The Latest Development of Electron Beam Lithography as a Tool for Nanotechnology

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Why e-beam lithography ?

- Highest resolution (< 5nm)
- Large substrate size (6” wafer)
- Multi-level patterning (alignment error <20nm)
- Reasonably high throughput
- High flexibility
- Fast prototyping

What are the alternatives ?

- STM/AFM lithography (low throughput, small substrate size)
- X-ray lithography (need masks, high investment)
- Nanoimprint (need masters, crude alignment)
- Optical lithography (need mask, >50nm resolution)

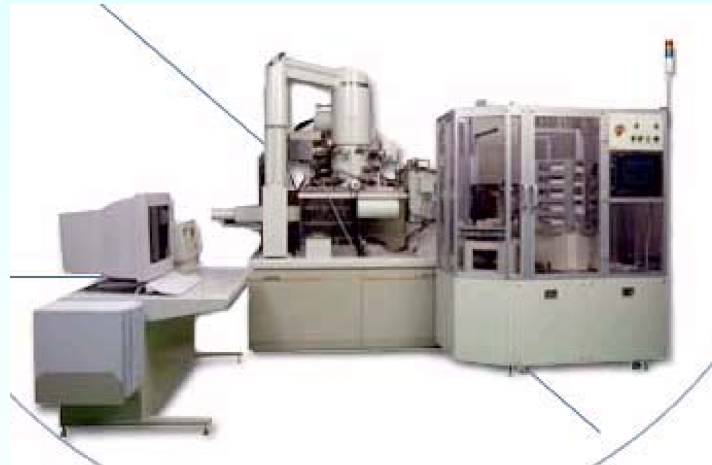
The available tools:

Commercial e-beam lithography systems

VB6-HR

Raith 150

LION-LV1



JEOL JBX9300FS

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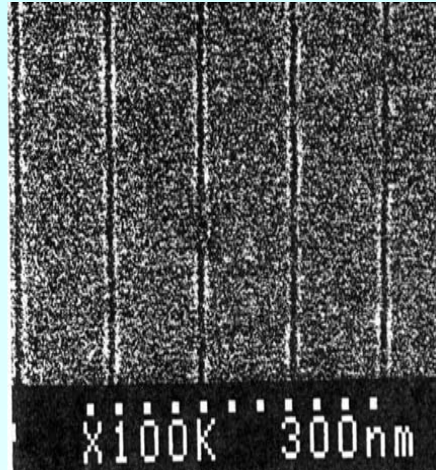
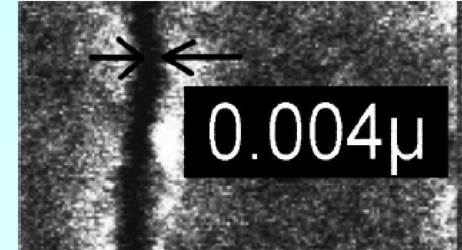
The capability:

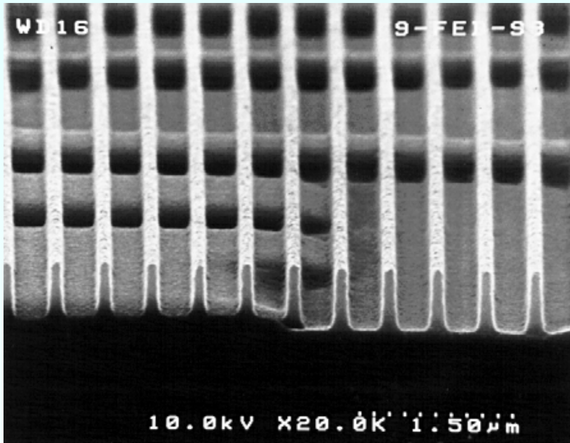
30nm line by VB6 (Z.Cui, RAL, 1998)



