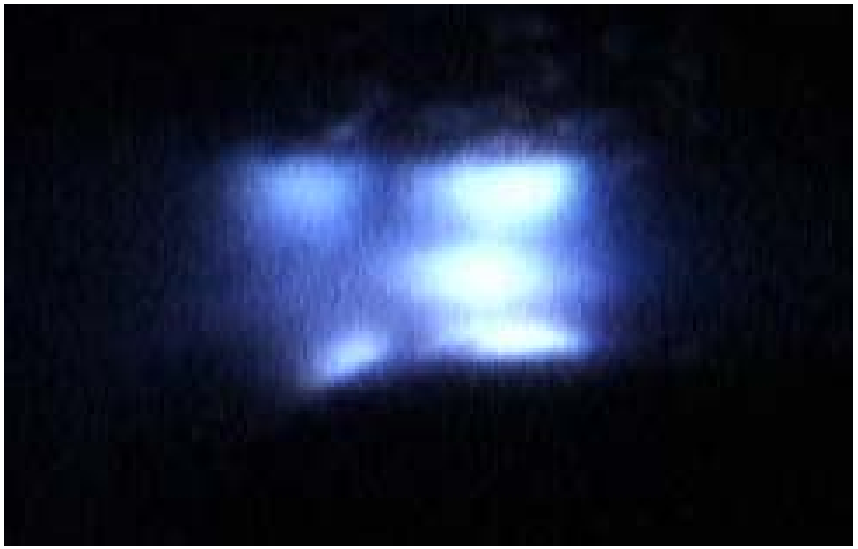
Voltage Breakdown and the Processing Mechanism



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Haven't We Conquered Field Emission and Voltage Breakdown Already?

Clean cavities are free of field emission;
we have learned how to clean cavities,
but cavities in an accelerator get dirty,
and performances deteriorates due to FE.

We still need to know how better to rid cavities of field emitters in situ. Ironically, we are now more interested in how to cause breakdown than how to avoid it.

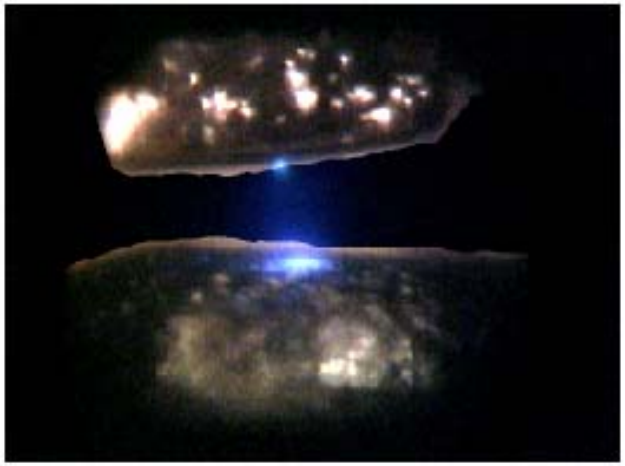
A Recipe For Breakdown

1. Start with enhanced field emission.
2. Add neutral gas.
3. Wait for a few nanoseconds;
   if there's no explosion of ions, repeat 2.

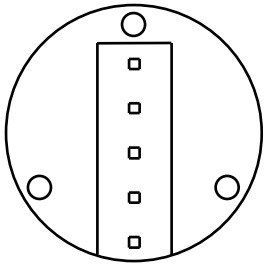
(There will be a demonstration later.)

Procedure:

- Clean cathode plate
- (Contaminate plate with powder in methanol)
- Photograph plate in SEI
- Install plate; adjust gap
- Increase voltage until breakdown (max: 15kV)
- Examine plate in SEM



