I. NTUF EBL Resists and Processing

PMMA Resist (950 K PMMA 3%, 6%)

Poly(methyl methacrylate) (PMMA) is the most popular e-beam resist, offering extremely high-resolution, ease of handling, excellent film characteristics, and wide process latitude. One of PMMA's primary attributes is its simplicity: PMMA polymer dissolved in a solvent (Anisole safe solvent). Exposure causes scission of the polymer chains. The exposed (lighter molecular weight) resist is then developed in a solvent developer.

Characteristics:

- Positive tone
- Very high resolution (20 nm), low contrast
- Poor dry etch resistance
- Several dilutions available, allowing a wide range of resist thickness
- No shelf life or film life issues
- Not sensitive to white light
- Developer mixtures can be adjusted to control contrast and profile

Basic Processing:

Surface Preparation	In general, no surface preparation (aside from normal cleaning) is necessary. Excellent adhesion to most surfaces.
Spin	Speed 1000-5000 rpm, 60 sec. (100-1000 nm)
Pre-bake	180°C hotplate, 90 s.
Expose	Line dose generally < 1.0 nC/cm 3% and > 1.0 nC/cm 6%; Area dose 150 – 250 $\mu C/cm^2$ at 30 kV.
Develop	1:3 MIBK:IPA, 70s.
Rinse	With IPA
Dry	Dry N_2
Post-Bake	95ºC convection oven 30 min.
Descum	Light! (But necessary for good liftoff and clean etching.) PMMA etches very fast in oxygen. In an oxygen RIE, descum times are short, around 5 sec. In a barrel asher, times can be around 1 minute, but beware! Do not preheat the PMMA. Removal rates increase dramatically with temperature.
Stripping	Most solvents, including methylene chloride and acetone will strip PMMA, as will NMP (Remover 1165). It is removed very well by strong bases (KOH), and by acid normally hostile to organics, such as NanoStrip. Oxygen plasmas etch PMMA very well.

P(MMA-MAA) Copolymer Resist

Copolymer, P(MMA-MAA), offers a higher sensitivity than PMMA, (thus can be exposed at a lower dose, thus faster), with a tradeoff in contrast. It is most useful in Bi-level resists with PMMA, to produce undercut profiles useful in liftoff processing.

Characteristics:

- Positive tone
- Low resolution, low contrast
- Poor dry etch resistance
- Several dilutions available, allowing a wide range of resist thickness
- No shelf life or film life issues
- Not sensitive to white light
- Developer mixtures can be adjusted to control contrast and profile

Basic Processing:

Surface Preparation	In general, no surface preparation (aside from normal cleaning) is necessary. Excellent adhesion to most surfaces.
Spin	Speed 1000-5000 rpm, 60 sec. (100-1000 nm)
Pre-bake	Prebake Copolymer @ 150ºC for 90 sec.
Expose	Line dose 1 – 6 nC/cm; area dose 150 to 500 $\mu C/cm^2$ at 30 kV.
Develop	1:1 MIBK:IPA, 1-2 minutes. (1:3 MIBK:IPA is an option, offering higher contrast, but lower sensitivity ie. higher dose.)
Rinse	With IPA
Dry	Dry N_2
Post-Bake	Not normally necessary. Flow can begin as low as 120°C. Does not seem to noticeably improve adhesion or etch resistance.
Descum	Light! (But necessary for good liftoff and clean etching.) PMMA etches very fast in oxygen. In an oxygen RIE, descum times are short, around 5 sec. In a barrel asher, times can be around 1 minute, but beware! Do not preheat the PMMA. Removal rates increase dramatically with temperature.
Stripping	Most solvents, including methylene chloride and acetone will strip PMMA, as will NMP (Remover 1165). It is removed very well by strong bases (KOH), and by acid normally hostile to organics, such as NanoStrip. Oxygen plasmas etch PMMA very well.

For further information on PMMA resists visit:
http://www.microchem.com/products/pmma.htm

SU-8 Photoresist

SU-8 (formulated in GBL) and SU-8 2000 (formulated in cyclopentanone) are chemically amplified; epoxy based negative resists. Standard formulations are offered to cover a wide range of film thicknesses from <1µm to >200µms. SU-8 and SU-8 2000 resists have high functionality, high optical transparency and are sensitive to near UV radiation. Images having exceptionally high aspect ratios and straight sidewalls are readily formed in thick films by contact-proximity or projection printing. Cured SU-8 is highly resistant to solvents, acids and bases and has excellent thermal stability, making it well suited for applications in which cured structures are a permanent part of the device.

Characteristics:

- Negative tone
- Sensitive to white light
- Less 100 nm resolution

Basic Processing:

Note: SU-8 is highly sensitive to UV light/ambient room light. Perform all preparation and processing in sample prep room equipped with UV filters.