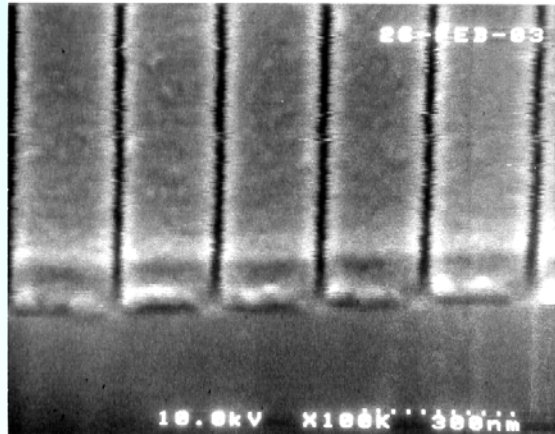
5-7nm lines by non-commercial e-beam system(W.Chen, Cambridge University, 1997)

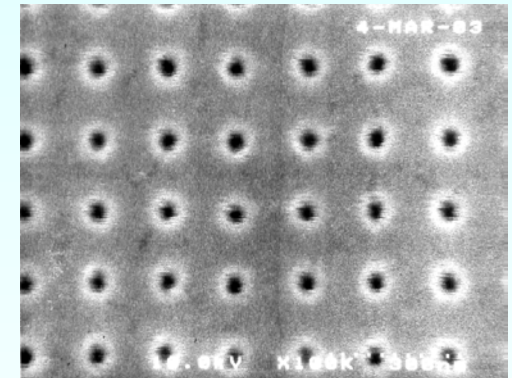


4nm line by non-commercial e-beam system (S.Yasin, Cambridge University, 2001)



150nm lines over 6” wafer by VB6 (Z.Cui, RAL, 1999)


20nm lines by VB6 (Y.Chen, RAL, 2003)



30nm holes by VB6 (Y.Chen, RAL, 2003)

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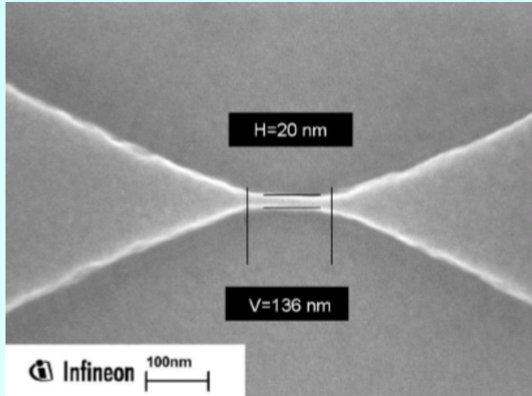
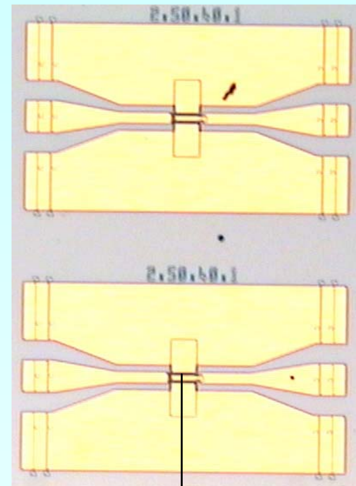
The applications:

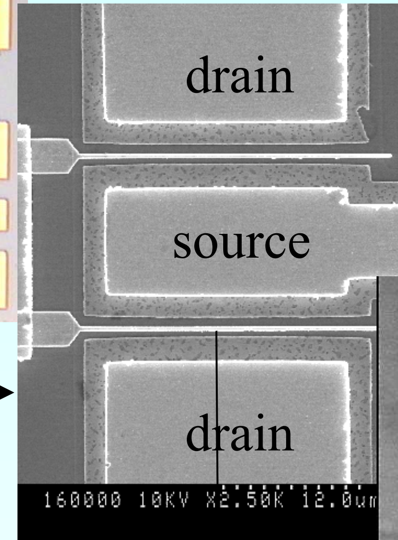
- Nanoelectronics
  - Nano MOSFET, single electron transistor, microwave device
- Nano devices based on carbon nano tubes
- Nano magnetic device for high density information storage
- Making master tools for nanoimprinting
- Nano surface modification for molecule self assembly
- Making nano electrode – connect nano world to micro and macro world