Cathode Plate



Test Apparatus

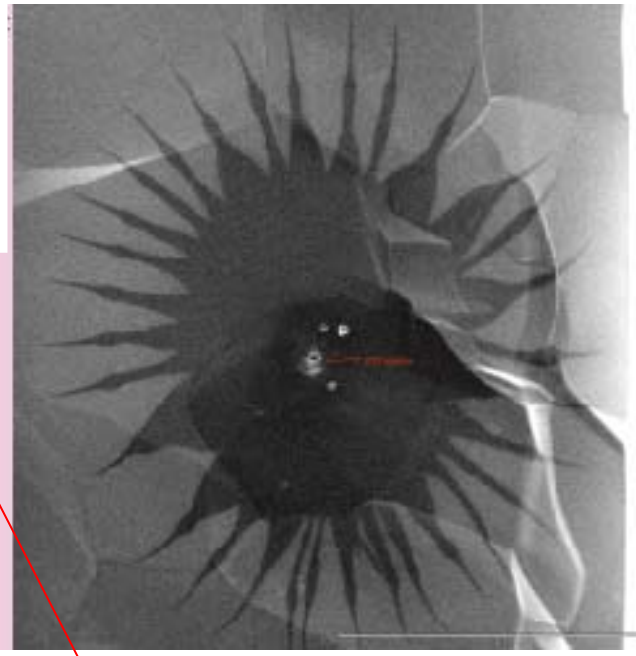
Another Clue to the Mechanisms of Breakdown

Thicker oxides reduce surface cratering during voltage breakdown.

