Ultra Low Work Function Coating for Combined Passive Electron Emission and Collection for Spacecraft Charging Neutralization and Electrodynamic Tether Applications

Lauren P. Rand, Colorado State University

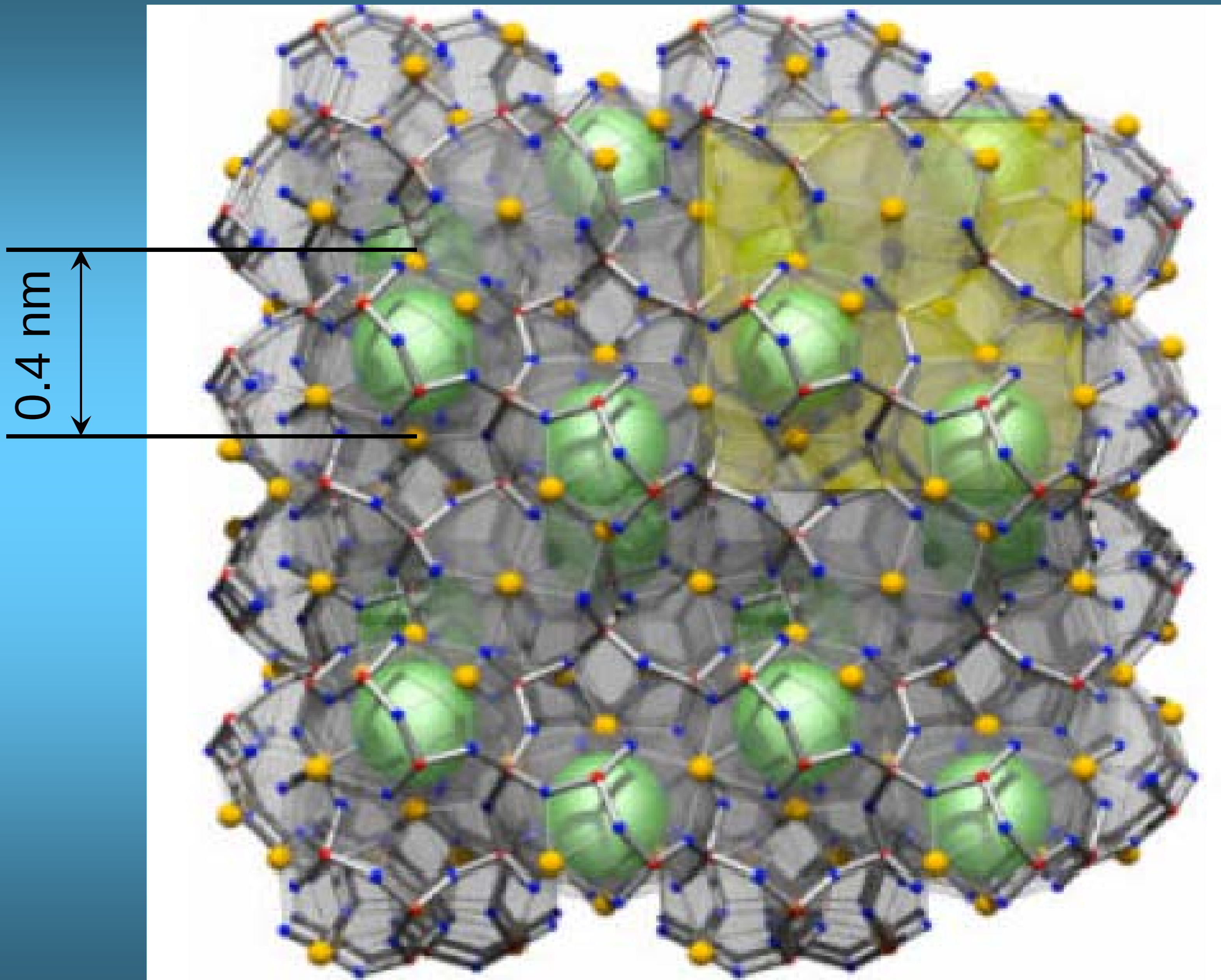
Sudhakar Mahalingam, TechX Corporation

Juan Sanmartin, Universiad Politécnica de Madridz

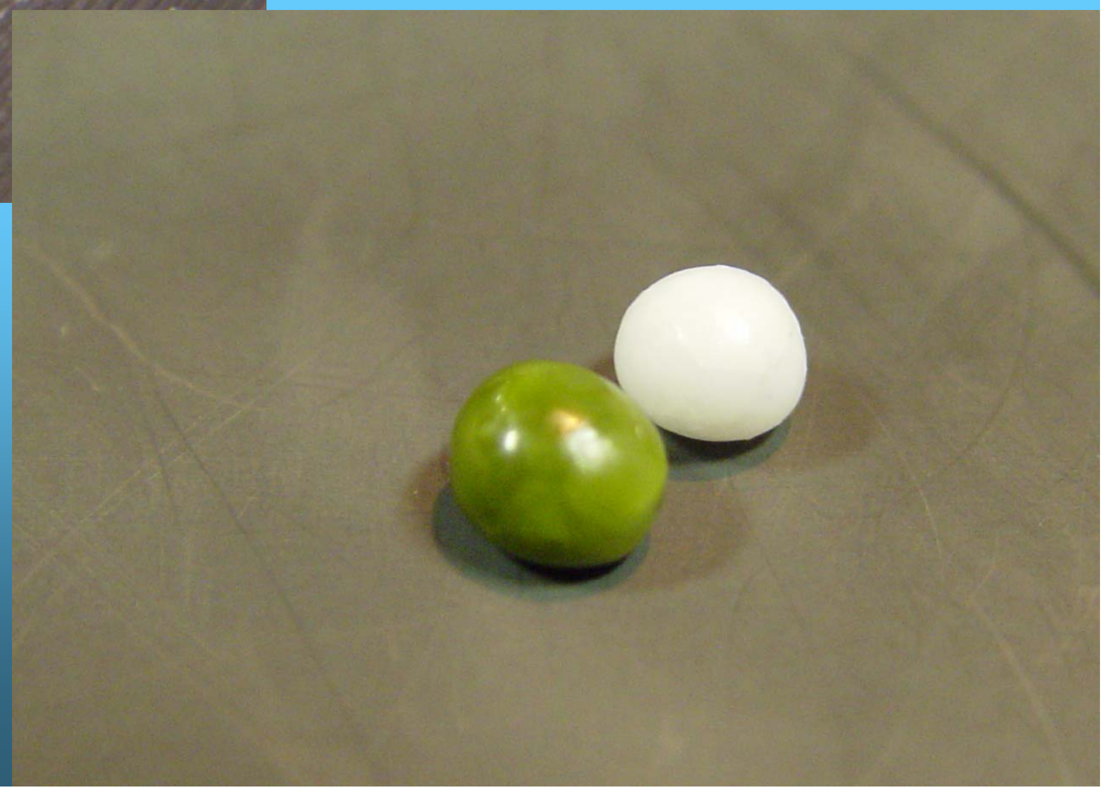
and

John D. Williams, Colorado State University

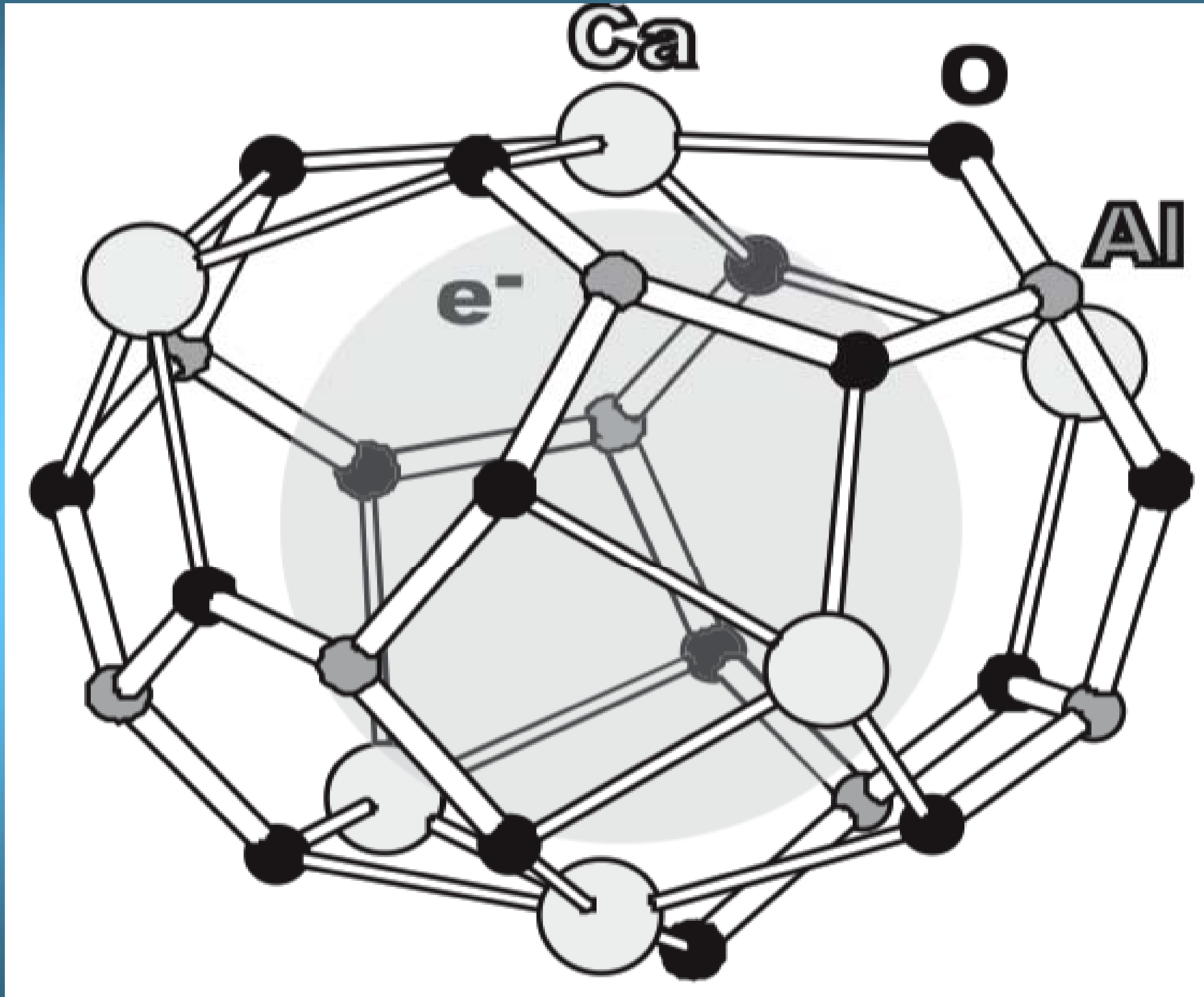
$12CaO\text{-}7Al_2O_3$ $[Ca_{24}Al_{28}O_{64}]^{4+}\ 2O^{2-}$



