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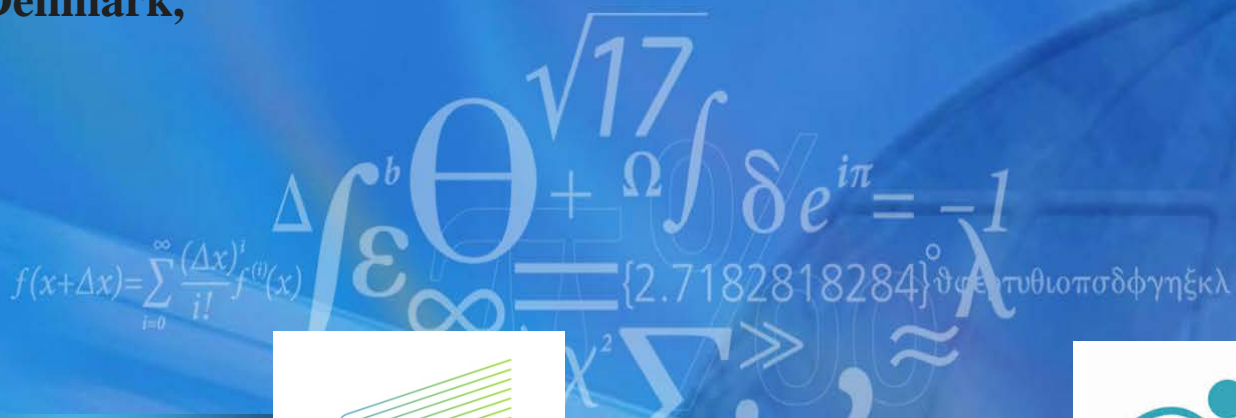
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Block Copolymer Self-Assembly based nanopattern creation for sub-16 nm device fabrication

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Why and How ?

- ❖ To continue Moores' law/ statement ...
- ❖ Betterment and strong demand for ICT
- ❖ Top-Down approach(Advanced Lithographic techniques)
- ❖ Bottom-Up approach(Block copolymer self-assembly)