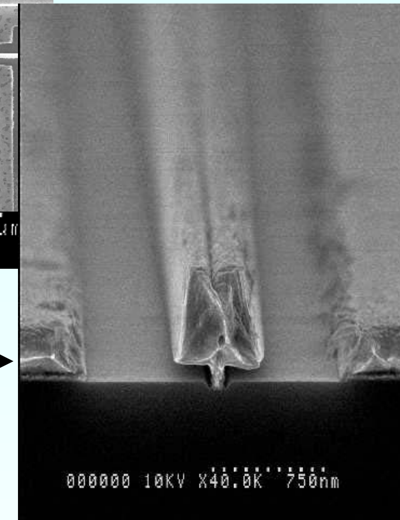


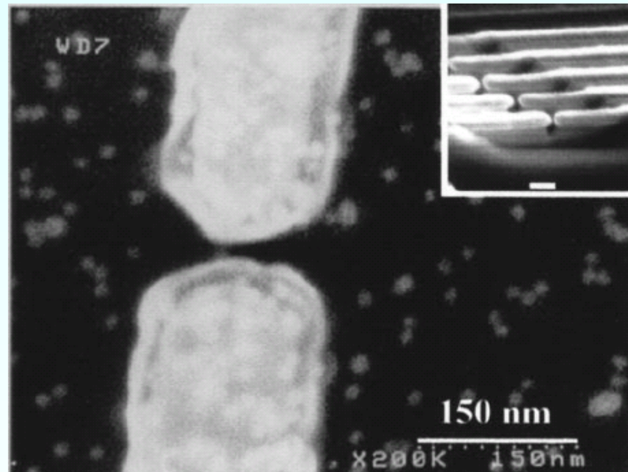
J. Kretz , L. Dreeskornfeld
"Process integration of 20 nm electron beam lithography and nanopatterning for **ultimate MOSFET device** fabrication", Micro. Eng. V.61-62, 207 (2002)



HEMT for >100GHz microwave circuits, where the 30nm T-gates are fabricated by e-beam lithography



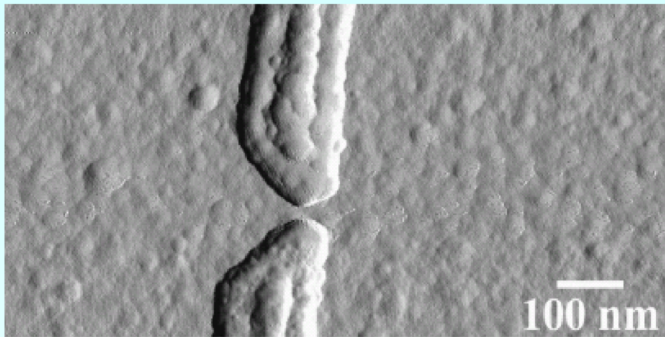




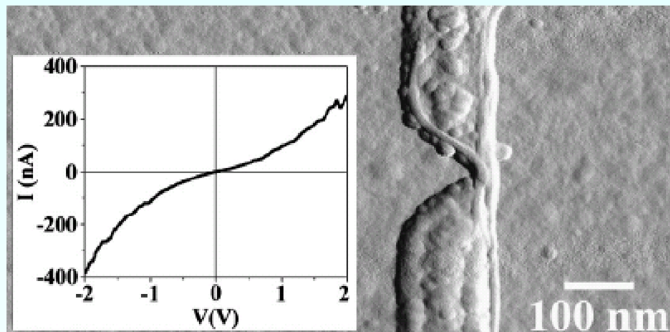
C.S.Wu, C.D.Chen, et al
"**Single-electron transistors** and memory cells with Au colloidal islands" Appl. Phys. Lett, V.84(24), 4595 (2002)

Y.Chen, D.Edgar, X.Li, D.Machintyre, S.Thoms
"Fabrication of 30 nm T gates using SiNx as a supporting and definition layer", J. Vac. Sci. Technol. B.18(6), 3521 (2000)

- Place nanotubes to electrodes:



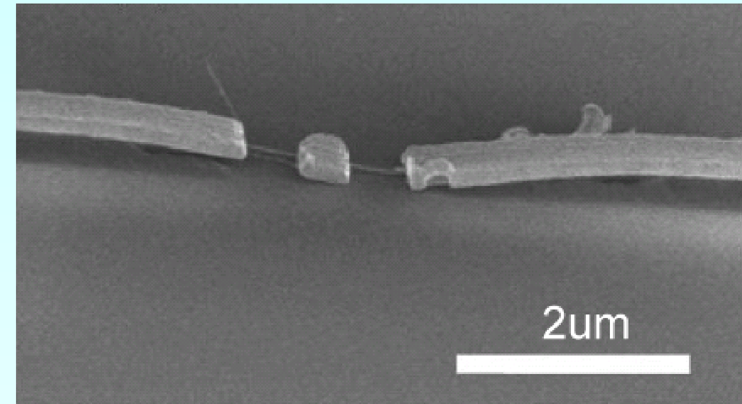
Electrode made by e-beam lithography, leaving 25nm gap

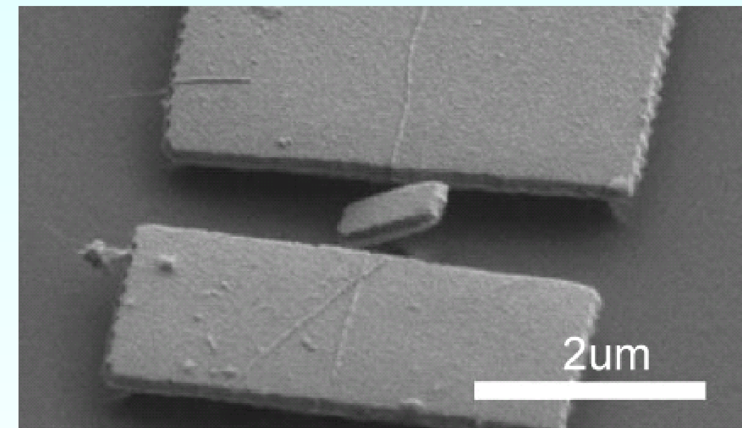


Two strands of bundled single-wall nanotubes bridge the nanoelectrode gap, inset is the I-V plot

Larry A. Nagahara, et al, "Directed placement of suspended carbon nanotubes for nanometer-scale assembly" Appl. Phys. Lett, V.80(20), 3826 (2002)

- Place electrodes to nanotubes:

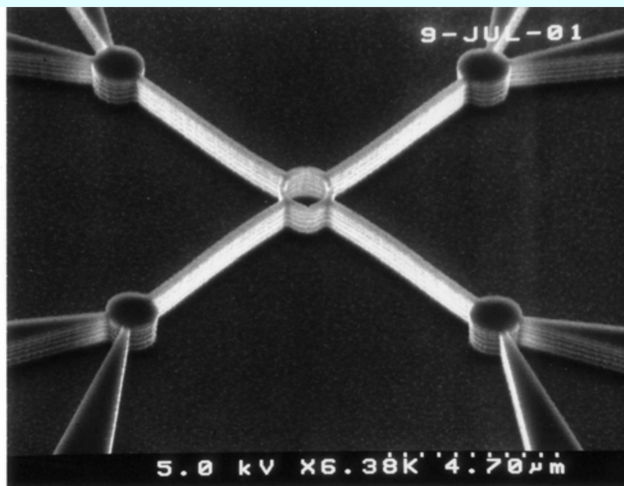




P.A.Williams, "Fabrication of nanometer-scale mechanical devices incorporating individual multiwalled carbon nanotubes as torsional springs", Appl. Phys. Lett, V.82(5), 805 (2003)