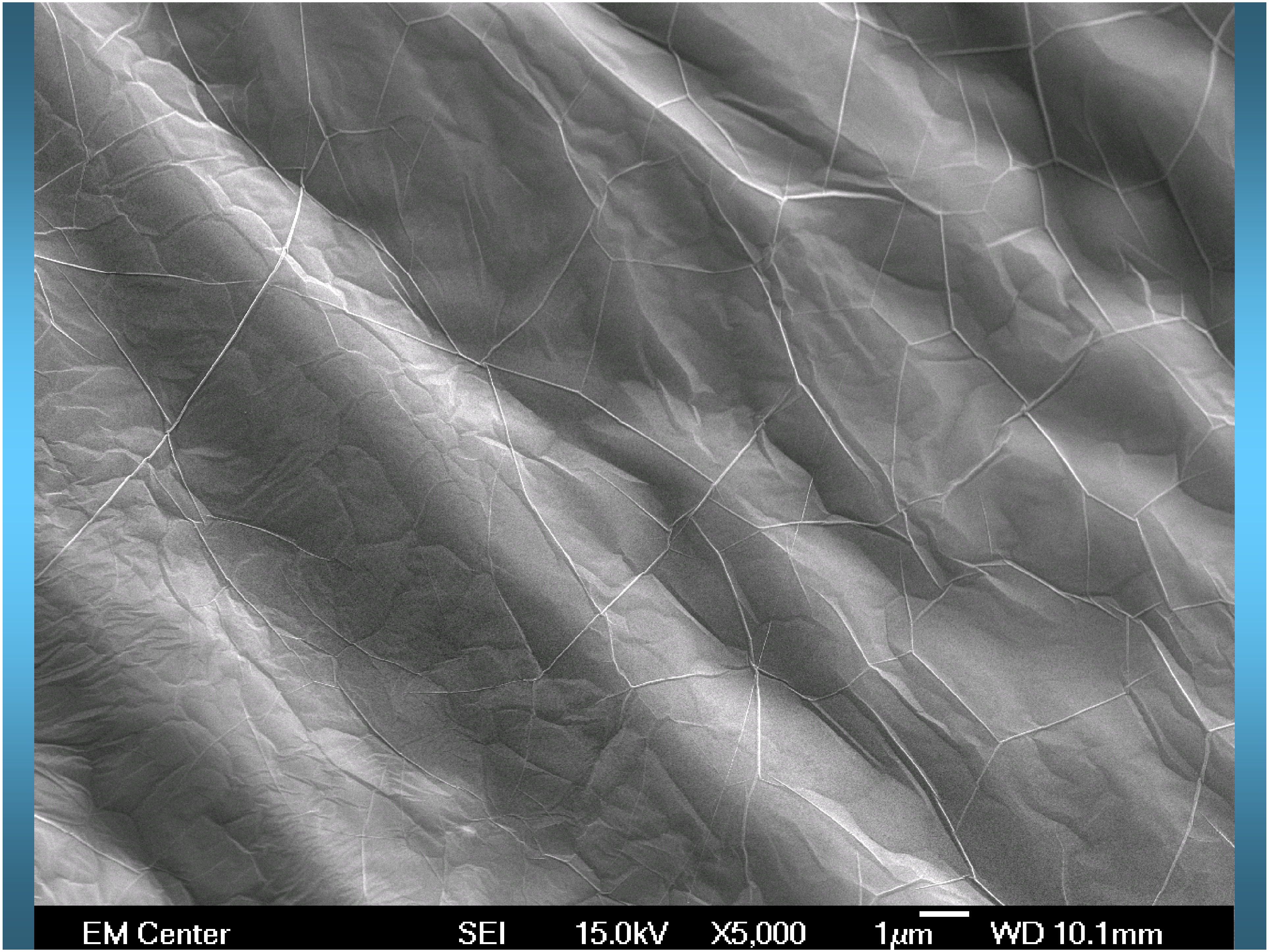
http://www.nanonet.go.jp/english/mailmag/2006/071a.html

