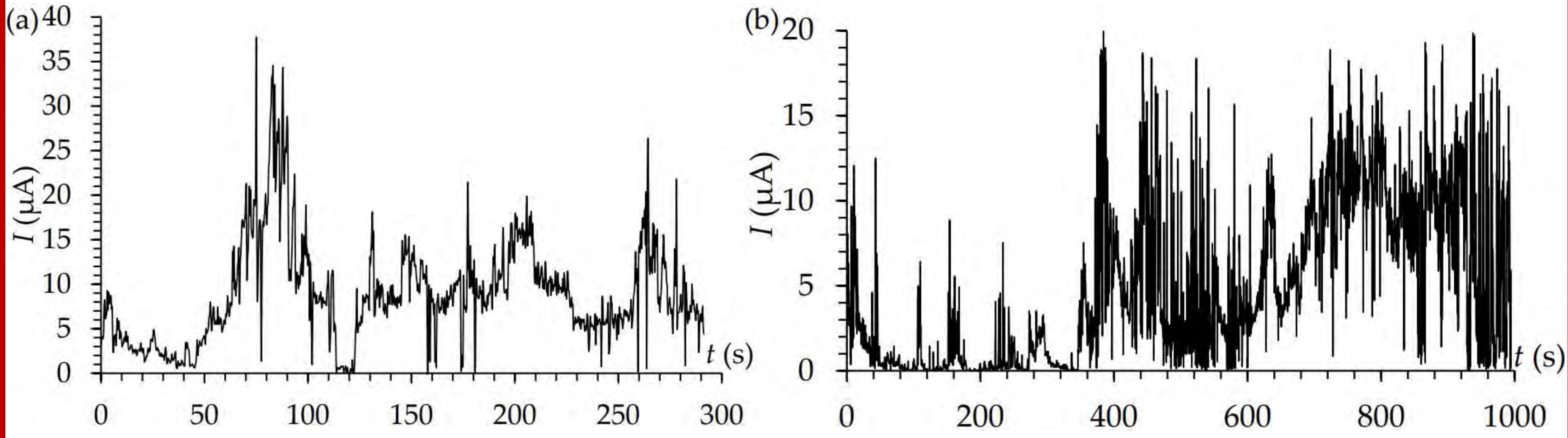
Sample(test result)	Slope Np.V	f_C^{low}	f_C^{up}	ζ_C nm	γ_{MC}	A_f^{SN} m^2	α_f^{SN}	PEB-ΔM eV	PEB-ΔW nm
Hybrid-GMF1(Fail)	−3565	0.63	0.74	—	—	—	—	4.06 – 4.39	0.07
Hybrid-GMF2(Pass)	−11672	0.23	0.32	149	6721	2.6×10^{-16}	1.2×10^{-8}	2.43 – 2.87	0.35
Film-GMF1(Pass)	−23995	0.18	0.27	306	3269	2.1×10^{-16}	6.9×10^{-7}	2.15 – 2.64	0.53
Film-GMF2(Pass)	−18500	0.25	0.35	236	4240	2.9×10^{-16}	9.6×10^{-7}	2.54 – 3.00	0.34





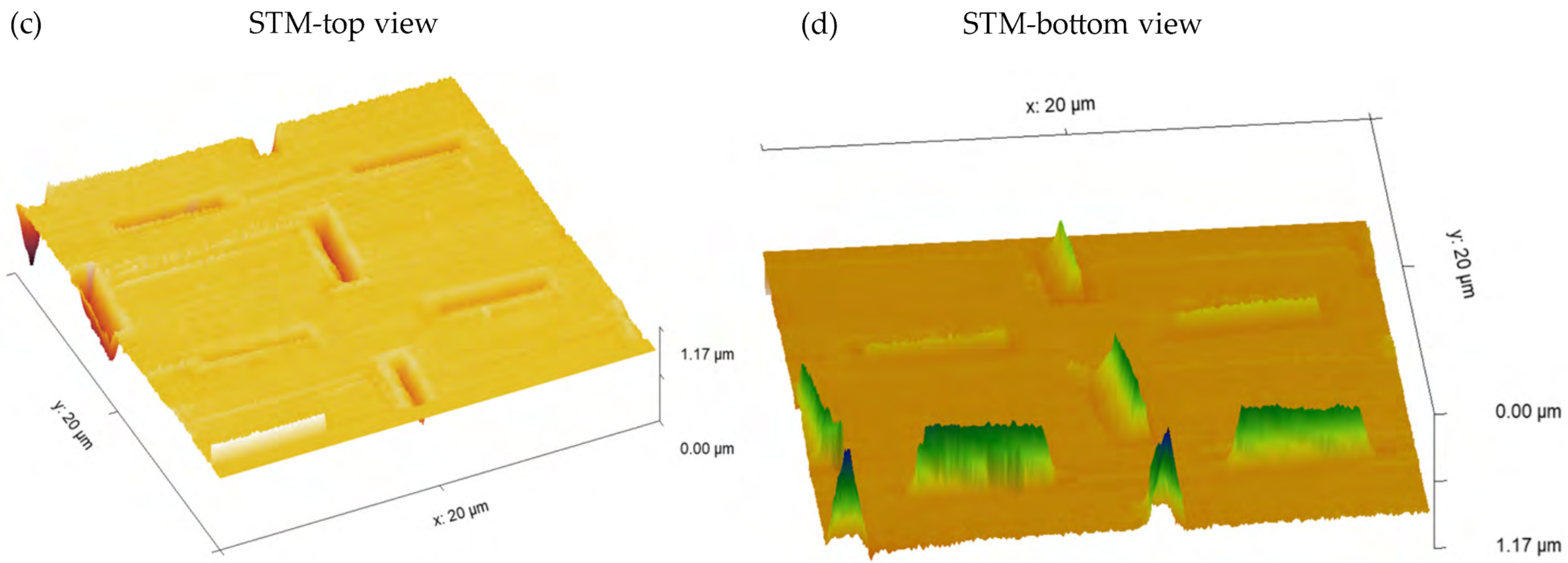
The field emission characteristics of the glass-graphite microtips.