The Cathode After Breakdown on a typical Nb surface

SEM (Secondary Emission) Images

AFTER

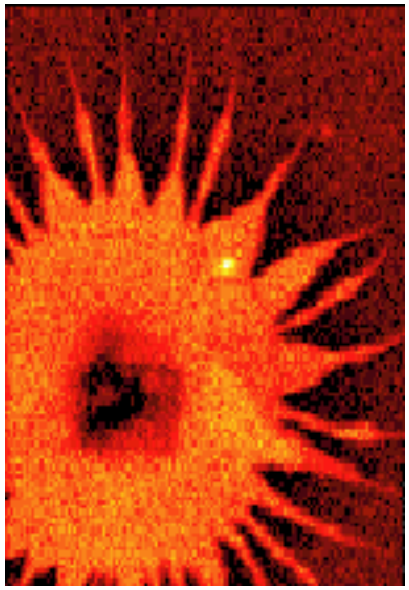


BEFORE

50um

Original particle was V

AES (Auger) images



Nb

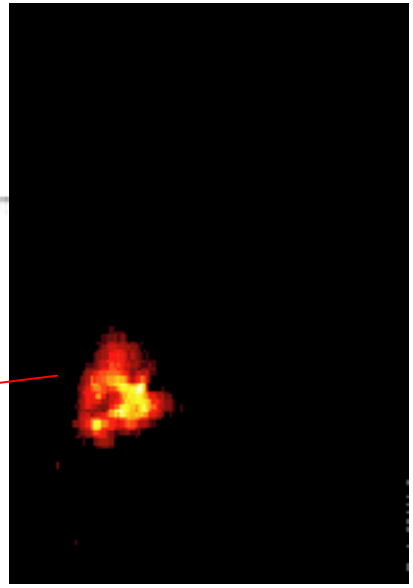
23550

0.0

C

81800

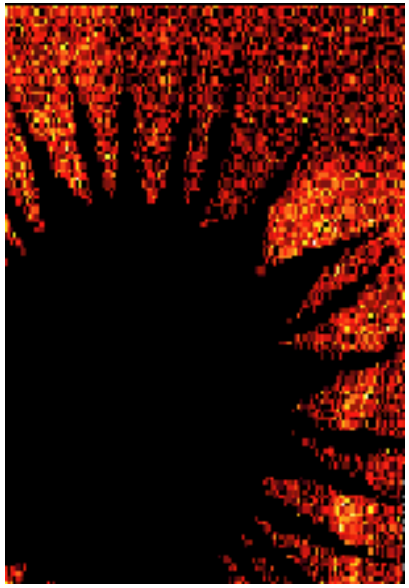
33078



V

35533

0.0

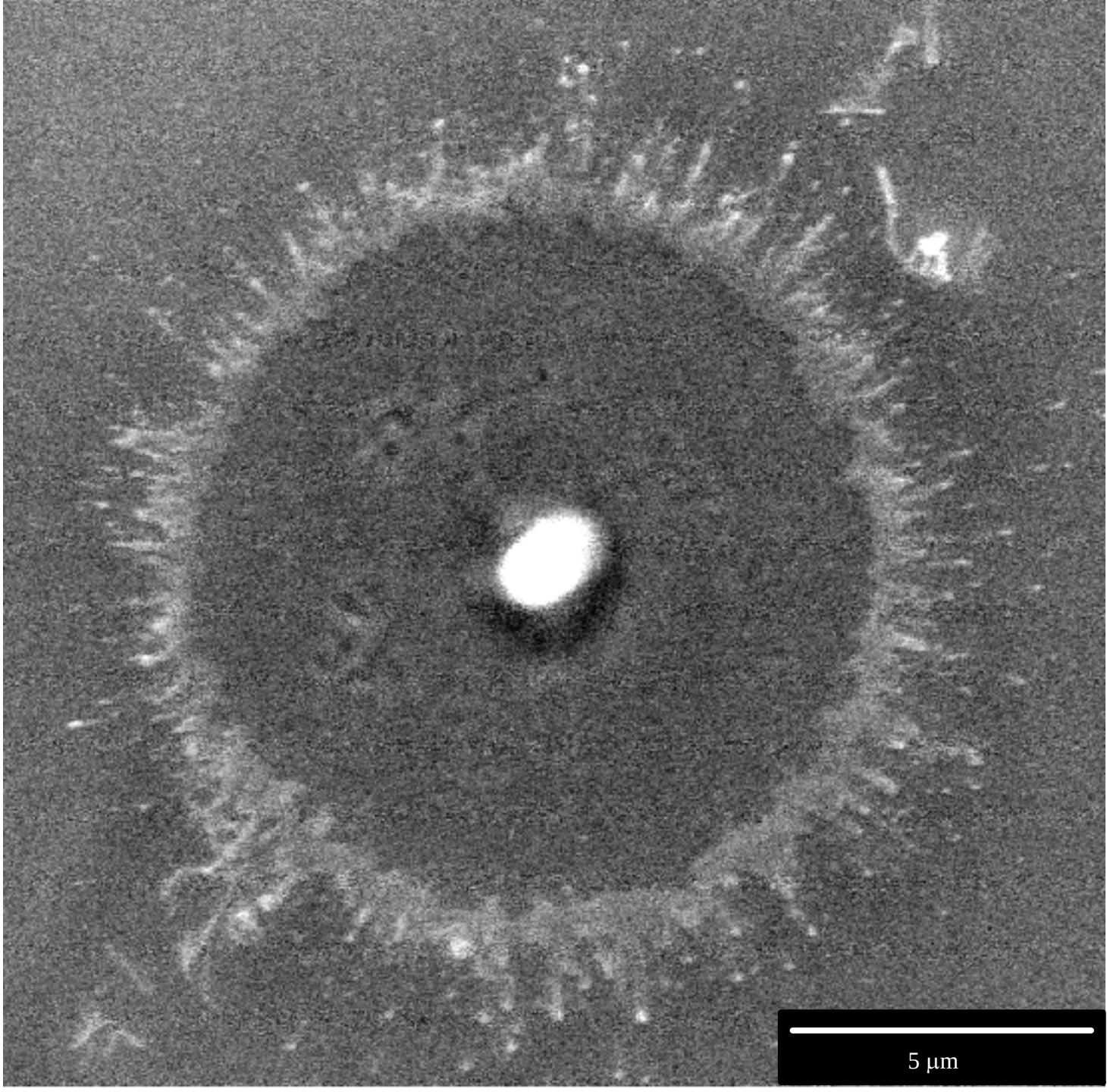


F

5900

0.0

A “starburst” on anodized Nb (oxide thickness = 600Å)