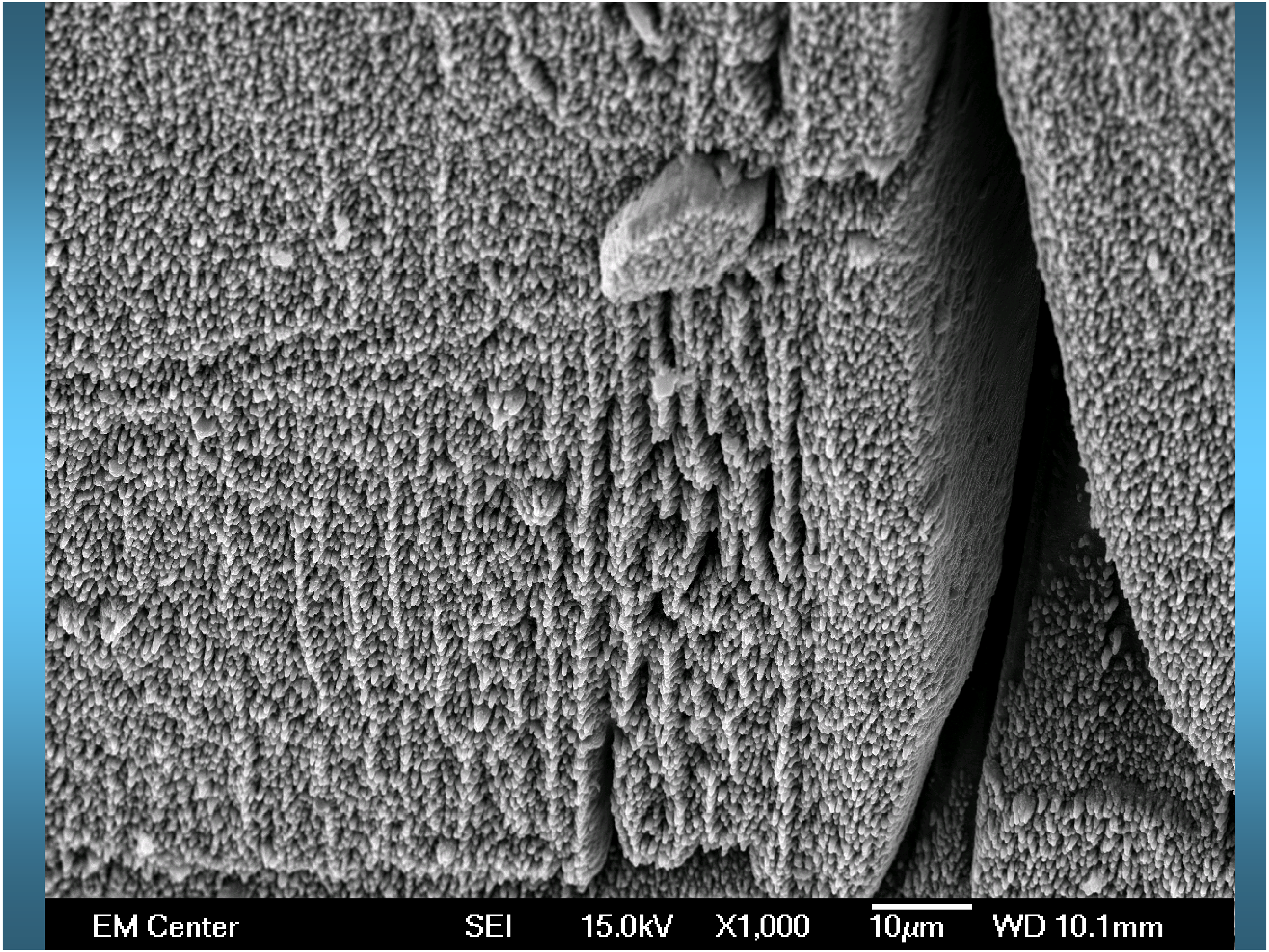


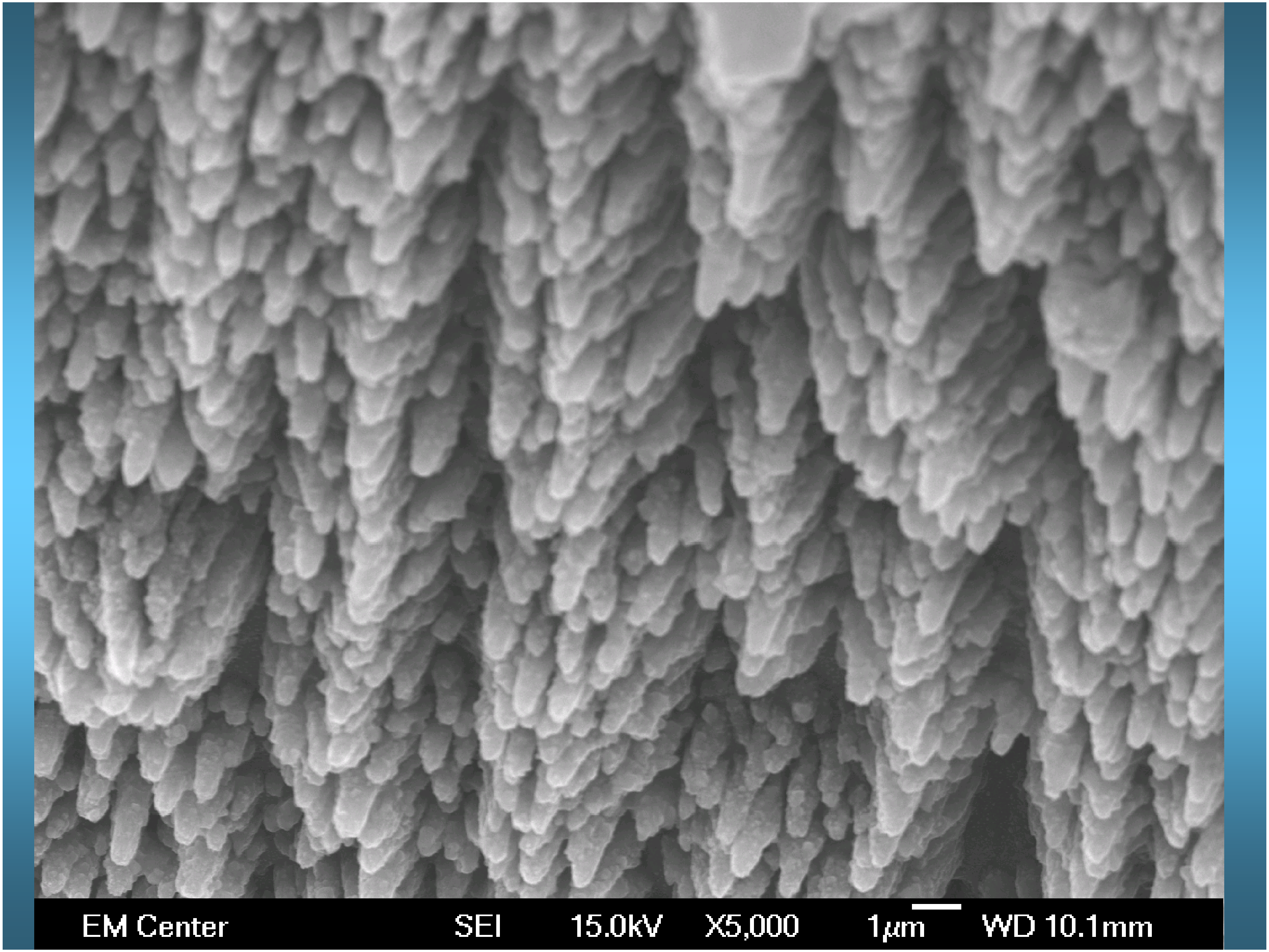
$[Ca_{24}Al_{28}O_{64}]^{4+}\ 4e^{-}$

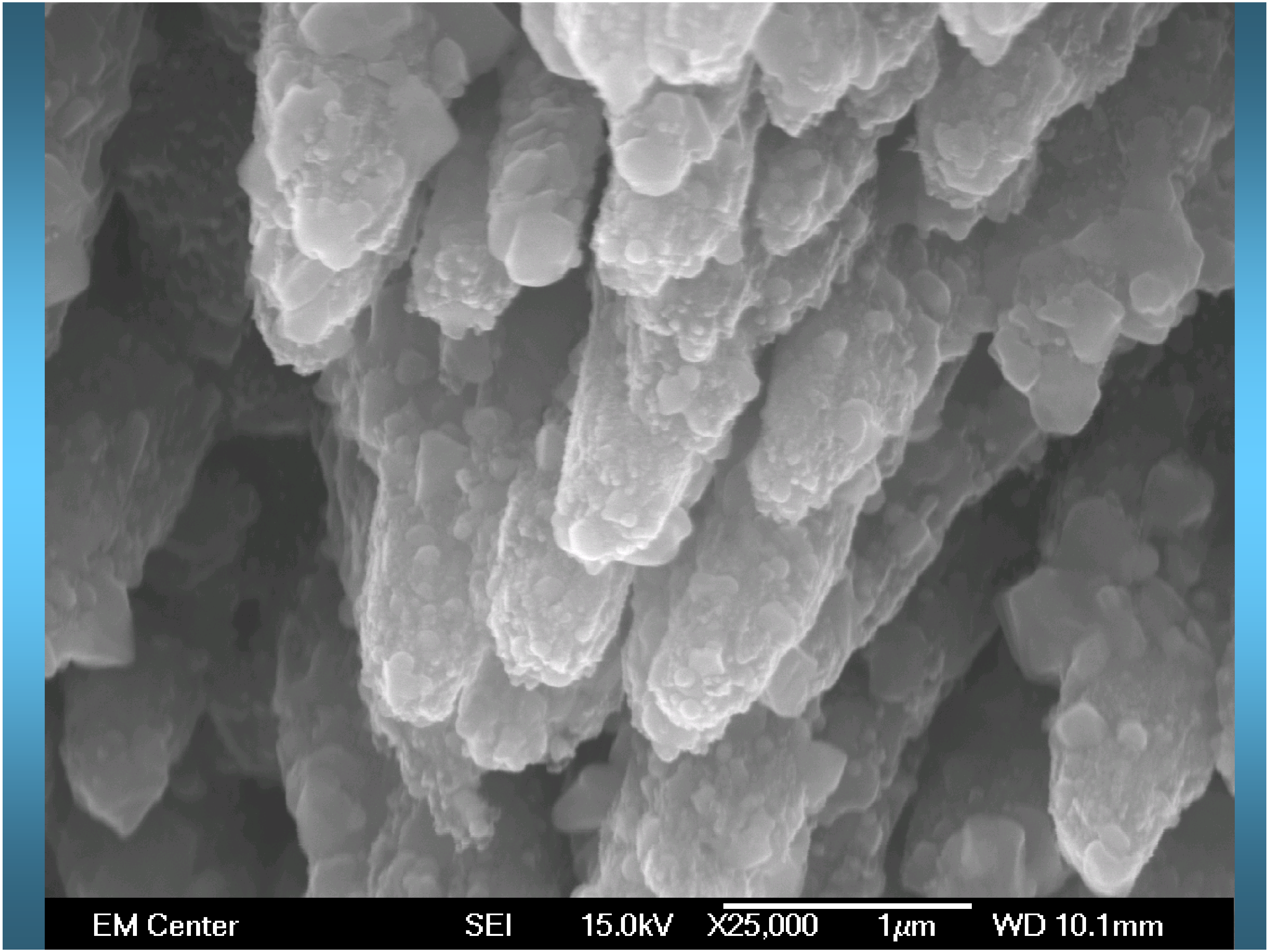


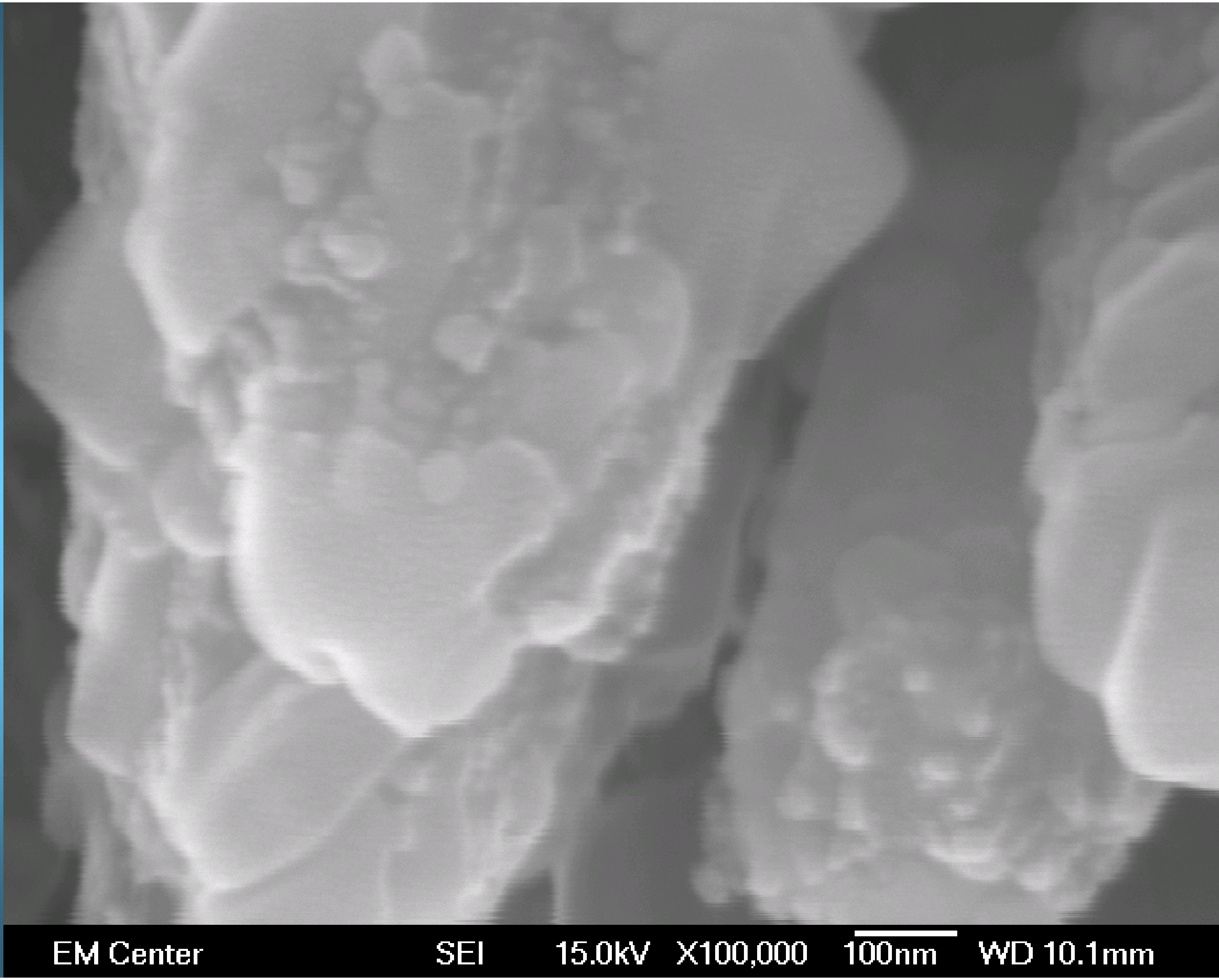
Toda, et al. Advanced Materials. 19, 2007.