Field emission characteristics of glass-graphite cathodes



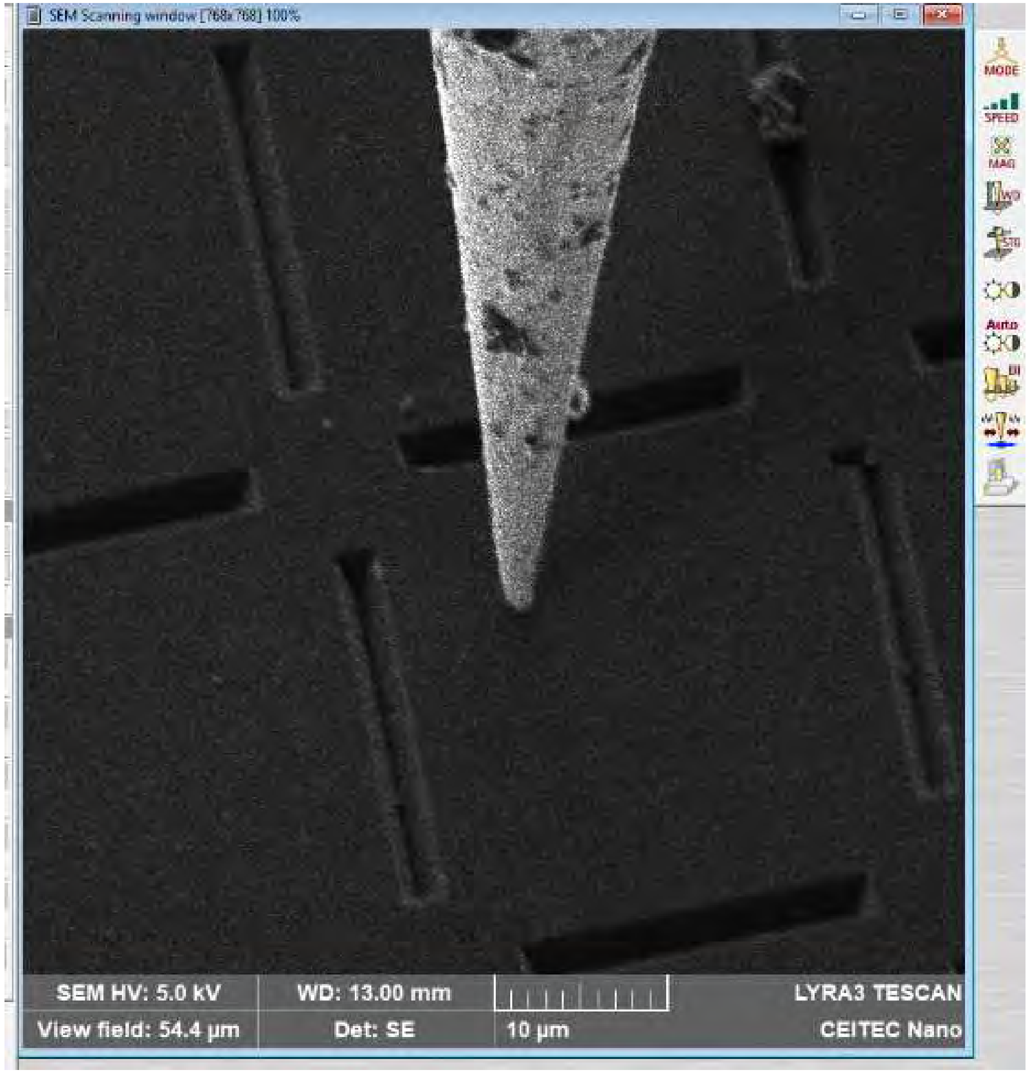
The field emission current-time characteristics of the glass-graphite microtips at pressure of 1 Pa.