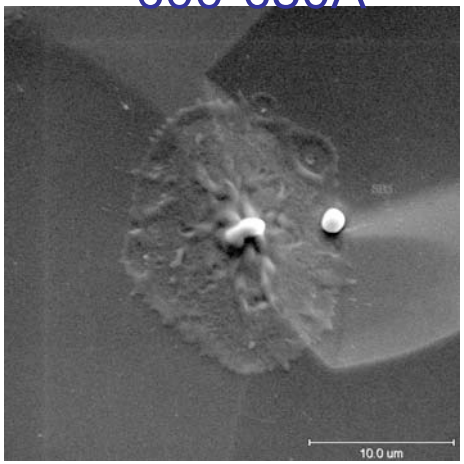


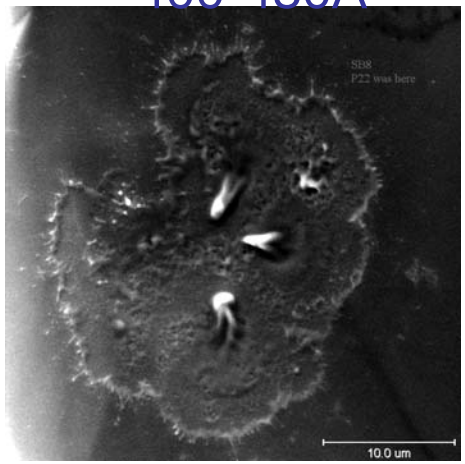
600-650Å

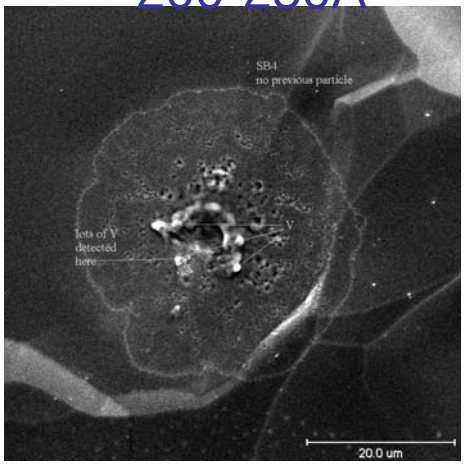
400-450Å

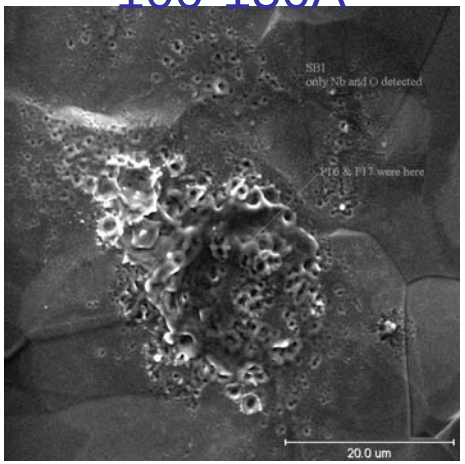
200-250Å

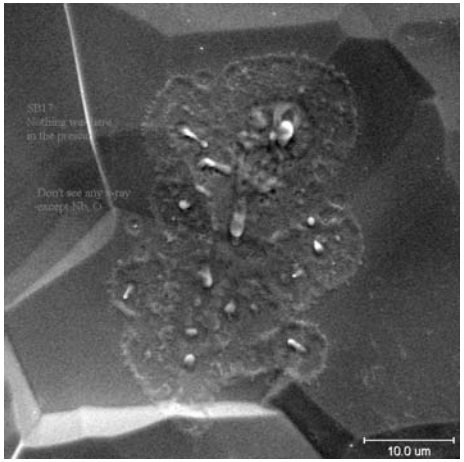
100-150Å

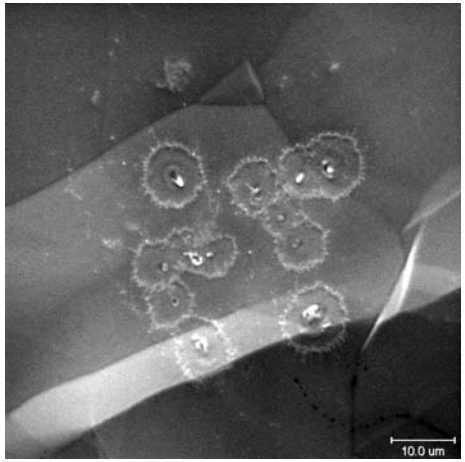