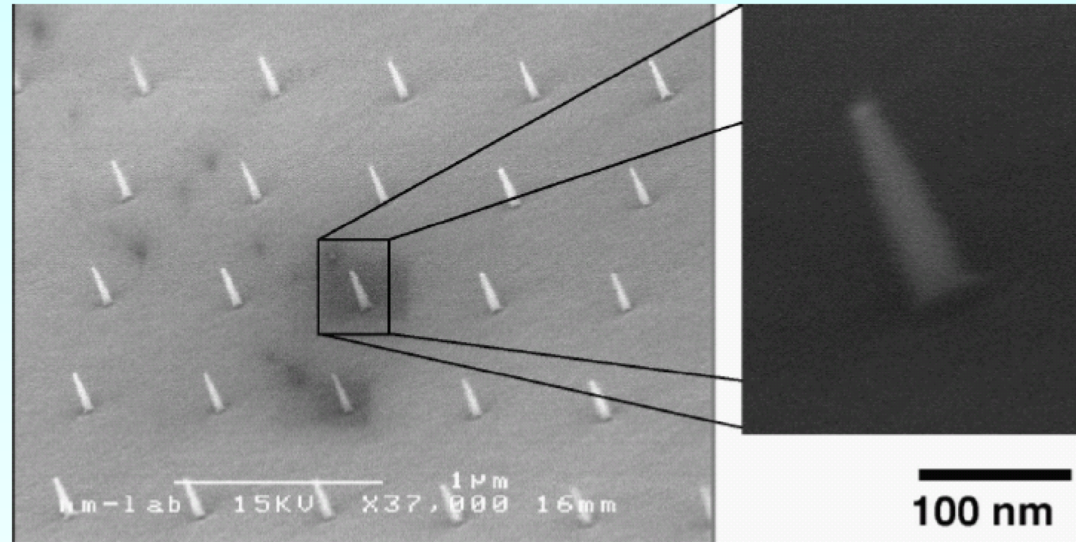
- Conventional magnetic recording devices rely on e-beam lithography to reduce dimension, therefore, increase storage density

Magnetic ring elements by e-beam lithography and dry etching for high density storage device



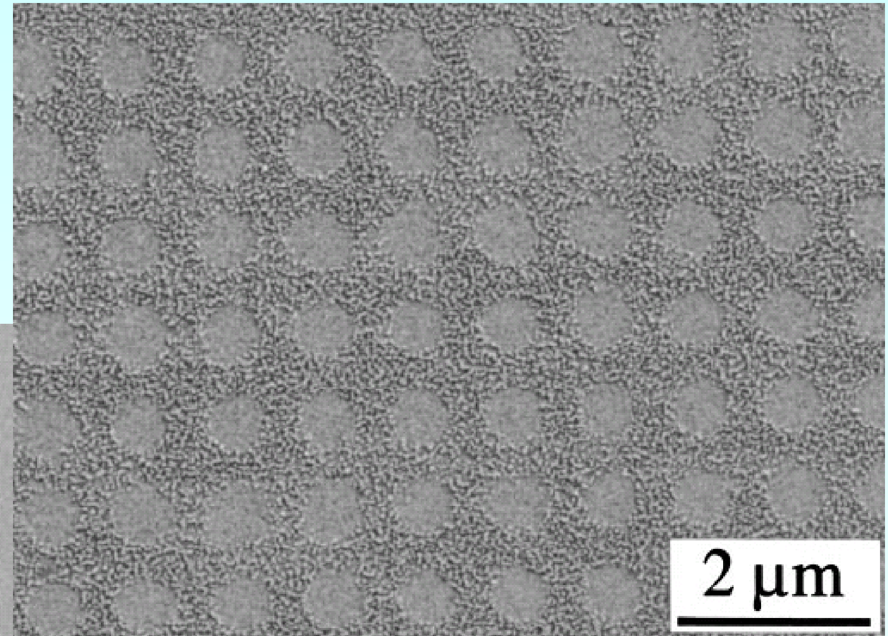
Z.Cui, et al, “Fabrication of magnetic rings for high density memory devices”, Micro. Eng., V.61-62, 577 (2002)