STM with a W-Graphite cathodes



STM measurement with a W-Graphite cathode ($P = 10^{-2}$ Pa)

STM with a W-Graphite cathodes



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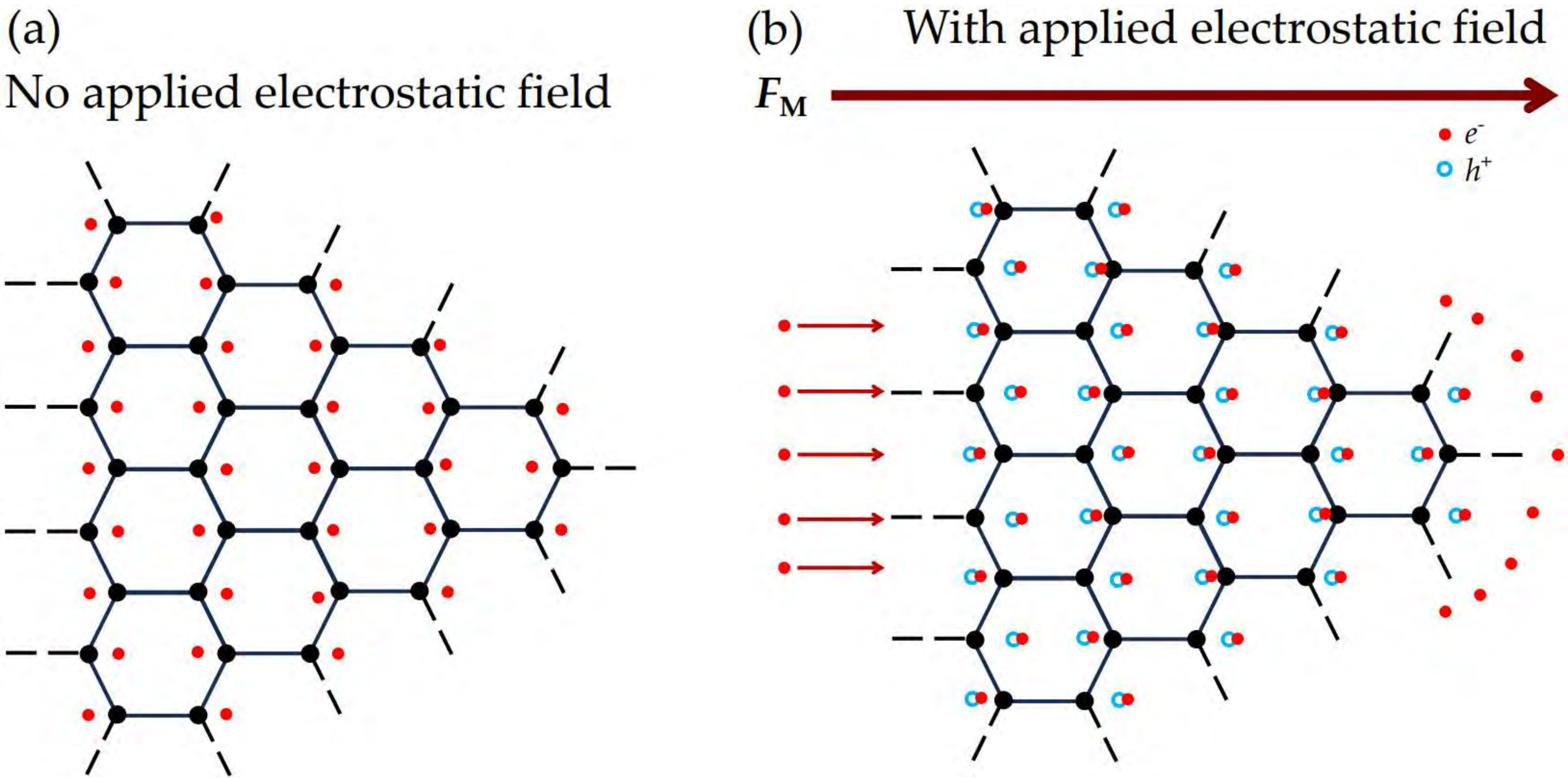
Summary



(a)
No applied electrostatic field
(b)
With applied electrostatic field
F_M
e^-
h^+

Summary

1. Tungsten cold field emission STM probes have limited performance outside UHV environments.

2. XPS and UPS showed a critical requirement for in-situ cleaning procedure in FEM and STM instruments.

3. Colloidal graphite showed good performance as coating material for cold field emission applications.

4. W-Graphite showed good cold field emission performance.

5. W-Graphite cold field emission STM probes showed good STM performance inside SEM chambers for topography studies.

6. Graphenic structure of graphene related materials is believed to be the reason behind the linear behavior in the corresponding current-voltage characteristics.

Thank you for your attention.
Questions?

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