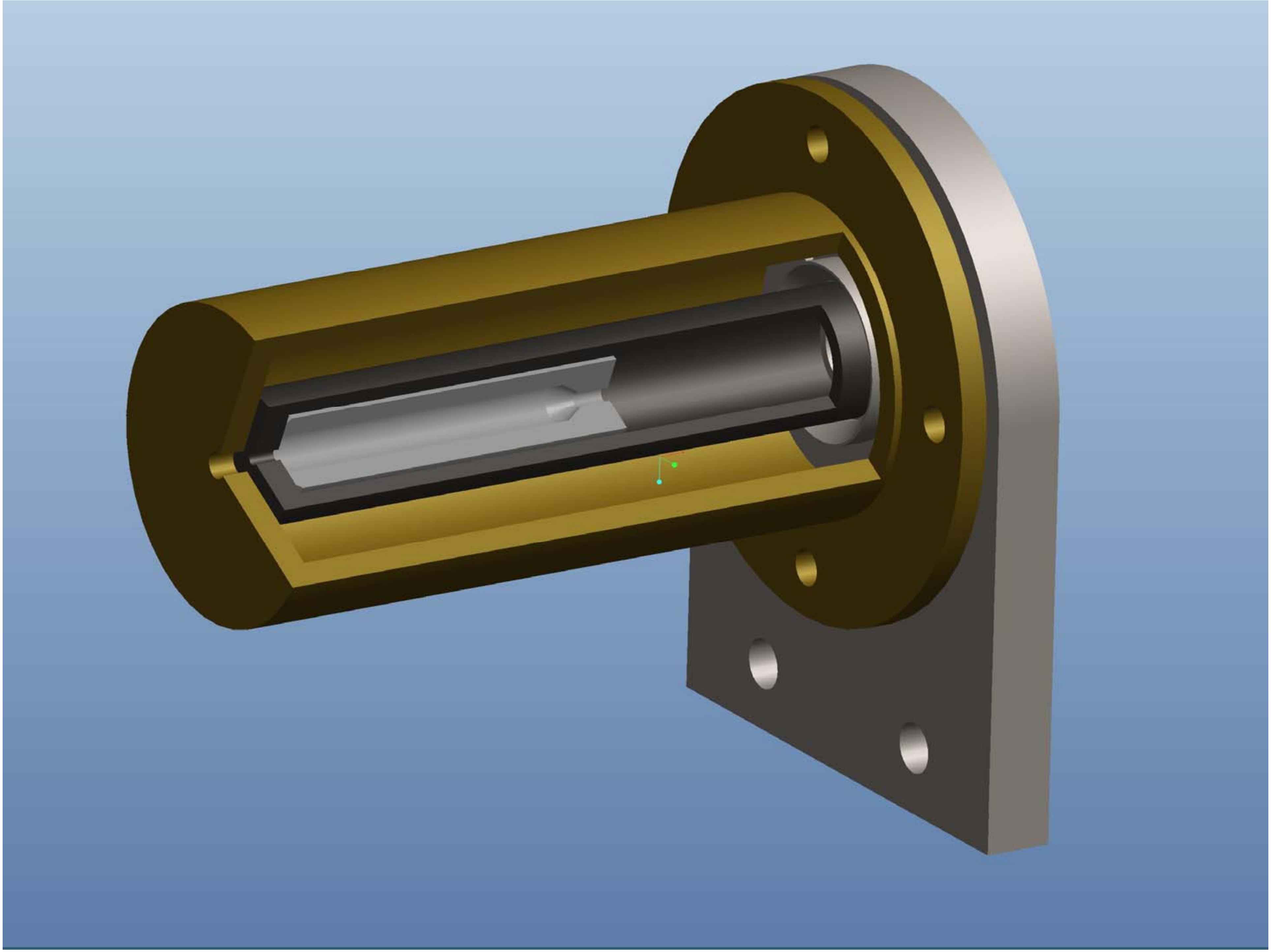

EM Center
SEI
15.0kV
X5,000
1μm
WD 10.1mm

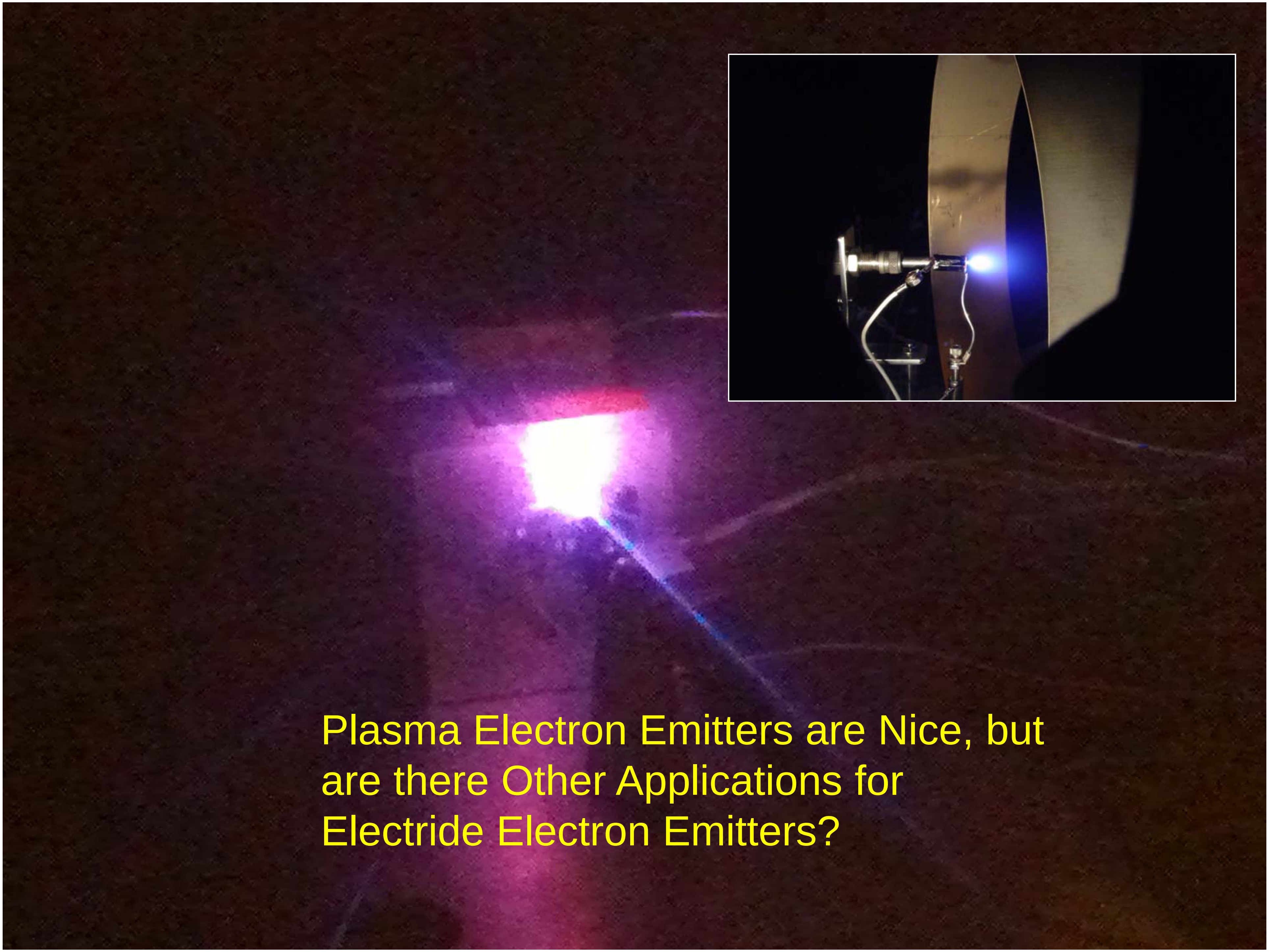

EM Center
SEI
15.0kV
X1,000
10µm
WD 10.1mm

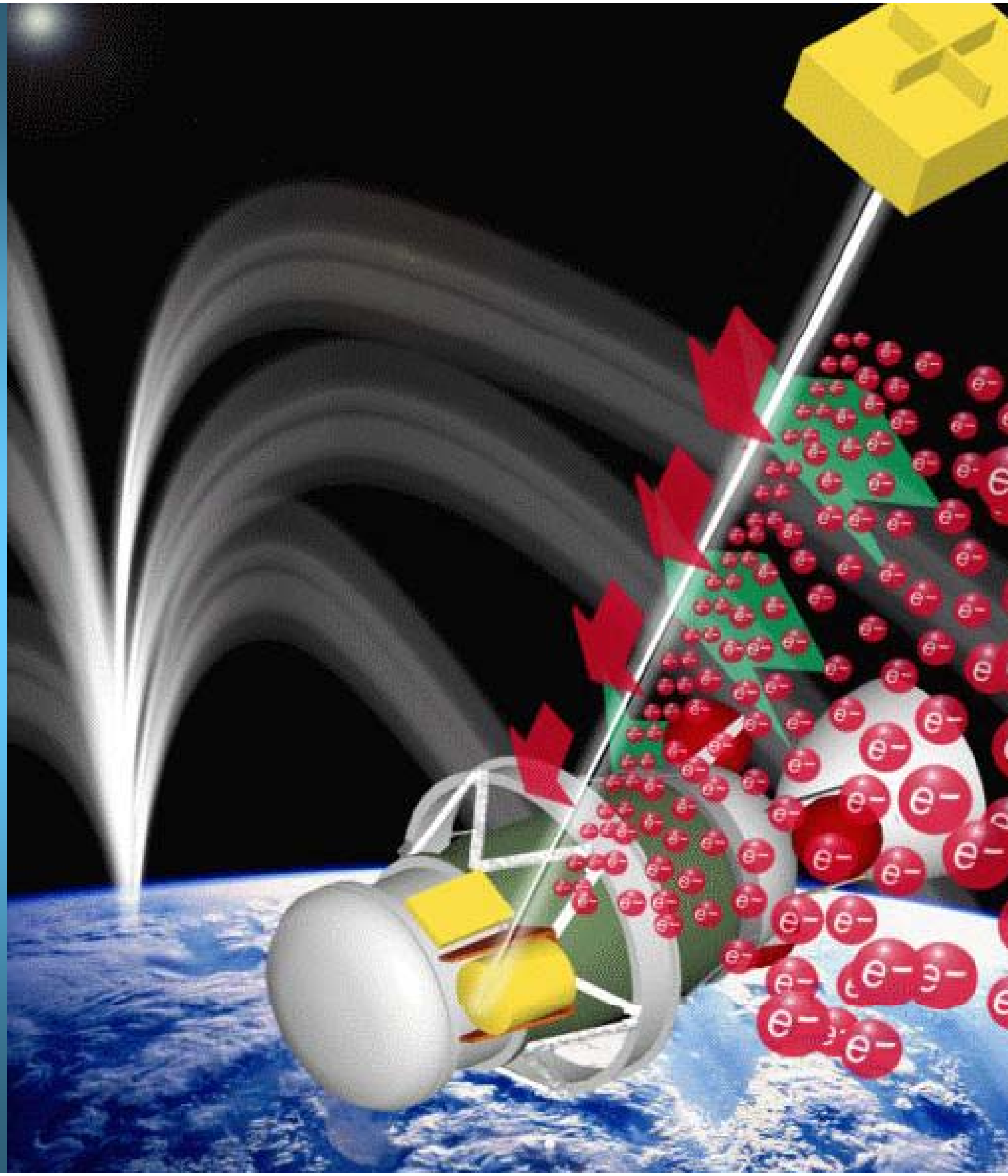

EM Center
SEI
15.0kV
X5,000
1μm
