Nanometer Scale Patterning and Processing

Spring 2016

Lecture 30

Deposit Composition (Carbon/Metal)

Focused ion beam (FIB)

1. Focused ion beam induced deposition.
2. Focused electron beam induced deposition.
3. Deposition rate (electron and gas flux-limited regimes)
4. Deposit composition (carbon/metal)

How to reduce carbon?

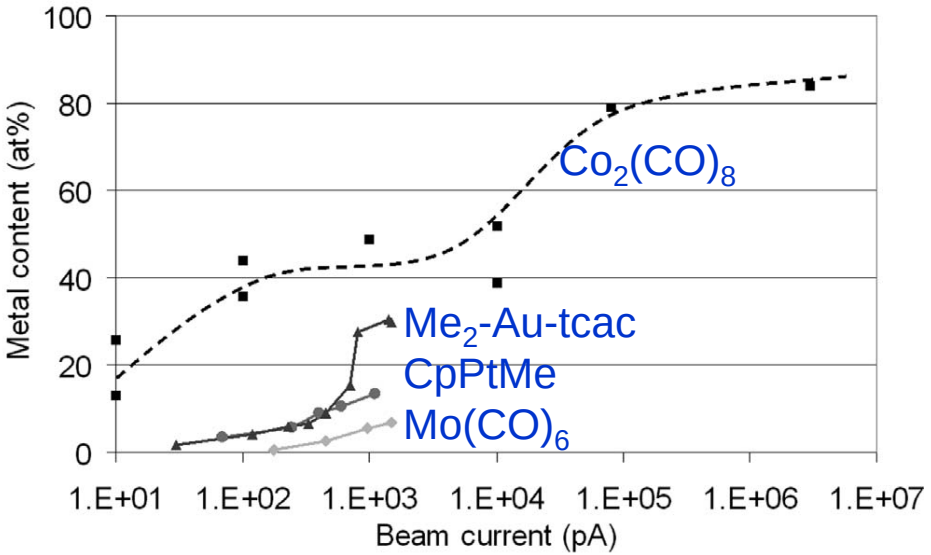
- Increase beam current.
- Add reactive gas such as H_2.
- Post-deposition processing – thermal treatment in oxidization environment.

Table 2. Carbon concentration of Pt deposit under different conditions Deposition

Extra Gas	Temp (°C)	C/Pt Ratio
none	150	10
H_2	150	10
H_2	200	10
H_2	250	10
H_2	300	5
H_2	310	No deposition

Effect of beam current on metal content and morphology

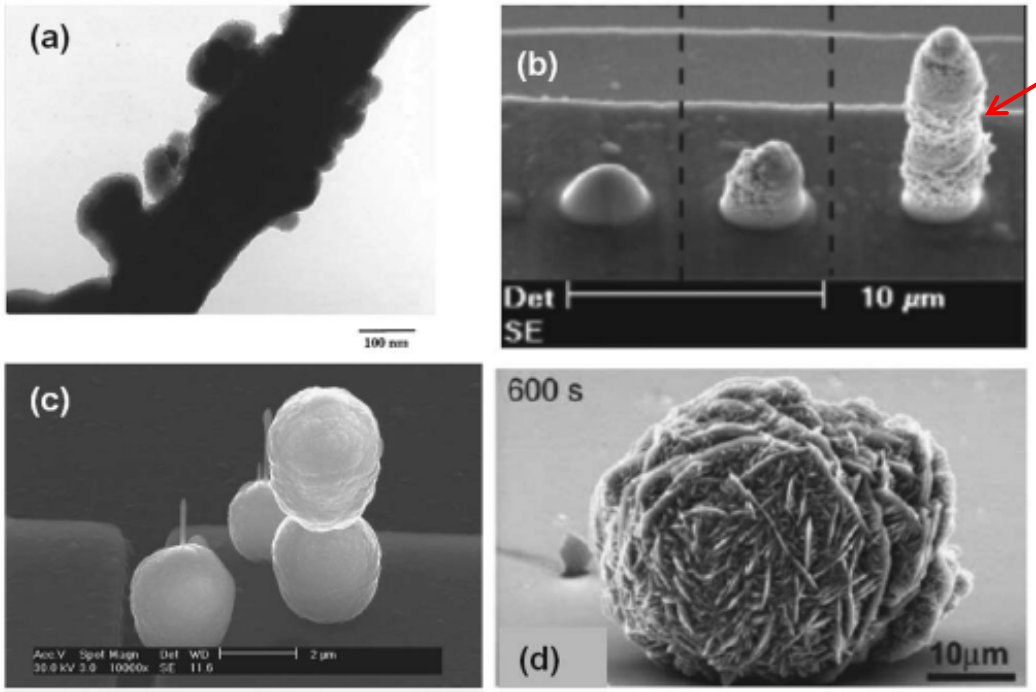
The metal content as a function of beam current.