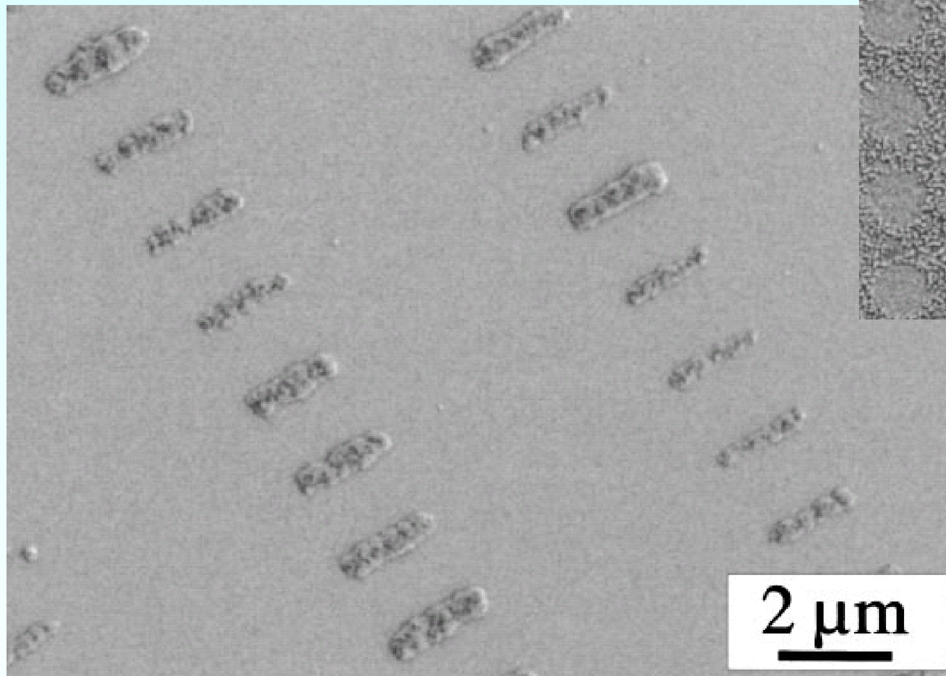
- Nanoimprinting relies on high resolution e-beam lithography to make the imprint master stamps



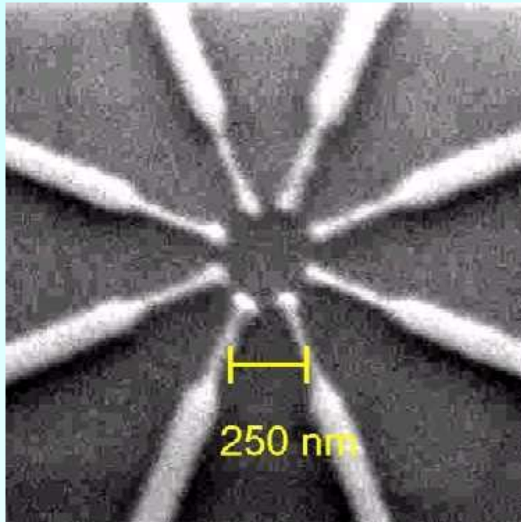
I. Maximov , E.-L. Sarwe, M. Beck, K. Deppert, M. Graczyk, M.H. Magnusson, L. Montelius
“Fabrication of Si-based nanoimprint stamps with sub-20 nm Features”, Micro. Eng., V.61-62, 449 (2002)

- Electron beam induced surface modification provides patterned sites for molecule self assembly