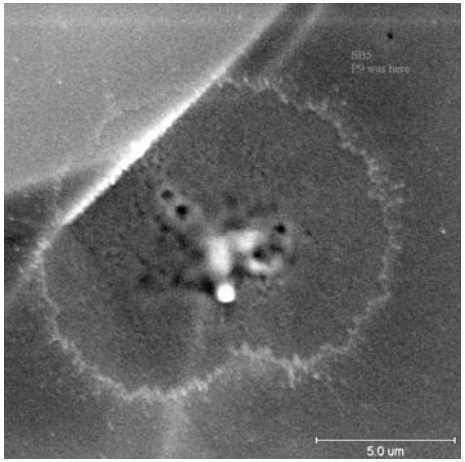


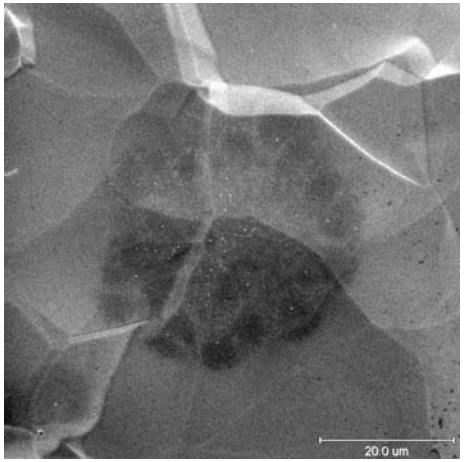




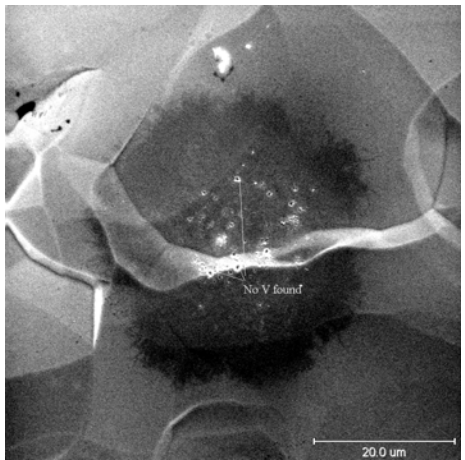


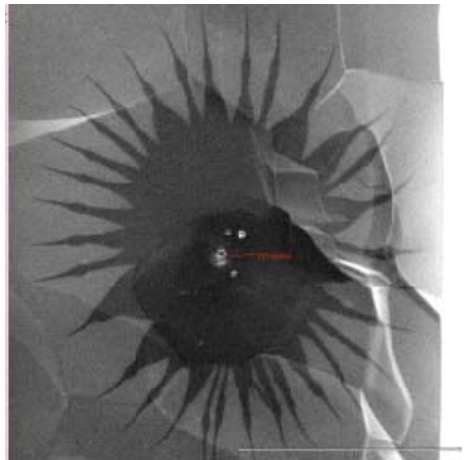






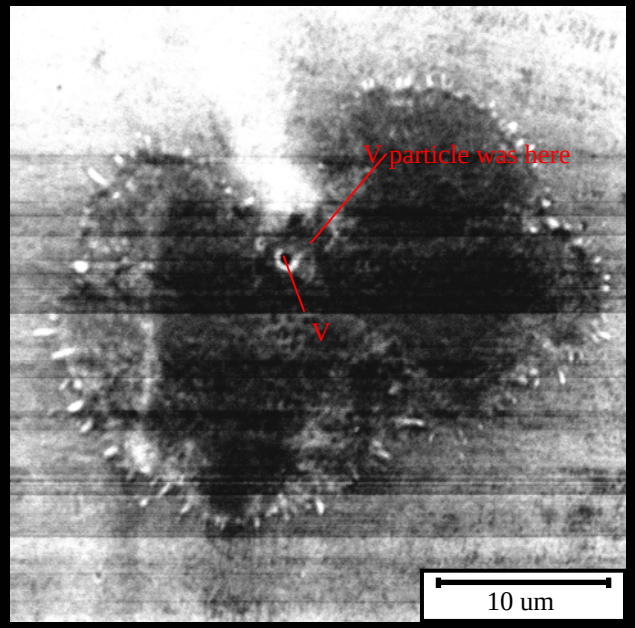
“Starbursts” on Nb anodized to different oxide thicknesses