The increase in metal content with beam current can be due to two parallel processes:

- Increase in beam current can induce an increase in the desorption of fragments of (initially only partially dissociated) precursor molecules. This can lead to higher concentrations of nonvolatile among others metal components in the final deposit.
- E-beam induced heating. A raise in temperature may, for instance, facilitate the desorption of volatile species as well as change the dissociation mechanism.

Effect of beam current on morphology



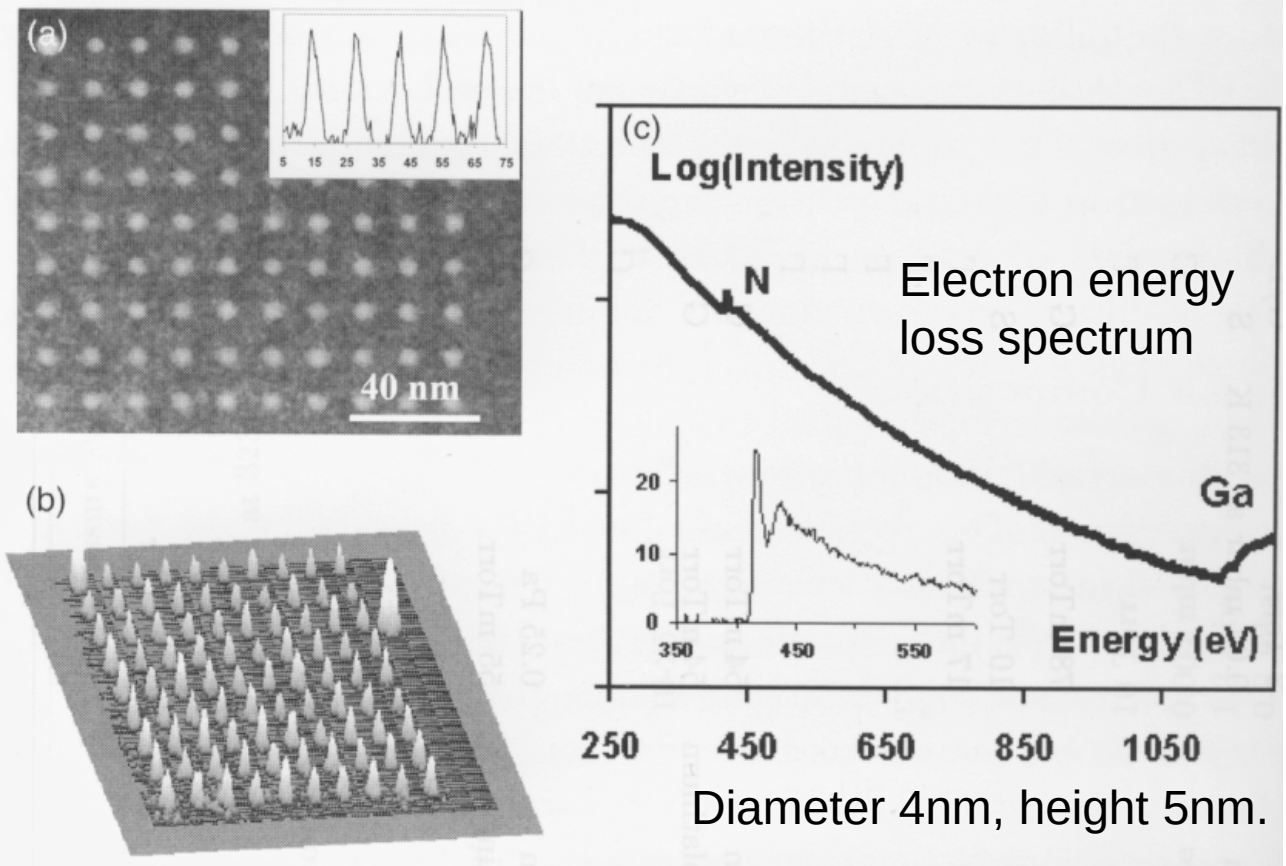
Higher current, rougher

Surface morphologies for high current deposits created with the beam in spot mode.

a) $Mo(CO)_6$
b) hfac-Cu-VMTS
c) c) $Co(CO_3)NO$
d) $Co_2(CO)_8$.