Diblock copolymer self-assembly

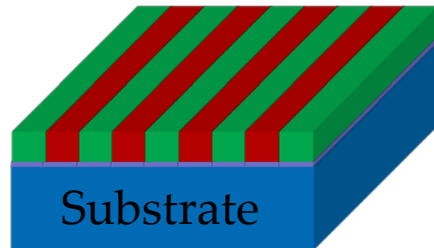
Symmetric Diblock Copolymer



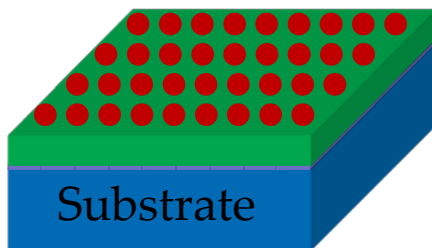
Asymmetric Diblock Copolymer



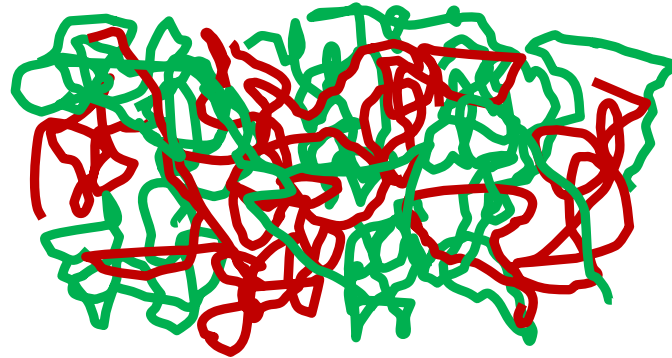
Symmetric Diblock Copolymer



Asymmetric Diblock Copolymer

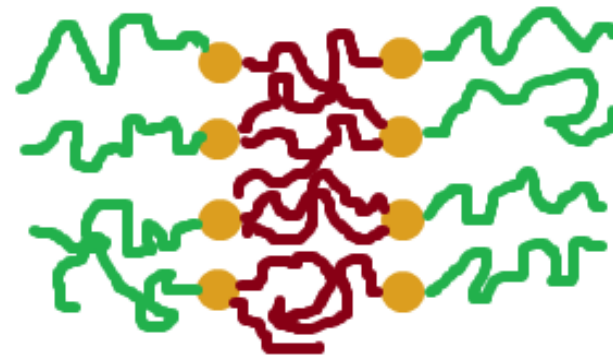


Entangled Polymer Chains



Annealing above T_g

Phase separation after annealing

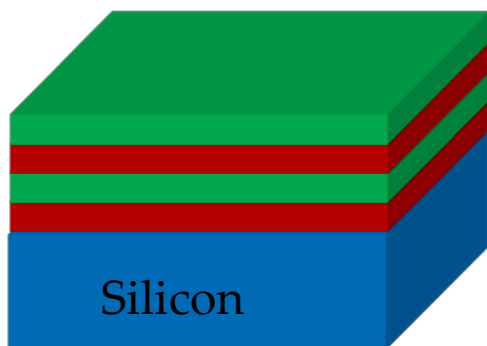
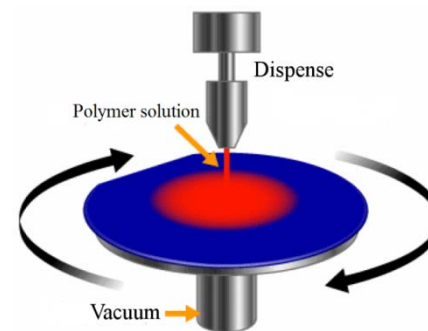


Two BCP systems:

- ❖ PS-*b*-PMMA, PS (polystyrene) - PMMA (polymethylmethacrylate)
- ❖ PS-*b*-PDMS, PS (polystyrene)- PDMS (polydimethylsilixane)

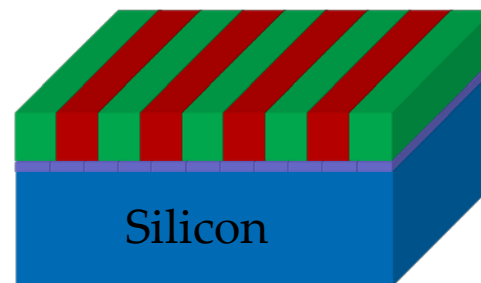
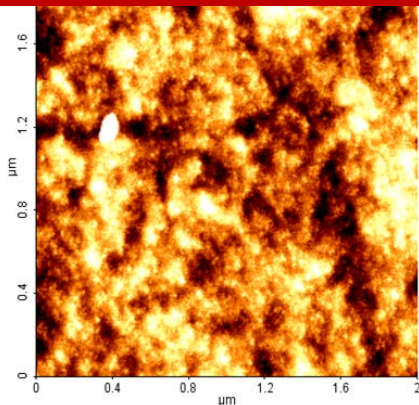
Preparation and orientation of diblock copolymer thin film

- Spin coating for 30sec with ramp of time 5sec
- Uniform film thickness
- Low surface roughness



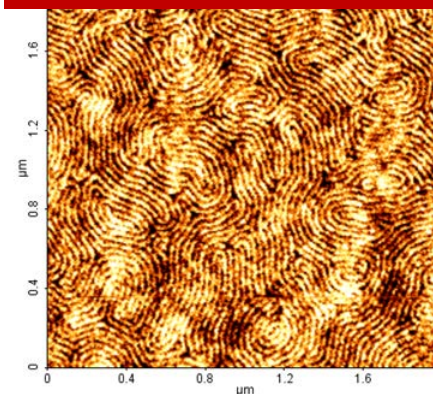
Parallel orientation

PS-b-PMMA(18k-18k)



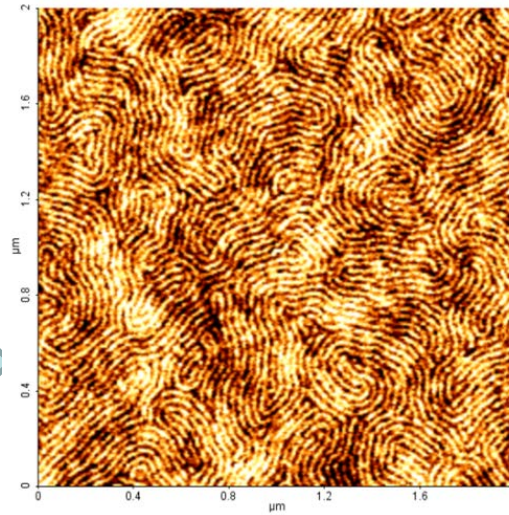
Perpendicular orientation

PS-b-PMMA(18k-18k)