WD 10.1mm


EM Center
SEI
15.0kV
X25,000
1µm
WD 10.1mm

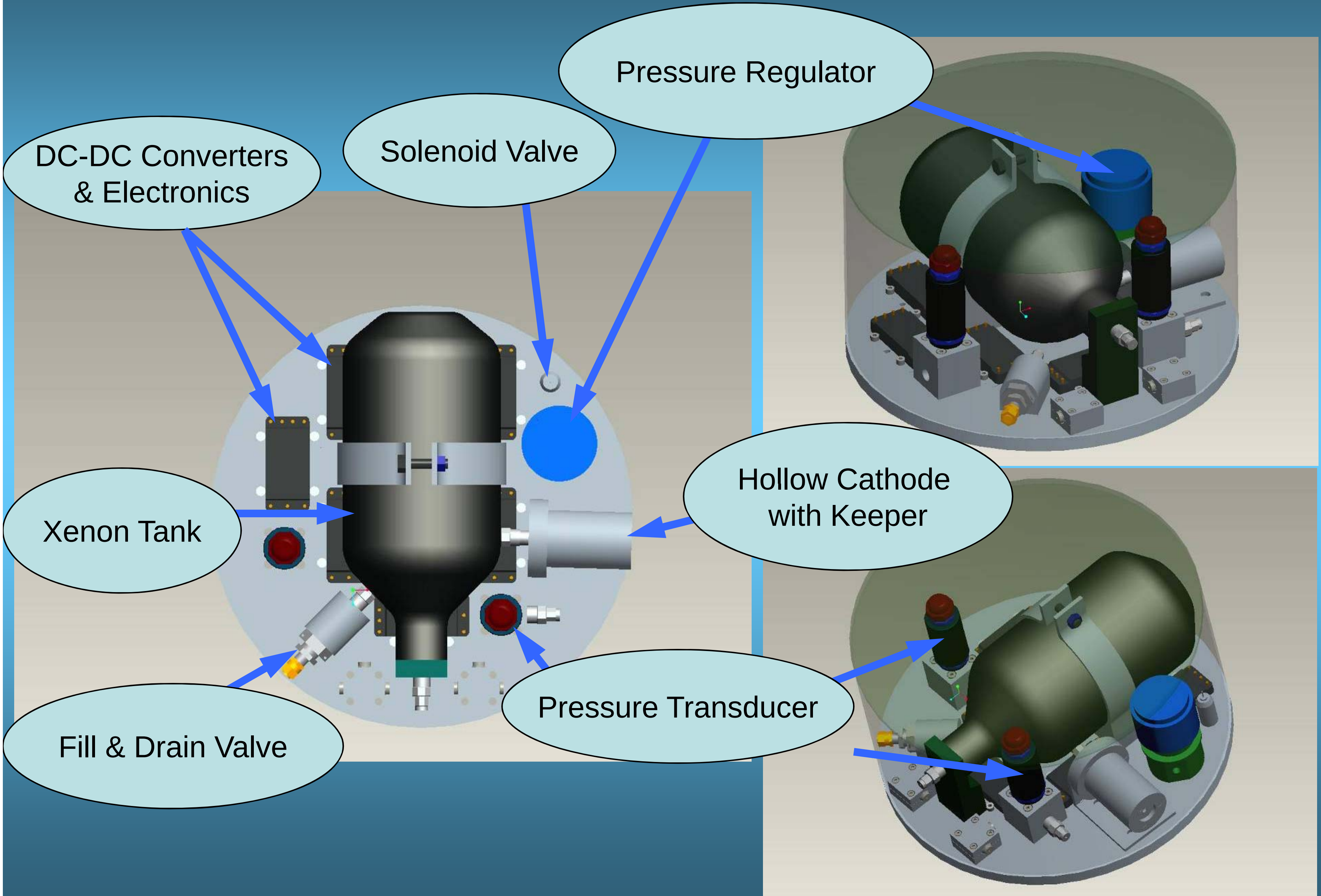

EM Center
SEI
15.0kV
X100,000
100nm
WD 10.1mm




Plasma Electron Emitters are Nice, but
are there Other Applications for
Electride Electron Emitters?