Generally, at low beam currents, the deposit is smooth and completely amorphous with high impurity concentration.
At high beam currents, the deposit is rougher with irregular shape and is polycrystalline, the crystallites being between 2nm and 8nm in size.

Contaminant-free deposit of GaN in UHV

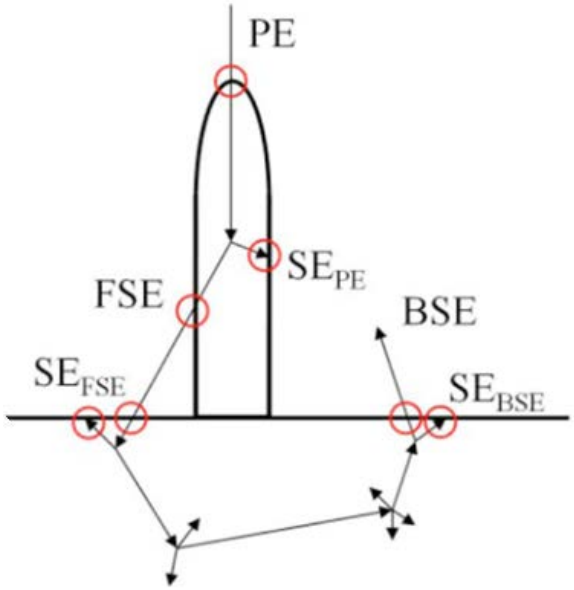


Precursor gas is D_2GaN_3

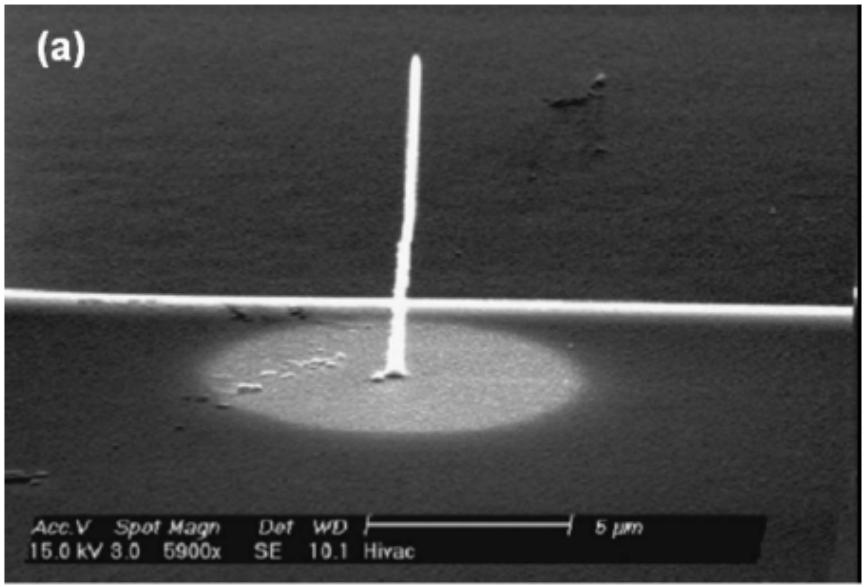
$D_2GaN_3 + e^- \rightarrow GaN\ (solid) + D_2 + N_2$

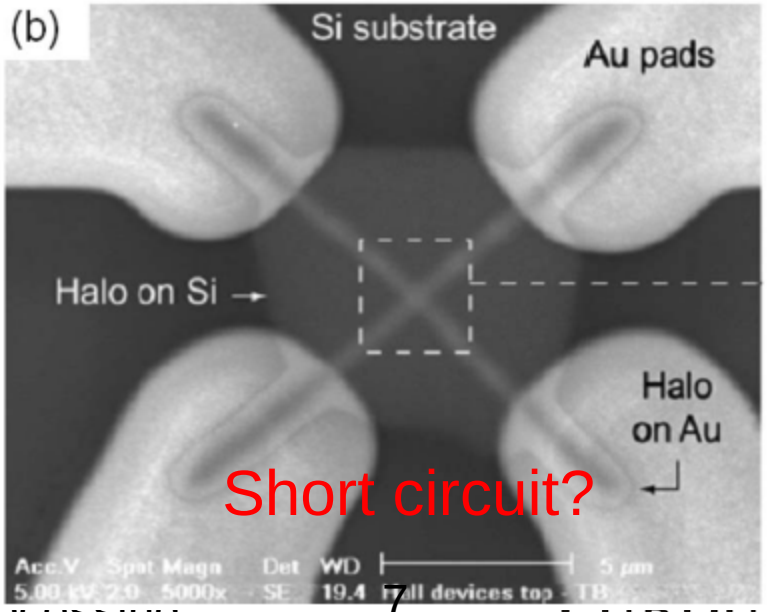
Proximity effect

- Proximity effect is due to backscattering
- It leads to deposition over large surface area at the base.
- It may cause short circuit.