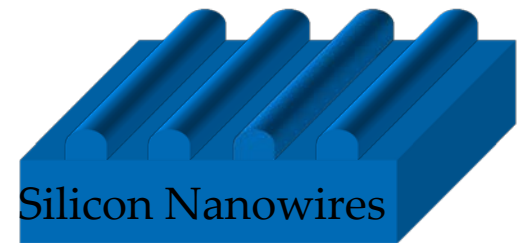
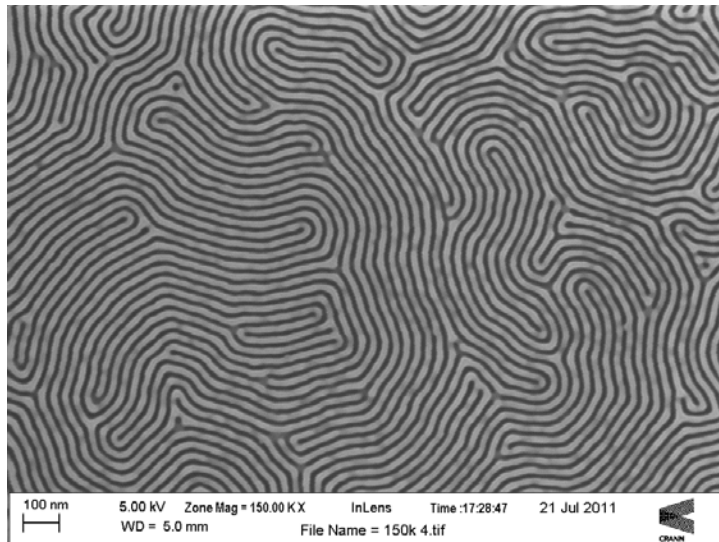
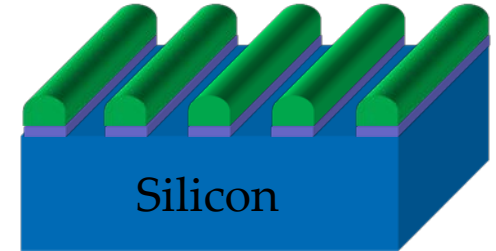