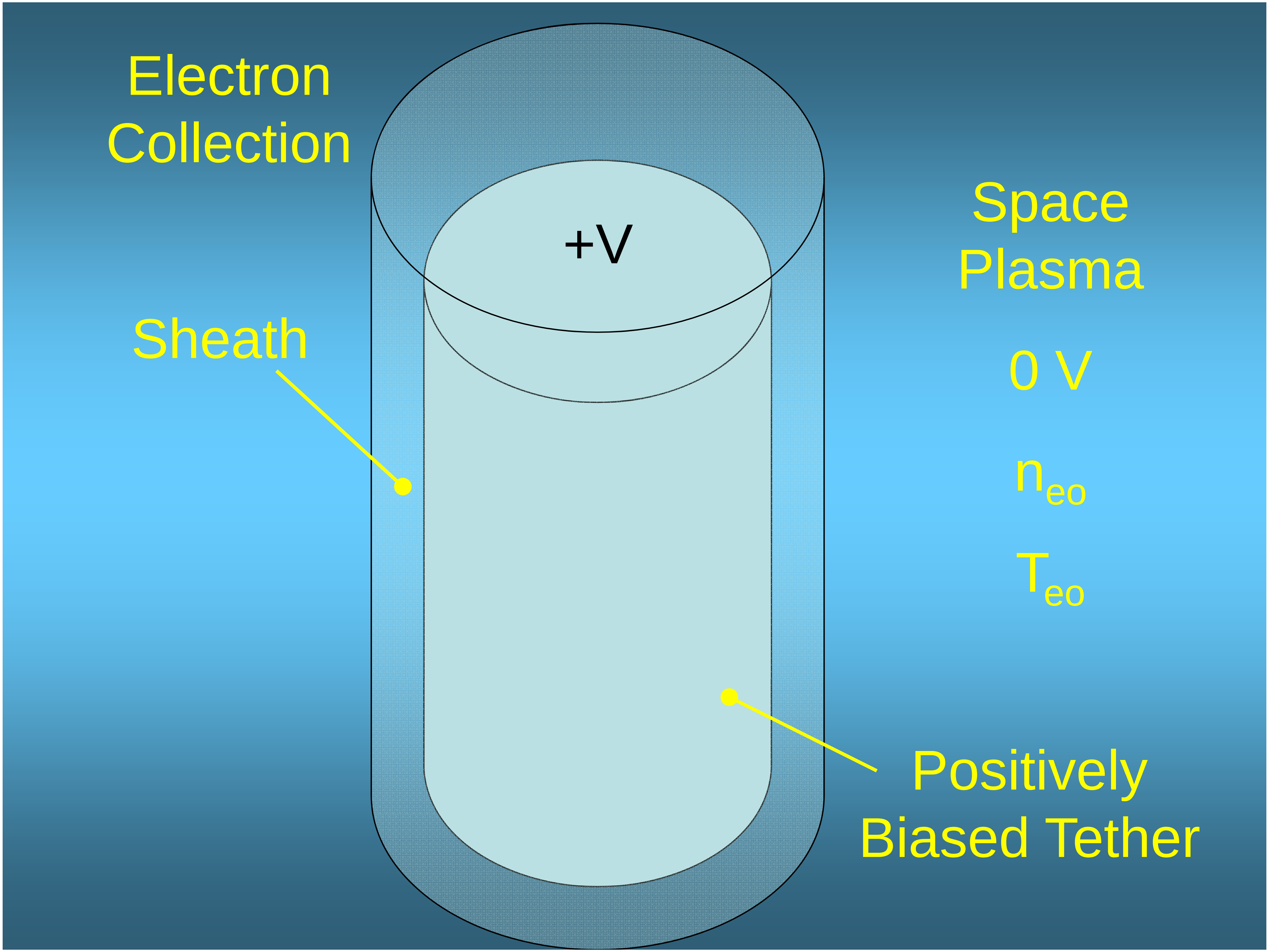

e^-

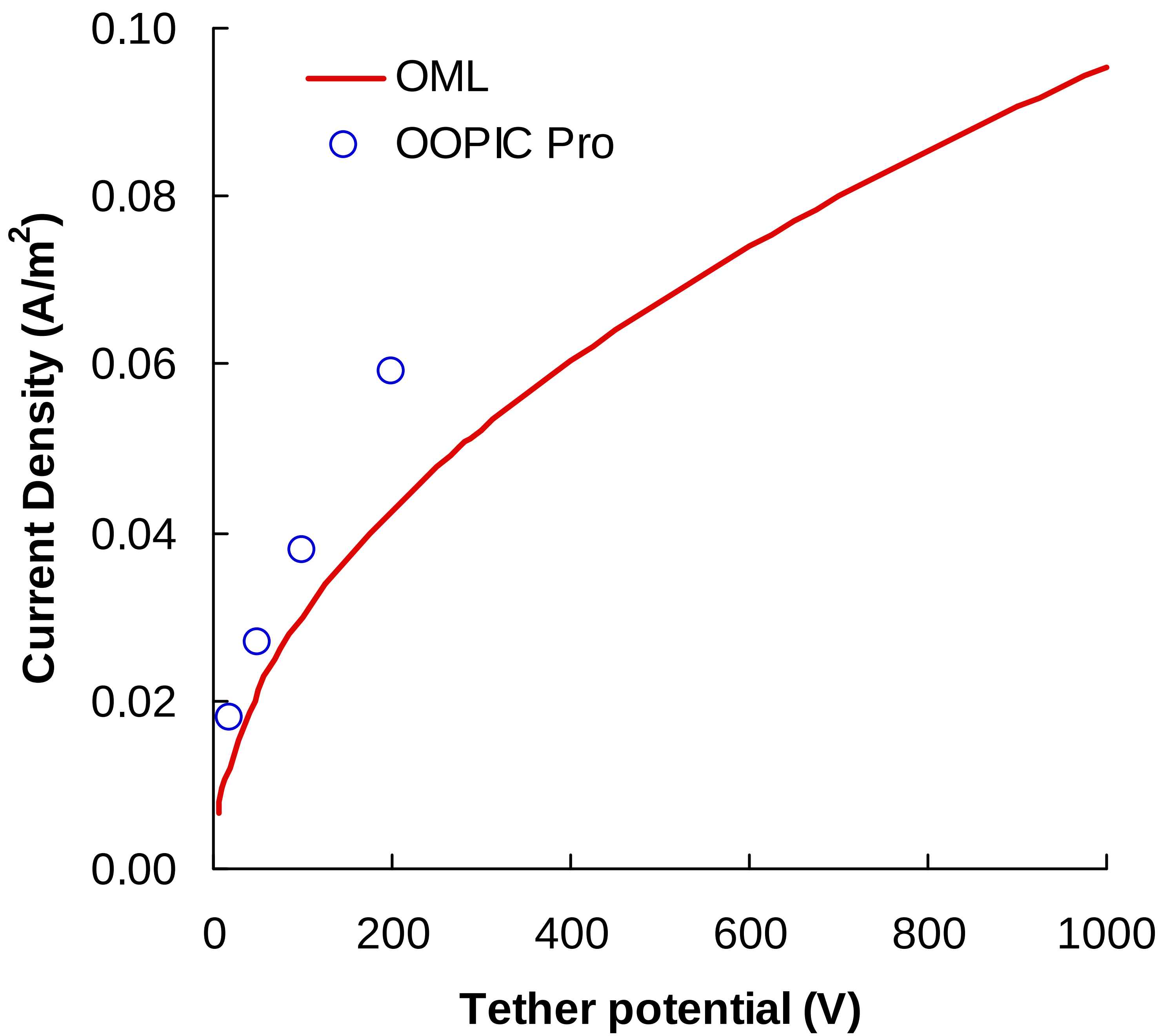
Plasma Contactor



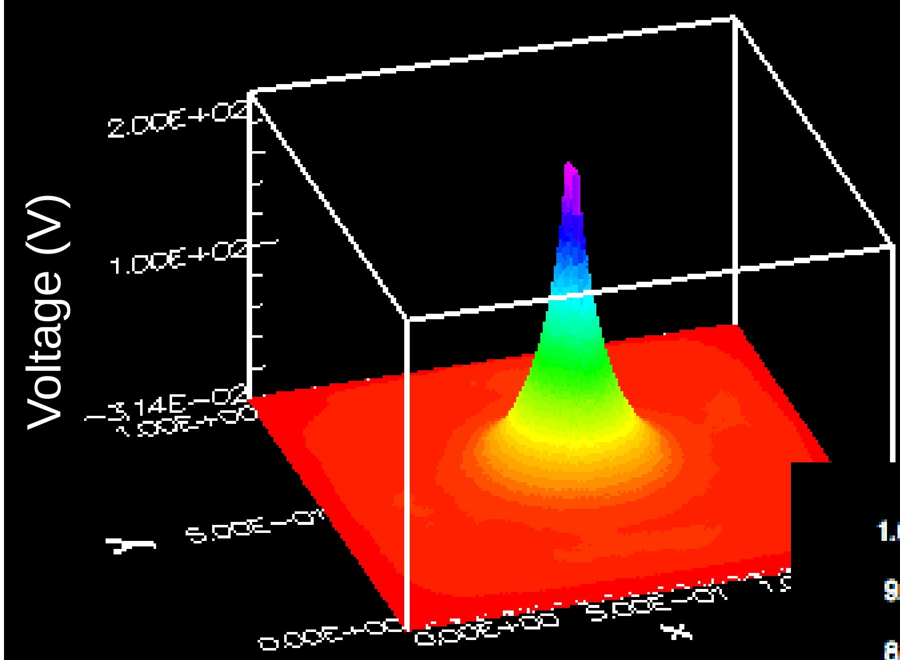
- Why not use electride to coat a tether and passively EMIT and COLLECT electrons?

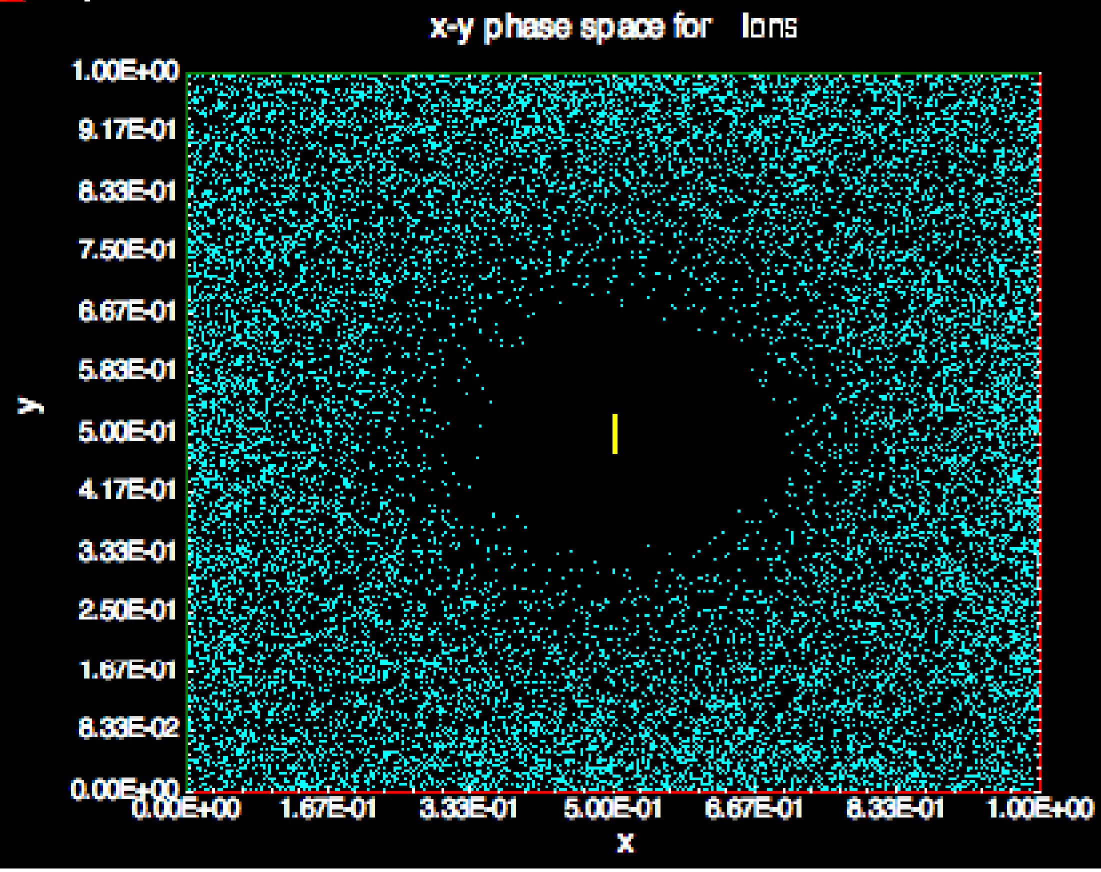
- One question to answer is where the floating point will end up.
  - How long is the negatively biased section relative to the positively biased section?