Surface Preparation	To ensure proper adhesion, substrates should be cleaned by sonication with solvent or Nanostrip bath.
Dehydrate	200°C hotplate, 5 minutes
Spin	Speed 4000 rpm, 60 sec., SU8 2005 ~ 500 nm; SU8 2002 ~ 100-200 nm
Soft-bake	65ºC hotplate, 60s (step 1); 95ºC hotplate, 60s (step 2)
Expose	Dose SU8 2002: line .01 - .015 nC/cm, area .9 $\mu C/cm^2$ at 30 kV; SU8 2005: line .02 - .05 nC/cm, area 1 -2 $\mu C/cm^2$ at 30 kV
Post-Bake	65ºC hotplate, 60s (step 1); 95ºC hotplate, 60s (step 2). PEB must be done before developing.
Develop	MicroChem SU-8 developer for 60 seconds.
Rinse	IPA
Dry	Dry N_2
Stripping	Difficult to remove with conventional solvent based strippers. Can use Omnicoat with Remover PG, 50-80ºC, immerse 30-90 min.

For further information on SU8 please visit:
http://www.microchem.com/products/pdf/SU8_2002-2025.pdf

II. Other Resist Options

ZEP SERIES

The ZEP series encompasses positive-tone, chemically amplified electron beam resists with high resolution and excellent dry-etching resistance for device fabrication. The series is ideally suited to the creation of photo masks and X-ray masks as well as ultra-fine processing.

Characteristics :

- Positive tone
- Resolution at least 20nm
- Dry etch resistance comparable to most photo resists
- Film Life
- Wide process margin

Basic Processing (based on data from Cornell University):

Surface Preparation	In general, no surface preparation (aside from normal cleaning) is necessary. Excellent adhesion to most surfaces.
Spin	Speed 1000-5000 rpm, 60 sec. (100-1000 nm)
Pre-bake	170°C hotplate, 2 minutes
Expose	10 - 20% the dose requirement of PMMA
Develop	Solvent develop depending on resist
Rinse	With IPA
Dry	By spinning or dry N_2
Post-Bake	Not normally necessary.
Descum	RIE conditions: 30 sccm O_2, 30 mTorr total pressure, 90 W (0.25 W/cm^2), 5 sec. or: Descum in barrel etcher, 0.6 Torr of oxygen, 150W, 1 min.
Stripping	Remover 1165 overnight @ RT, or 1165 @ 70°(bath in PG room) for (30 minutes. O_2 plasma etches NEB very well. Remove residual resist with oxygen RIE: 30 sccm O_2, 30 mTorr total pressure, 0.25 W/cm^2, 5 min.

For further information on the ZEP series, ZEP 520 and ZEP7000
http://www.zeon.co.jp/business_e/enterprise/imagelec/imagelec.html#ie1-3

Toray EBR-9 Resist

EBR-9 is a fast, medium resolution positive resist used mostly for mask masking.

Characteristics:

- Positive tone
- 500 nm best resolution
- Poor dry etch resistance
- For masks, normally applied at 3000 rpm / 320nm thick
- Long shelf life for resist solution
- No film life issues
- Not sensitive to white light
- Developer mixtures can be adjusted to control contrast and profile

Basic Processing (based on data from Cornell University):

Surface Preparation	In general, no surface preparation (aside from normal cleaning) is necessary. Excellent adhesion to most surfaces.
Spin	Speed 3000 rpm, 60 sec. (320 nm)
Pre-bake	170°C oven, 1 hr. Non-critical. Must be $170 < T < 180$ degrees, for at least 30 minutes. May also be hot-plate baked.
Expose	Dose around 17 uC/cm^2 at 40 kV.
Develop	3:1 MIBK:IPA, 4 minutes. (Note that this is not 1:3 MIBK:IPA !)
Rinse	With IPA
Dry	By spinning or dry N_2
Descum	RIE conditions: 30 sccm O_2, 30 mTorr total pressure, 90 W (0.25 W/cm^2), 5 sec. or: Descum in barrel etcher, 0.6 Torr of oxygen, 150W, 1 min.
(Cr Etch for mask plate)	Etch with Transene Cr etchant, ~1.5 min
Stripping	Most solvents, including methylene chloride and acetone will strip EBR-9, as will NMP (Remover 1165). It is removed very well by strong bases (KOH), and by acid normally hostile to organics, such as NanoStrip. RIE in oxygen. Do not use a barrel etcher. RIE conditions: 30 sccm O_2, 30 mTorr total pressure, 90 W (0.25 W/cm^2), 3 min.

For further information about EBR resists:
http://www.toray.com/products/ele/index.html

III. Resist Summary

Resist	Tone	Resolution	Contrast	Etch Resistance	Thickness	Shelf Life	Film Life	Sensitive To White Light
PMMA	Positive	Very High	Low	Poor	Many dilutions	Long @ RT	Long	No
P(MMA-MAA)	Positive	Low	Low	Poor	Many dilutions	Long @ RT	Long	No
SU-8	Negative	High	Low	Good	Many Dilutions	Long @ RT	Long	Yes
ZEP	Positive	Very High	High	Good	Several Dilutions	Long @ RT	Short	Yes
EBR-9	Positive	Low	Low	Poor	Single Dilution	Long @ RT	Long	No

NOTE: Any e-beam exposure is highly dependant upon processing and substrate, so use this information as a starting point, and experiment to optimize things for your work. Some of the information contained here is reprinted from resist data sheets from the manufacturer. Often, more information is available when you need to develop a specific resist process to use.