Nanowire fabrication using PS block as a soft mask

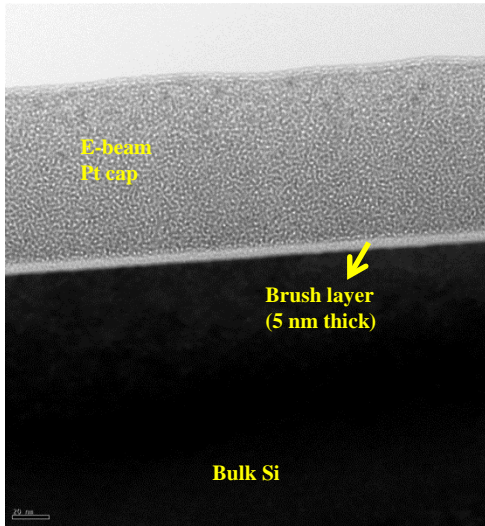
Surface
Neutralization



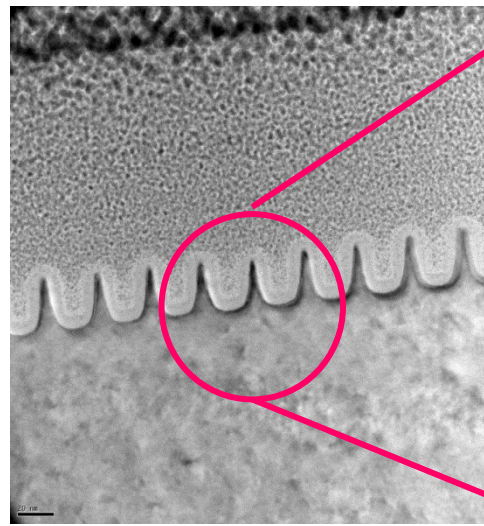
Selective etching of
PMMA block



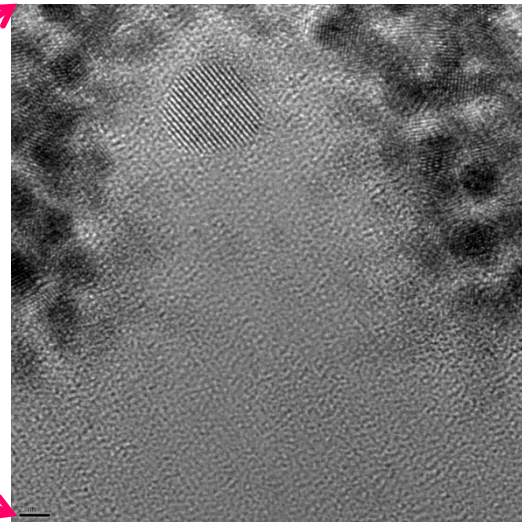
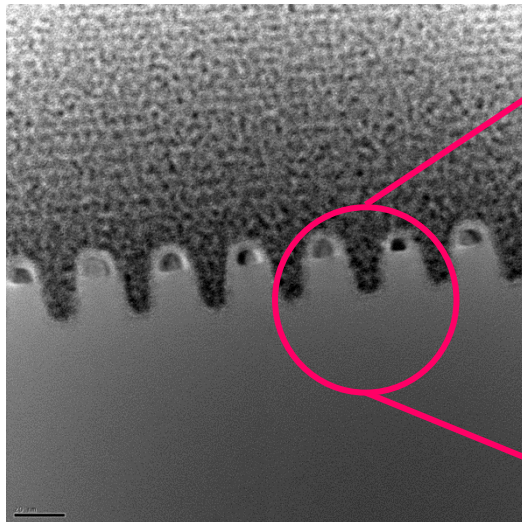
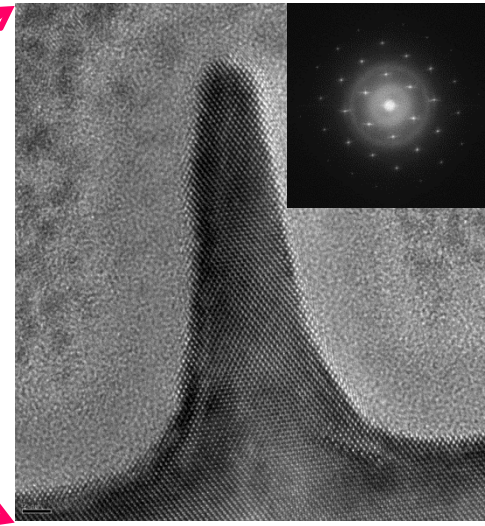
High resolution TEM images