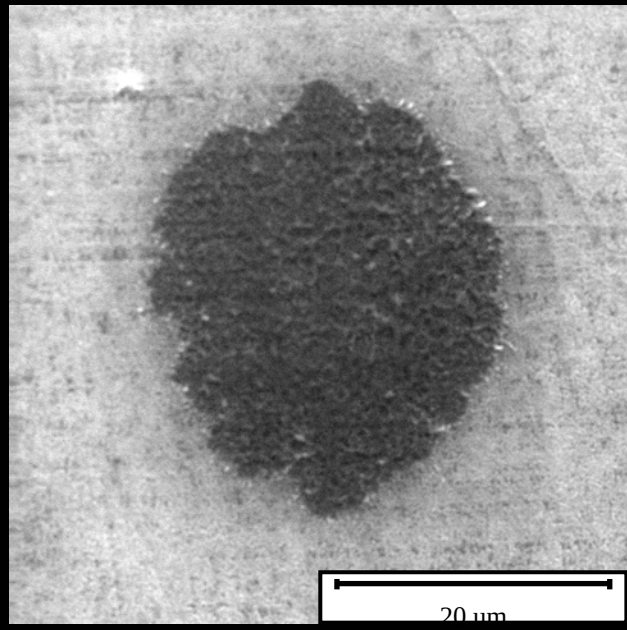


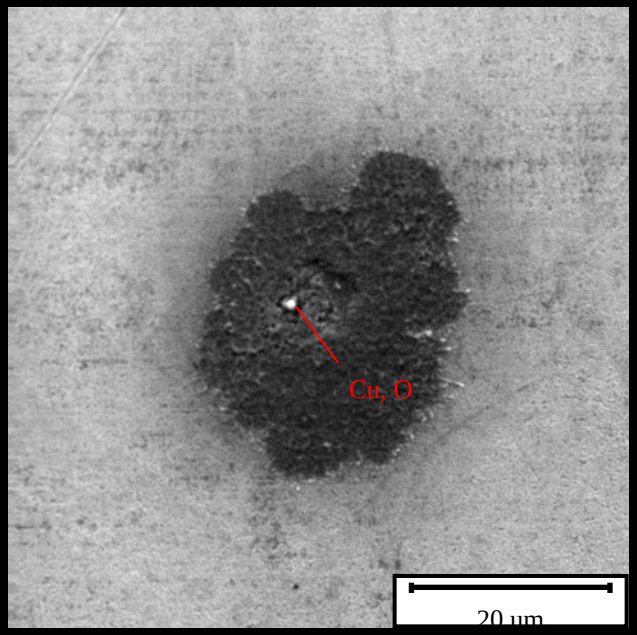


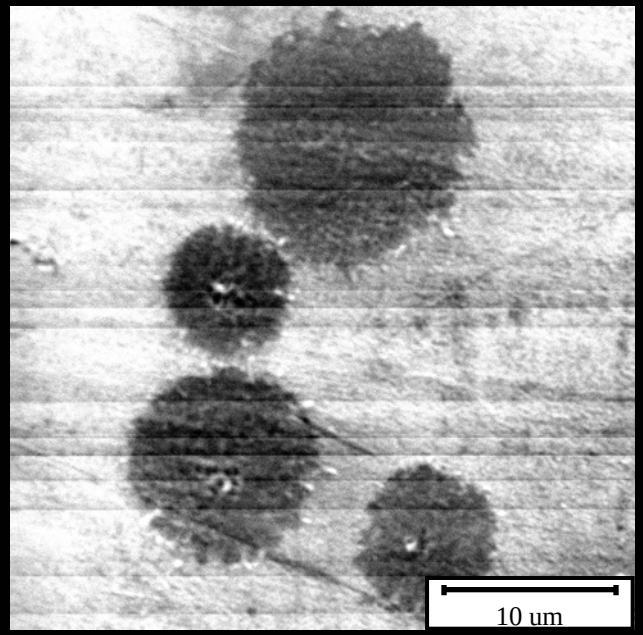
30-70Å

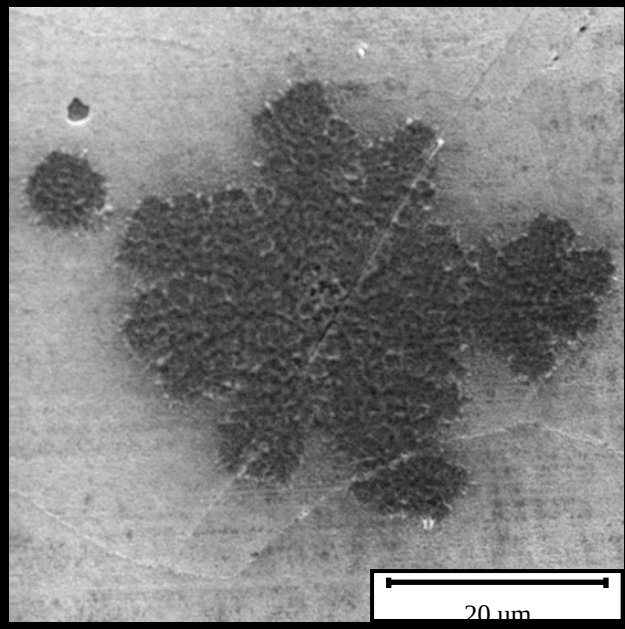
Starbursts on oxidized Cu (diamond-turned, not brazed) show less cratering



