Advanced resists for e-beam lithography: processing, exposure and characterization (Part III)

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Processing Steps for Lithography

Substrate cleaning

Dehydration Bake

Adhesion Promoter

Resist Spinning

Pre-bake

Plasma Flash

Development

Post-exposure Bake

Exposure

Etching

Hard Bake

Deposition (Lift-off)
Lift-off (one monolayer)

a.)

b.)

c.)

d.)

e.)

Lift-off (bilayers - PMMA and PMGI)

a.)

b.)

c.)

d.)

e.)
Transferring patterns to the sample

- Etching (wet or dry)

- Lift-off

Lift-off (bilayers - PMMA and PMGI)

Dependência do tamanho da abertura definida na camada superior no tamanho do undercut. Quanto maior for o tamanho da abertura maior será o tamanho do undercut.
Lift-off (bilayers - PMMA and PMGI)

Dependência da concentração do solvente do solvente no tamanho do undercut para um sistema ZEP520/LOR. Na figura 4.a o solvente estava concentrado e na Figura 4.c o solvente estava diluído em 40% onde se verifica que a camada inferior não foi removida completamente.

Lift-off using a Bilayer (ZEP520/PMGI)

For nanolithography, the production of high-resolution objects requires a precise control of the undercut length.

MICRO AND NANO STRUCTURES FABRICATION ON INSULATOR SUBSTRATES

CORRECTION ON AN OPTICAL LITHOGRAPHY MASK

IS EASY TO MAKE A SIMPLE LITHOGRAPHY ON AN INSULATOR SUBSTRATE???

CHARGING EFFECT

Electron Beam

Resist

Initial Condition

Insulator substrates

Future Condition

Repulsive electric potential lines

Negative charge accumulation

Negative charge accumulation

CAUSE BEAM DEFLECTION AND THUS PATTERNING DISTORTIONS

nanolithography.gatech.edu/anti_charging.html
PATTERNING DISTORTIONS DUE TO CHARGING EFFECT

Substrate: MgF₂

Substrate: glass

Another possible insulators substrates:
- Quartz, glass;
- SiO₂, Si₃N₄ (semiconductor application);
- GaN, sapphire (opto-electronics);
Substrate: 1μm thermal oxide

Substrate: optical masks
Resist: PMMA(140nm)/ PMGI(120nm) with adhesion promoter Omnicoat

How to minimize this effect?
COMERCIAL SOLUTION

Espacer

✓ Conducting polymer;
✓ Produced by Showa Denko K.K (www.showa-denko.com);
✓ Soluble in water;
✓ There are two series:
  □ #100: it is an acidic solution used for non chemical amplified resists
  □ #300: it is a weak acidic solution and applicable for the both type of resist: chemical amplified resists and non chemical amplified resists.

BUT WE DON´T HAVE IT AND IT IS RATHER EXPENSIVE ($1500 for 100mL).

ESPACER 300 (Results from Raith)

✓ Optical Images;
✓ Additional spin coating step;
Au on top as a conductive layer

- Au can be coated on top of resist to dissipate charge typically 100A is sufficient (10nm).
- Au must be deposited with Evaporation or Sputtering
  Electron beam evaporation will expose resist
- Au must be stripped with Potassium Iodine prior to resist development

Disadvantage: in some case deposition of Au can introduce electric contamination on the sample

Patterning by Critical Energy Electron Beam Lithography

- In an e-beam system, the total electron yield, which is the sum of secondary electrons and the backscattering electrons, changes as a function of the accelerating voltage.
- It is more intuitive that at high accelerating voltages, an e-beam negatively charges insulators ($\sigma<1$).
- But it is less commonly know that at LOW BEAM ENERGIES, the surface can actually be charged positive ($\sigma>1$) when more electrons are ejected form surface than stored itself.
- AT A CRITICAL ENERGY, $\sigma$ equals unity, and a charge balance between incoming and oucoming electrons is satisfied even for insulator substrates.
**Patterning by Critical Energy Electron Beam Lithography**

No distortions at $E_2 = 1.3\text{keV}$

Charging effect at $E = 5\text{keV}$

*Figure 5.* Pattern distortion in electron beam lithography as a result of surface charging. (a) Design of the desired pattern. SEM images of 10 nm thick Au electrodes on glass sub-lith-of PMMA patterned at (b) $1.3\text{ keV}$ ($E_2$) and (c) $5\text{ keV}$. Charge induced pattern distortions are prominent at $5\text{ keV}$ (circled). Scale bar $= 10\text{nm}$. 
Patterning by Critical Energy Electron Beam Lithography

30kV e spot de 2,5

1kV e spot de 2,5

Projeto Grafeno