PS-r-PMMA brush layer



8 nm Silicon nanowires



Si nanowires developed in SOI substrate

Fabrication of Germanium nanowires

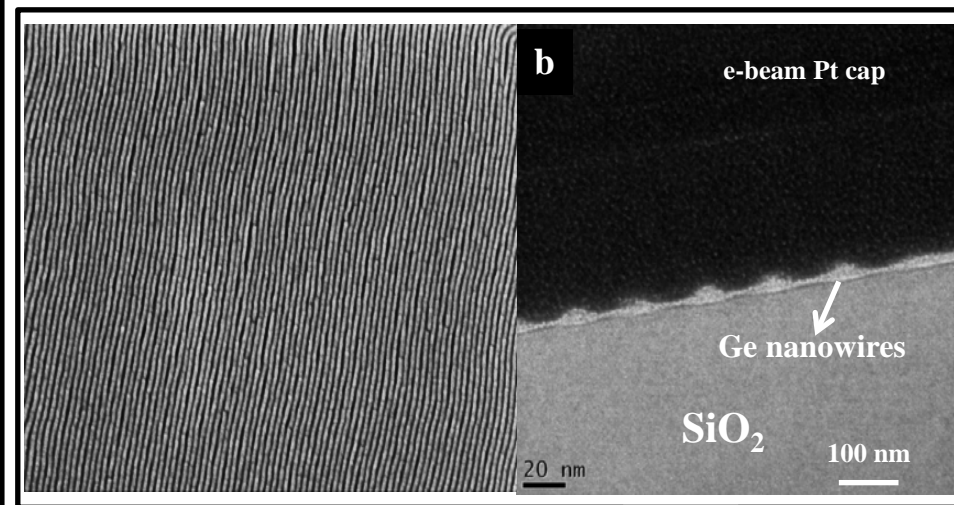
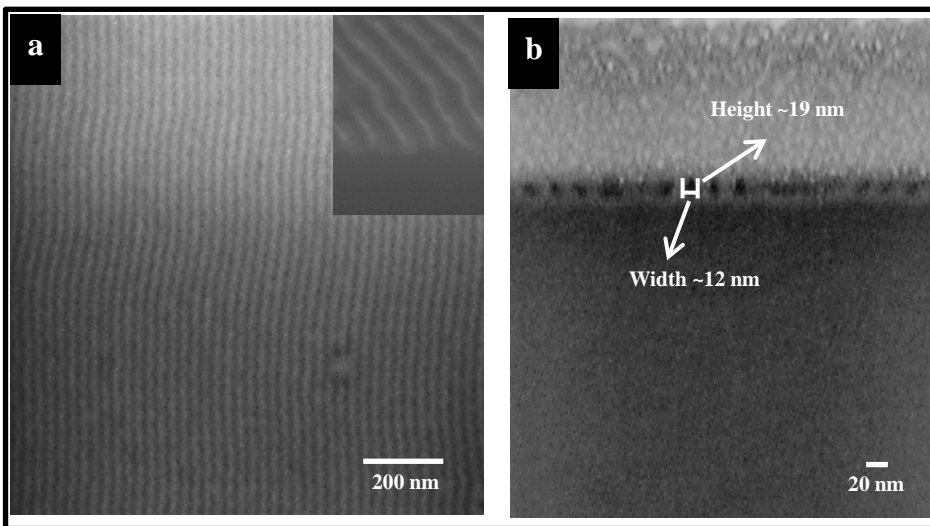
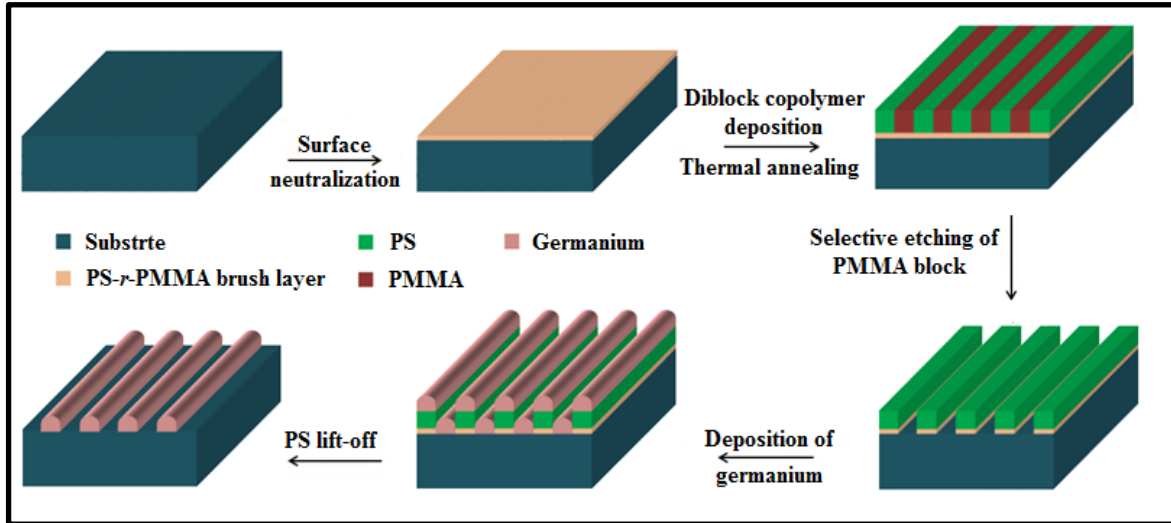
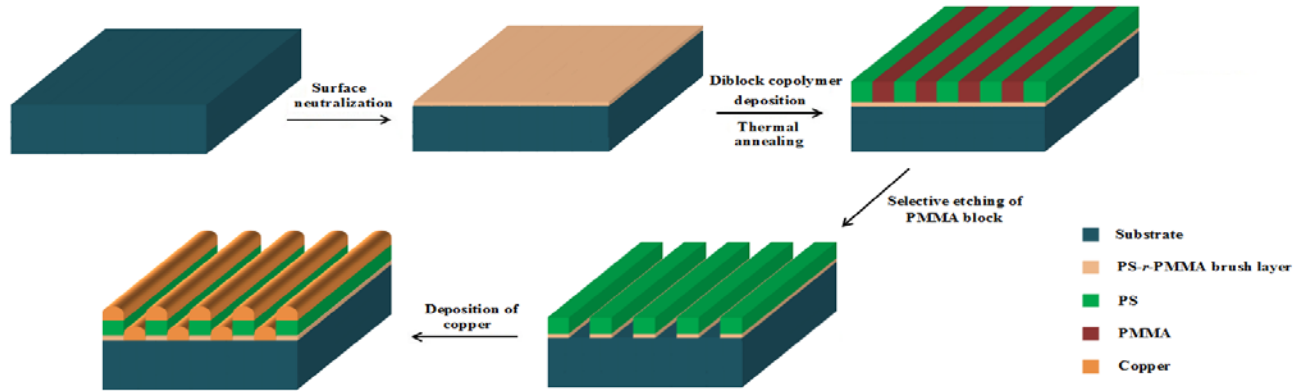