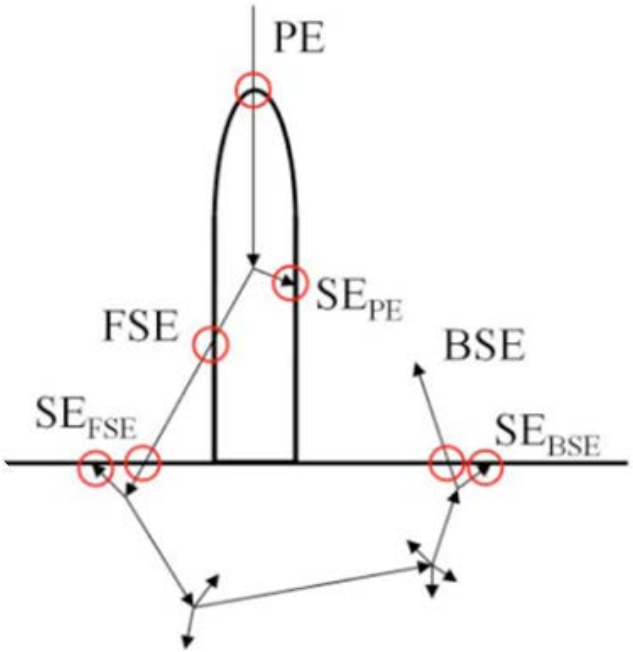
A halo around a deposited tip due to proximity effect as it is known in e-beam lithography.





High aspect ratio structures

- It is possible, but not as easy as FIB-induced deposition.
- Electron penetrate deep inside the nano-rod and can escape from a point far below the rod apex, causing continuous deposition at points well below the apex.



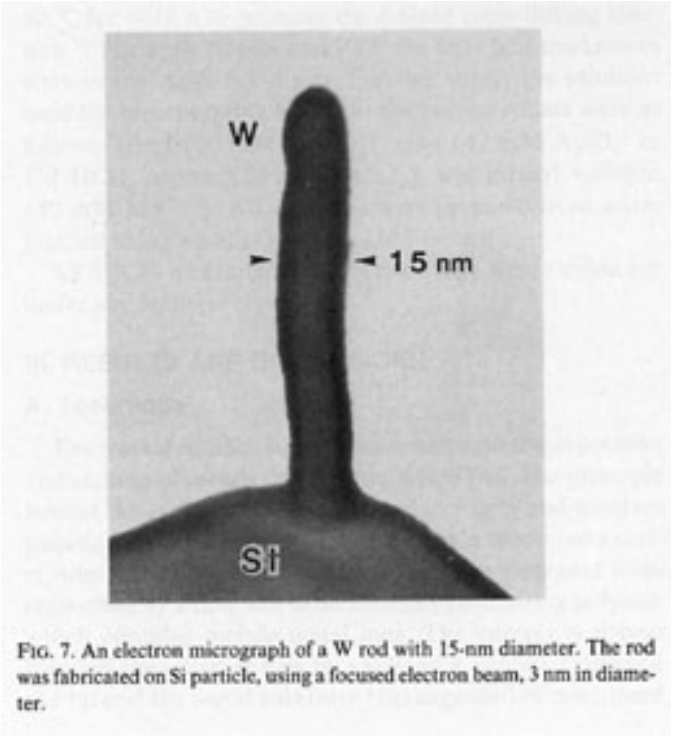


FIG. 7. An electron micrograph of a W rod with 15-nm diameter. The rod was fabricated on Si particle, using a focused electron beam, 3 nm in diameter.

Focused electron beam deposition
Tip diameter: 15nm (W-tip)
V=120kV, beam diameter = 3nm

Focused ion beam deposition,
high aspect ratio easy to achieve

S. Matsui and T. Ichihashi, JAP 53 (1982) 34