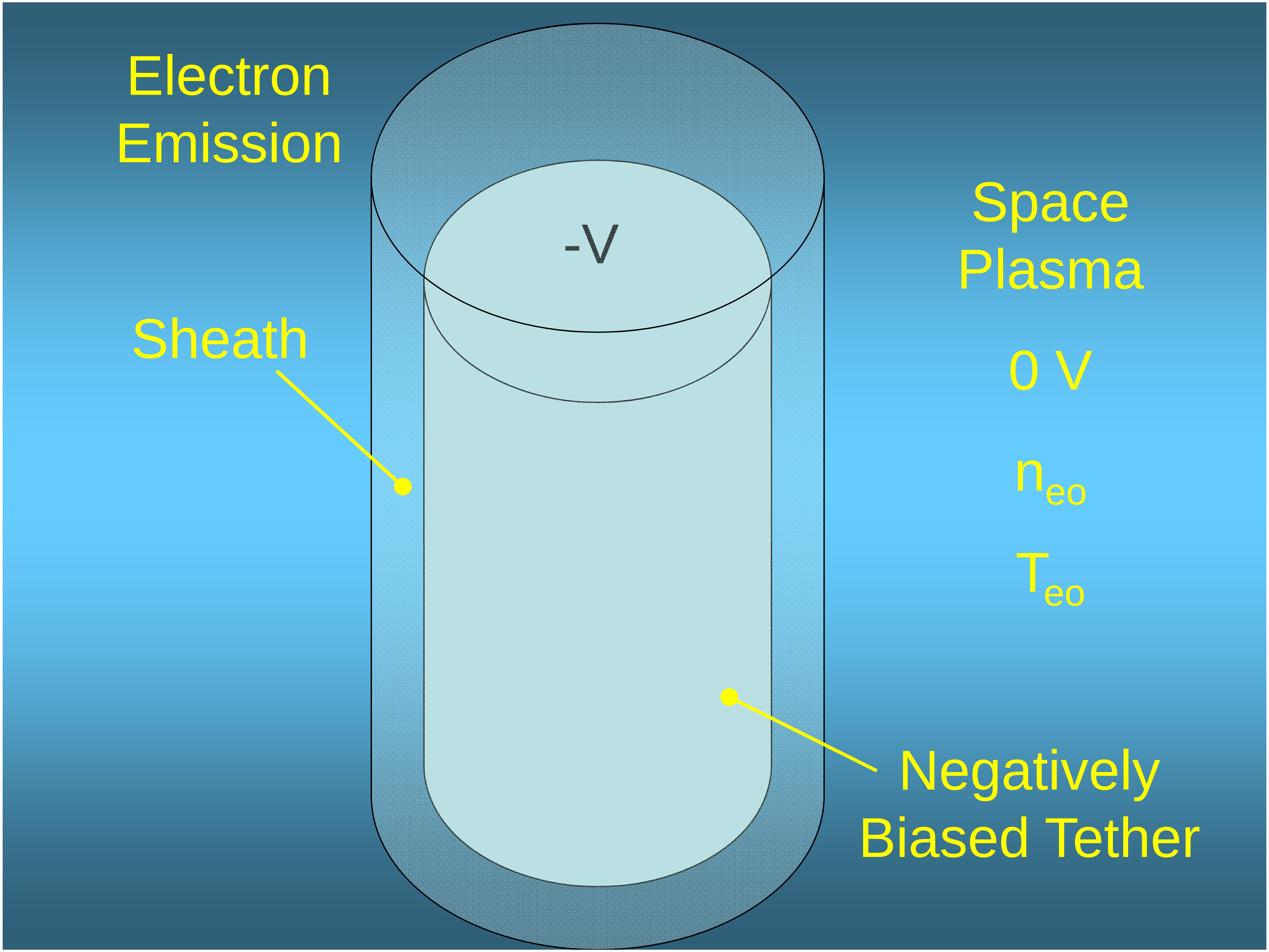

Electron
Collection
+V
Space
Plasma
0 V
n_{eo}
T_{eo}
Sheath
Positively
Biased Tether



OML
OOPIC Pro
Current Density (A/m^2)
0.10
0.08
0.06
0.04
0.02
0.00
0
200
400
600
800
1000
Tether potential (V)


Voltage (V)
2.00E+02
1.00E+02
-3.14E-02
5.00E-01
0.00E+00
y
x


x-y phase space for Ions
1.00E+00
9.17E-01
8.33E-01
7.50E-01
6.67E-01
5.83E-01
5.00E-01
4.17E-01
3.33E-01
2.50E-01
1.67E-01
8.33E-02
0.00E+00
y
0.00E+00
1.67E-01
3.33E-01
5.00E-01
6.67E-01
8.33E-01
1.00E+00
x


Electron
Emission
-V
Space
Plasma
0 V
n_{eo}
T_{eo}
Sheath
Negatively
Biased Tether

Thermionic Emission

$$j = AST^2 \exp\left(\frac{-e\Phi}{kT}\right)$$

$$S = \exp\left(\sqrt{\frac{e^3 V}{4\pi d \varepsilon_o}}\frac{1}{kT}\right)$$

Space Charge Limited Current

$$j = \frac{2}{9\pi}\sqrt{\frac{e}{2m}}\frac{V^{\frac{3}{2}}}{d^2}$$

$$j = (2.25x10^{-6})\frac{V^{\frac{3}{2}}}{d^2}$$

$j_{TE} > j_{SCLC}$?

$$j = (2.25x10^{-6})\frac{V^{\frac{3}{2}}}{d^2}$$

$j_{SCLC} > j_{TE}$?

$$j = AST^2 \exp(\frac{-e\Phi}{kT})$$

Some typical high current density emitters

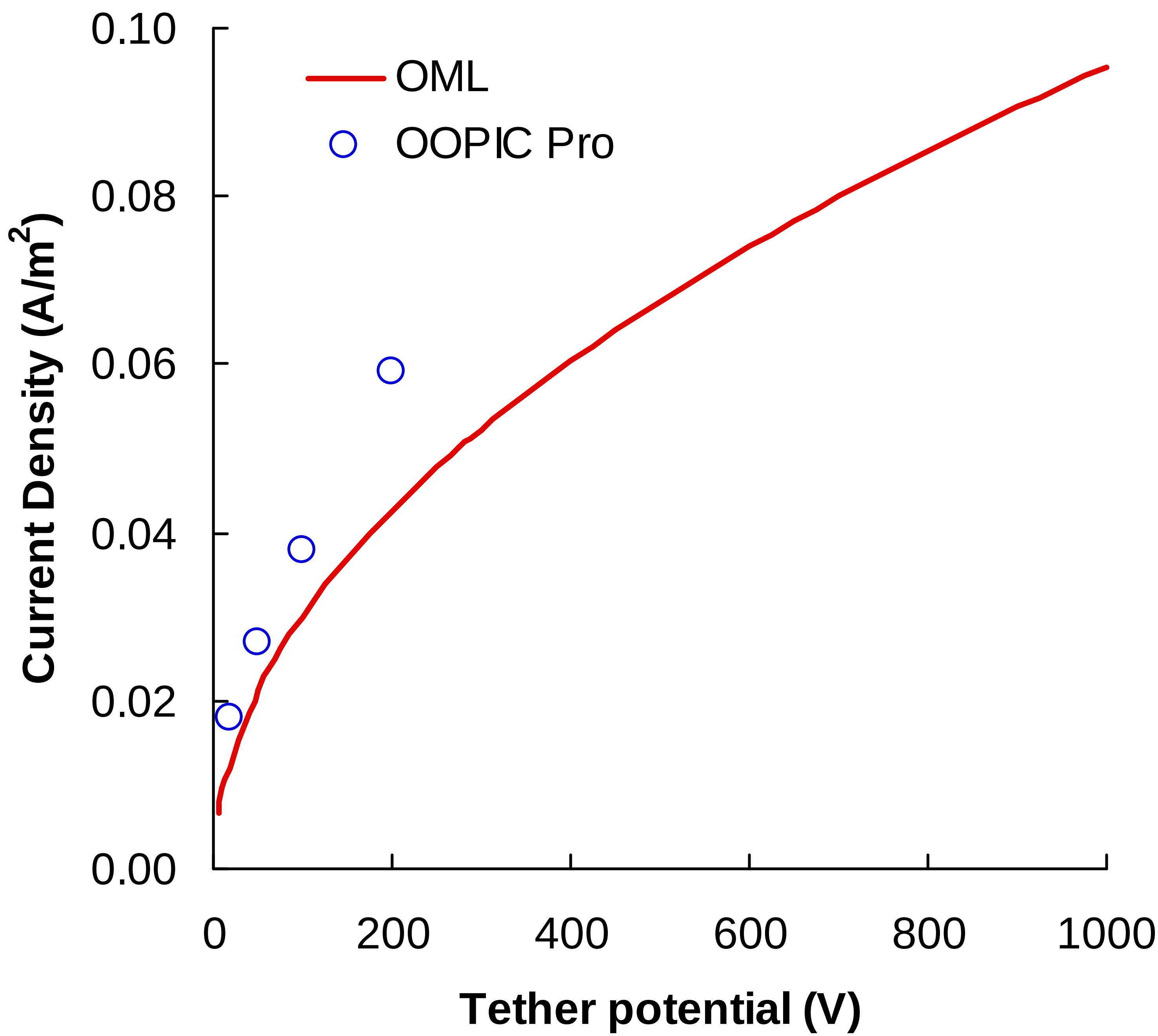
	Φ (eV)
LaB_6	2.66
CeB_6	2.43
Ba-W	2.14
C12A7	0.6

Same Geometry?