Figure 1. (a) Top-down SEM image of the PS template created by a selective etch of the PMMA block. Inset (b) is the cross-section SEM image. (b) FIB cross-section image of PS template.

Figure 2. (a) Top-down SEM image of GeNWs obtained after PS lift-off (b) Bright-field TEM cross-section image of GeNWs obtained after PS lift-off.

Rasappa, S., D. Borah, et al. (2013). "Fabrication of Germanium Nanowire Arrays by Block Copolymer Lithography." *Science of Advanced Materials* 5: 1-6.

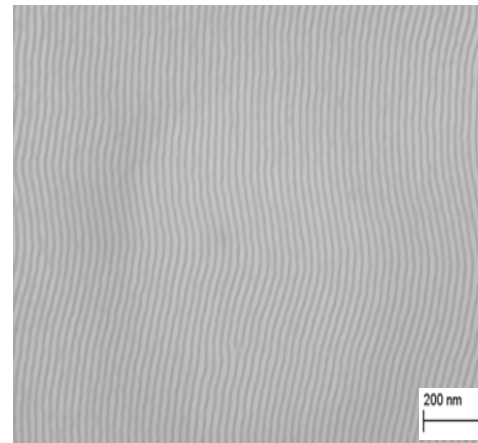
Fabrication of 3-D Copper nanowires



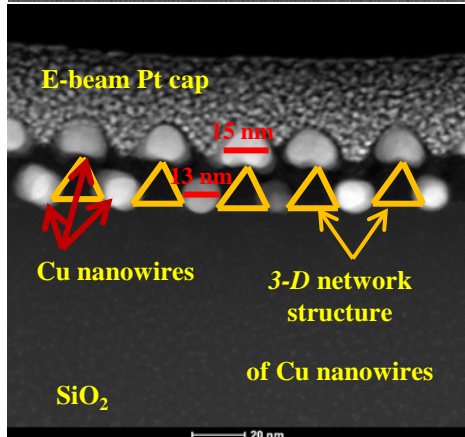
a



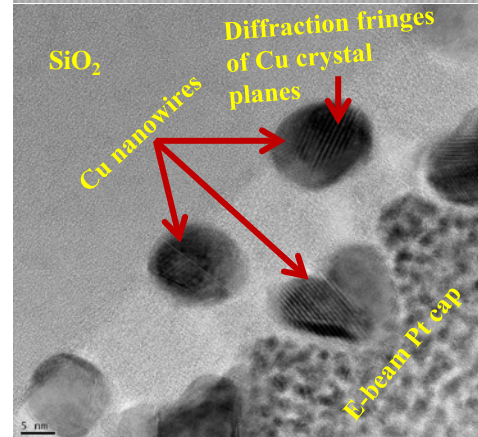
b



c

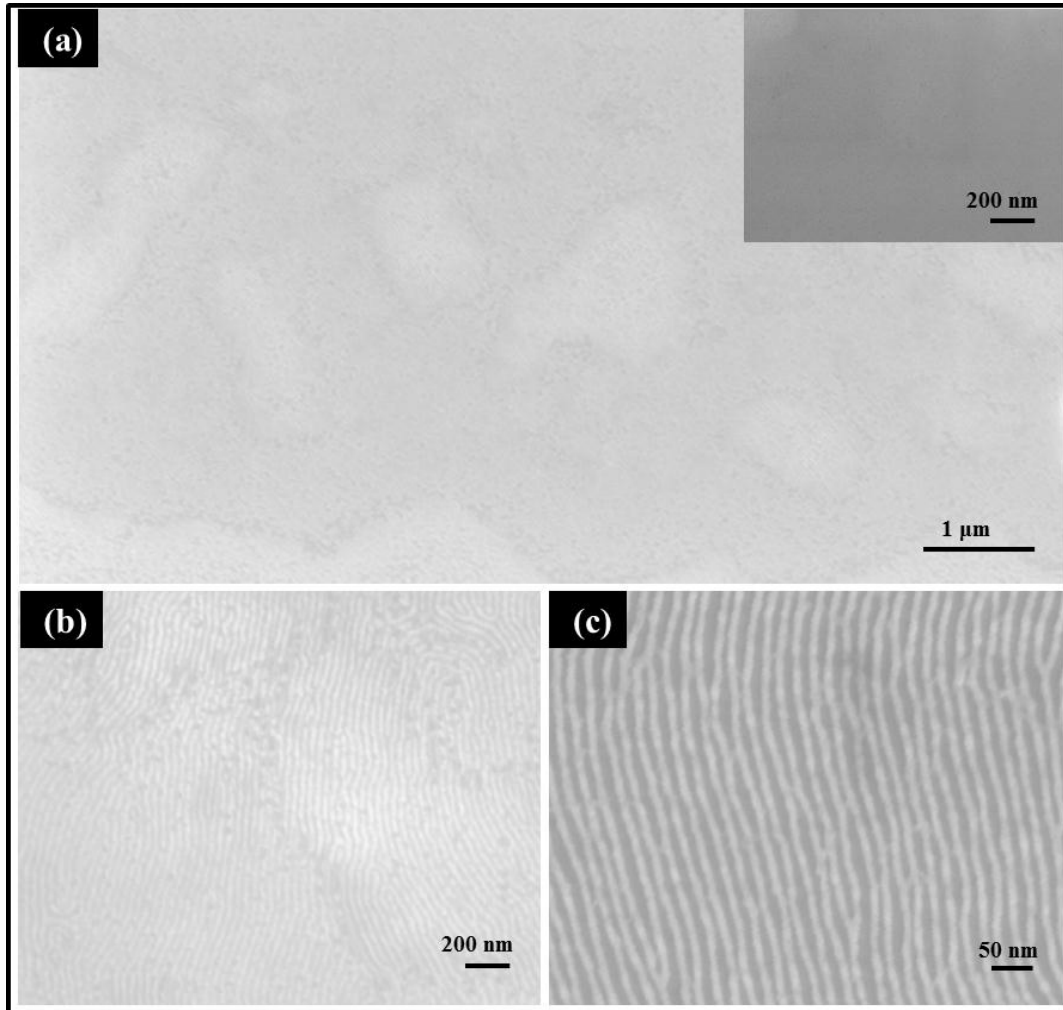


d



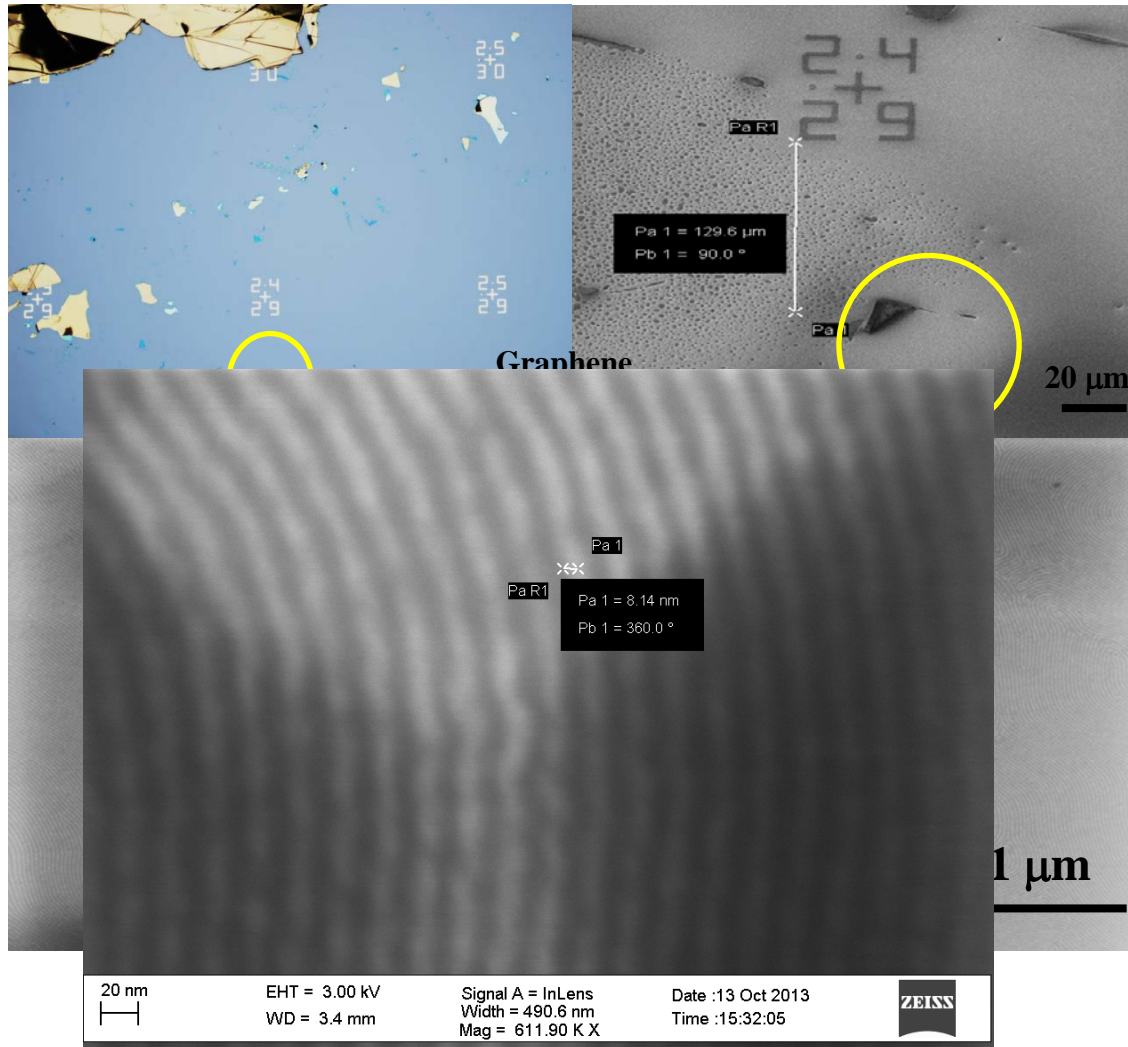
(A) Top-down SEM image of PS template
 (b) Top down SEM images after copper deposition
 (c) Dark-field and
 (d) bright-field TEM cross-section images of Cu nanowires with 3-D geometry.

PS-*b*-PDMS based sub-16 nm device structures



Top-down SEM images of PS-*b*-PDMS in 4 Inch wafer. (a) Top-down SEM image of PS-*b*-PDMS after PDMS removal and inset shows PS-*b*-PDMS before upper PDMS removal which shows no patterns. (b and c) Low resolution and high resolution of oxidised PDMS cylinders.

PS-b-PDMS on Graphene



Conclusions:

- ❖ BCP is the potential candidate for low feature size device fabrications.
- ❖ BCP can acts as a template to fabricate cost effective metal and metal-Oxide structures for real device applications.
- ❖ BCP is a breakthrough for Graphene nanopatterning

Thanks You so much.,..... Looking forward for Expo 2020