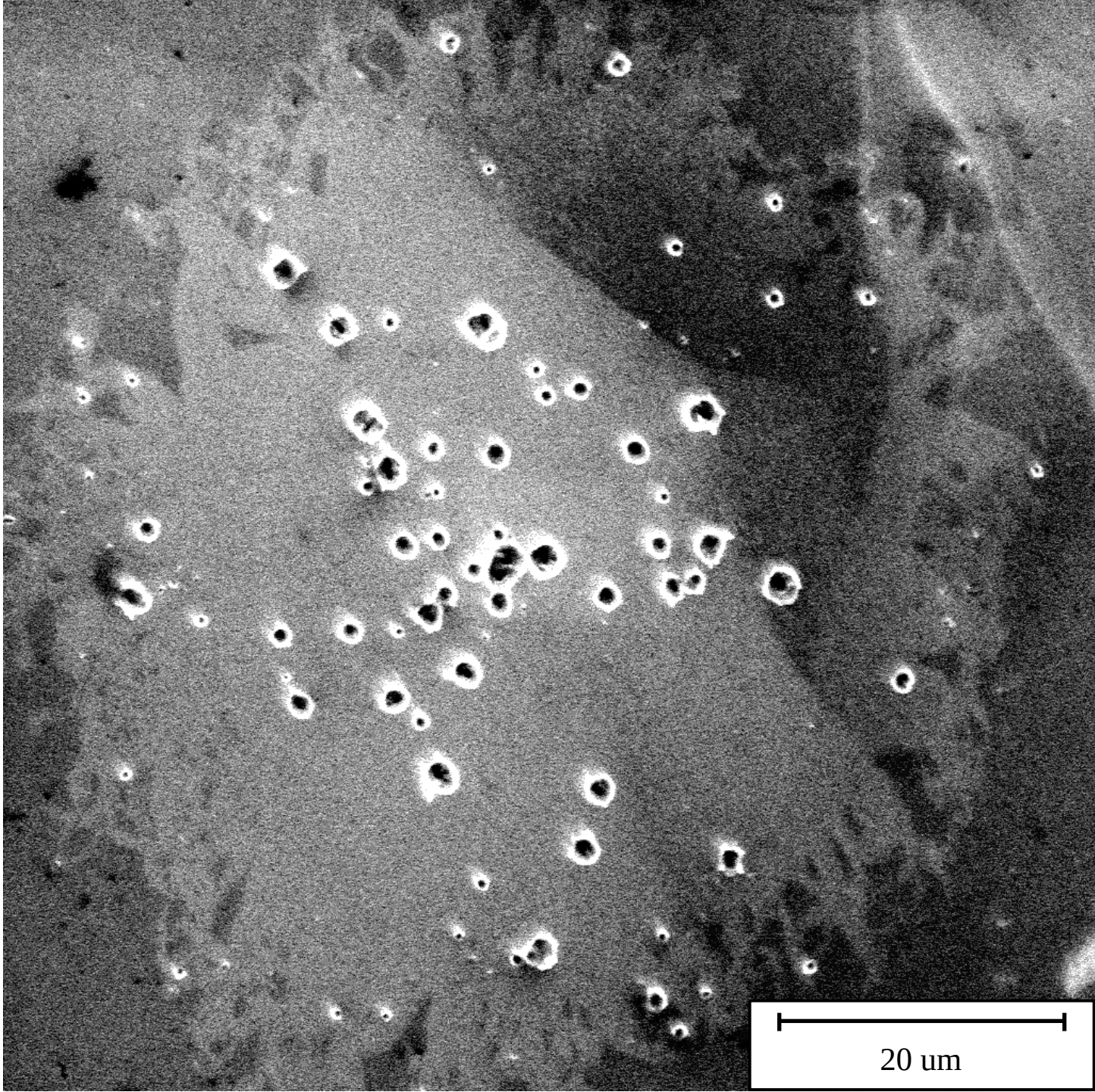








A starburst on 1000Å Au film on Nb substrate contains many small craters

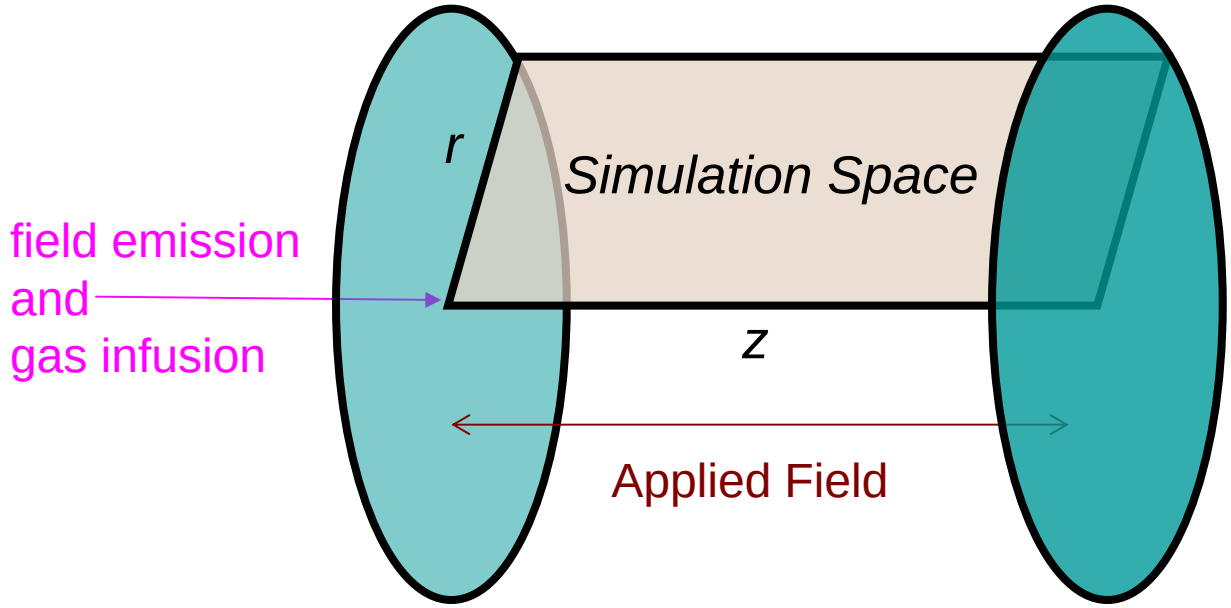


Simulation Code: OOPIC

Program: OOPICpro (object-oriented particle-in-cell code) maintained by TechX Corporation

- Open-source C++ code for Linux
- 2D square (x-y) and cylindrically symmetric (z-r) geometry
- Electrostatic and Electrodynamic field solvers (self-consistent, on mesh)
- Simulates particle collisions (including ionization) with Monte Carlo method

Our Simulation



Our simulations are similar to those done by Jens Knobloch using MASK:

Geometry: Cylinder, r=8um, z=32um, 64×128 grid

Field emission: β=250, A=0.034um^2

Electric Field: 30MV/m (DC or RF) Magnetic Field: ignored

Neutral gas: effuses from emitter region as if heated to 2000K

Timestep: 5 fs

5 GHz, 30MV/m, atoms/ions of mass 1 (H)

5 GHz, 30MV/m, atoms/ions of mass 40 (Ar)

DC, 30MV/m, atoms/ions of mass 40 (Ar)

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Phil Barnes
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