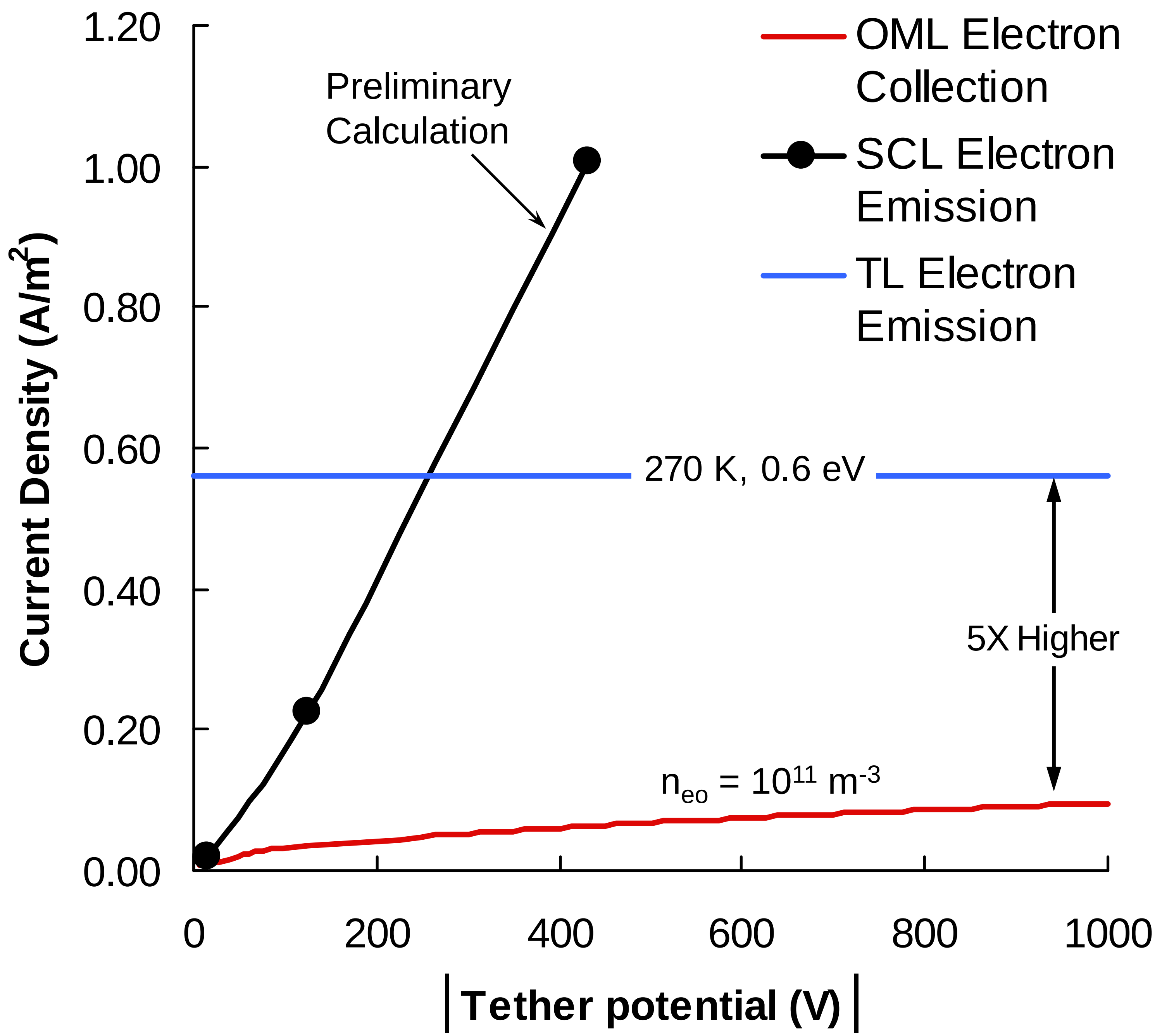
Same Applied Voltage?

Same Emission Current!

	T (K)
LaB_6	1900
CeB_6	1750
Ba-W	1350
C12A7	440



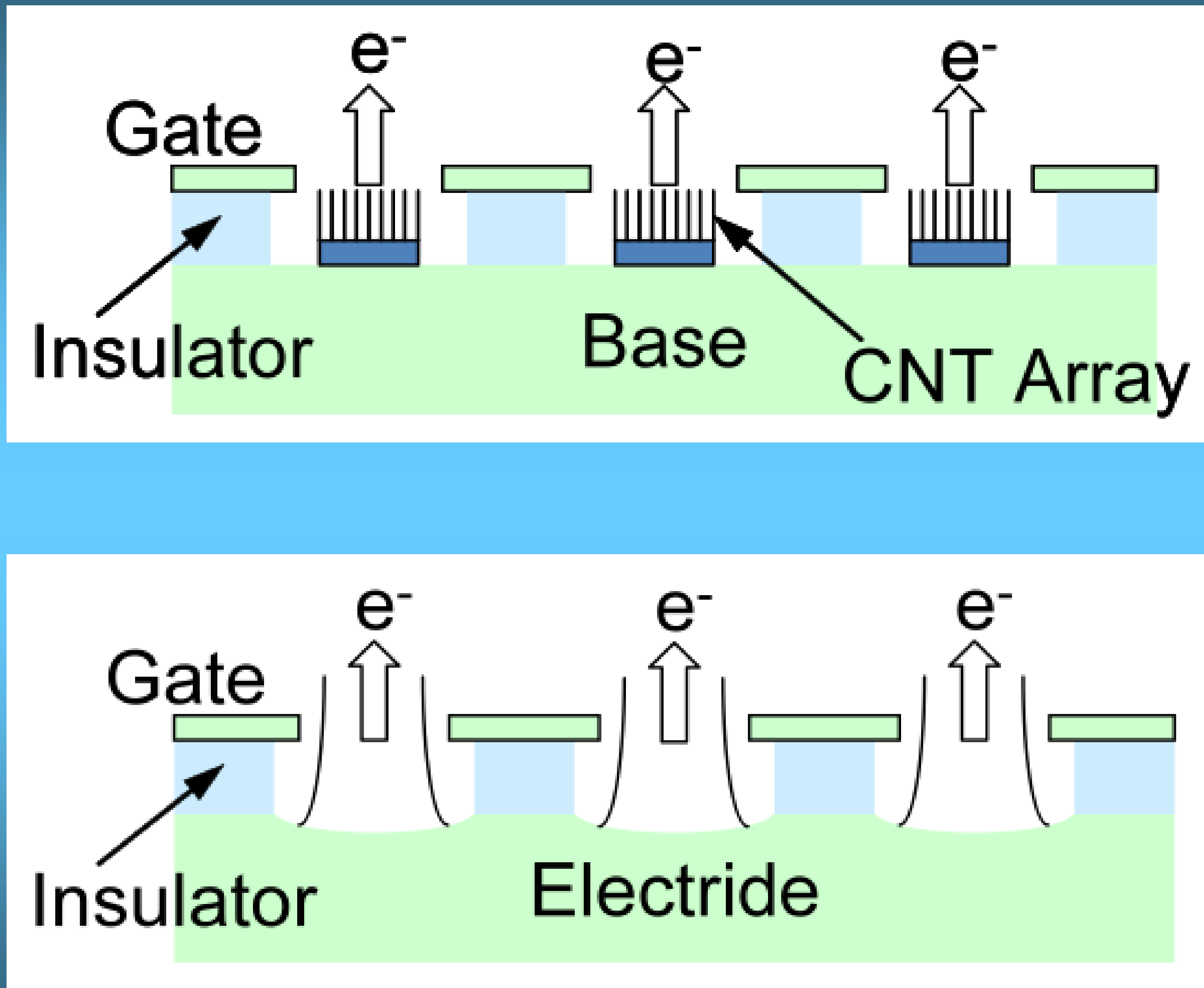
OML
OOPIC Pro
Current Density (A/m^2)
0.00
0.02
0.04
0.06
0.08
0.10
0
200
400
600
800
1000
Tether potential (V)



Current Density (A/m^2)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
200
400
600
800
1000
Tether potential (V)
Preliminary Calculation
OML Electron Collection
SCL Electron Emission
TL Electron Emission
270 K, 0.6 eV
5X Higher
$n_{eo} = 10^{11}\ m^{-3}$

Conclusion

- A new material may be available soon that has a very low work function that is stable under high emission current
- Preliminary calculations suggest that electron emission length of a bare tether might be ~1/5 of the positively biased section
- Ohmic heating might reduce negative bias section length even more
- Configuration of electride into gun geometry might be an alternative to coating tether



e-
e-
e-
Gate
Insulator
Base
CNT Array
e-
e-
e-
Gate
Insulator
Electride