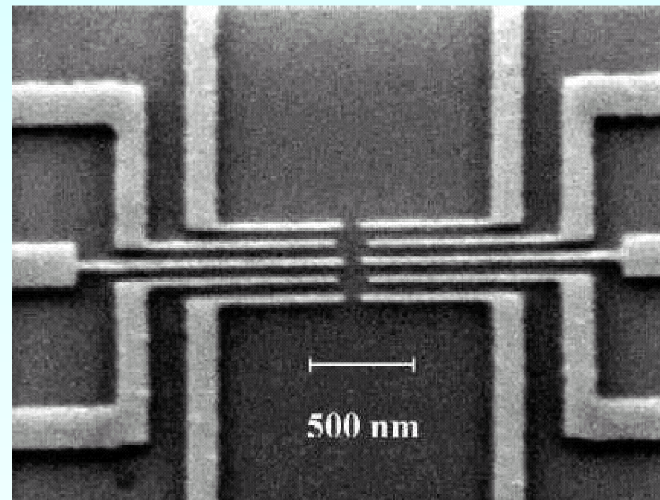


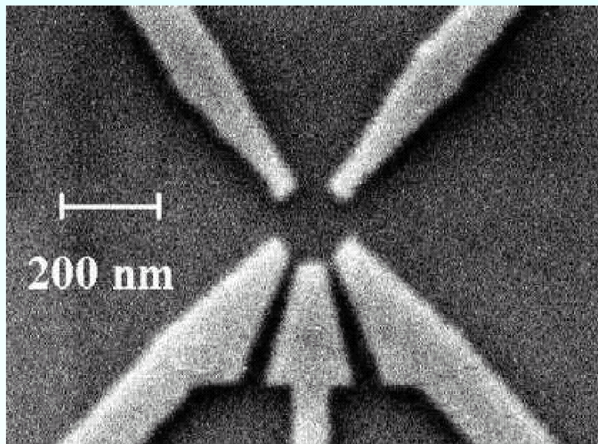


G. Kaltenpoth, B. Vo¨ lkel, C. T. Nottbohm, and A. Go¨lzha¨user
“Electrode modification by electron-induced patterning of self-assembled monolayers”
J. Vac. Sci. Technol. B20(6), 2734 (2002)



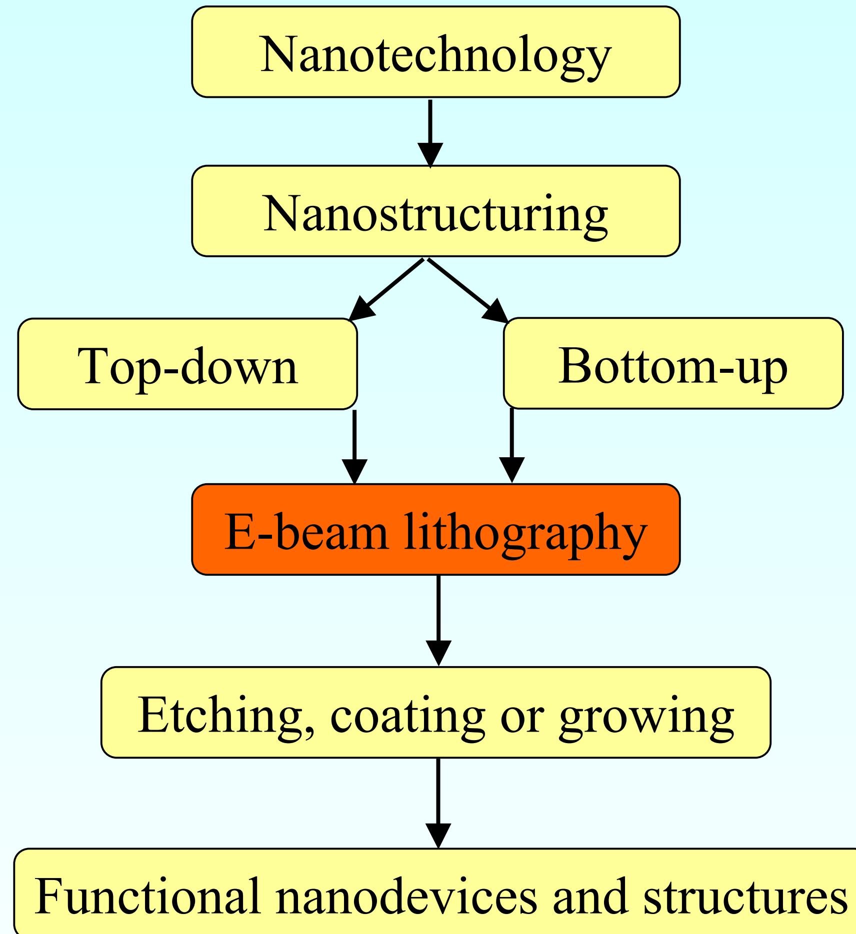
- Making connections between nano-world and micro/macro world





electrodes made by high resolution e-beam lithography and metal deposition, H. Jeong, Purdue University, 2000

The Conclusion:



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