**Overview**

Any e-beam exposure is highly dependant upon processing and the substrate.  This information is provided as a starting point and will required experimentation 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.

Many of the chemicals involved in resist processing can be extremely dangerous. Solvents such as acetone are highly flammable and explosive. Chlorinated solvents such as and methylene chloride are carcinogenic. Potassium hydroxide and TMAH developers are bases with a Ph of 14. Skin contact with these chemicals is immediately dangerous, and eye contact will quite possibly result in loss of sight. Mask processing involves use of highly dangerous strong acids.

BEFORE you can do any resist processing, you must be familiar with the chemicals you will be using, and know and respect the dangers of them.

**Resist Process Library**

| 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 |
| **NEB-31** | Negative | Very High | High | Good | Several Dilutions | Long @ RT | Short | Yes |
| **EBR-9** | Positive | Low | Low | Poor | Single Dilution | Long @ RT | Long | No |
| **ZEP** | Positive | Very High | High | Good | Several Dilutions | Long @ RT | Short | Yes |
| **UV-5** | Positive | High | High | Good | Several Dilutions | Long @ RT | Short | Yes |

**PMMA Resist**

Poly(methyl methacrylate) (PMMA) is far and away 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, 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** | 170℃ hotplate, 15 min., non-critical. Must be 150 < T < 200 degrees, for at least 10 minutes. May also be oven baked at 170℃ for 1 hour. |
| **Expose** | Dose around 800 $uC/cm^2$ at 100 kV. |
| **Develop** | For low resolution features: MIBK:IPA 1:1, 1-2 minutes. For Higher resolution features: MIBK:IPA 1:3, 1-2 minutes |
| **Rinse** | With IPA |
| **Dry** | By spinning or dry $N_2$ |
| **Post-Bake** | Not normally necessary. Flow can begin as low as 120℃. 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. |

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**Copolymer P(MMA-MAA)**

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** | 170℃ hotplate for 15 min., non-critical. Must be $150 < T < 200$ degrees, for at least 10 minutes. May also be oven baked at 170℃ for 1 hour. |
| **Expose** | Dose around 150 - 200 $uC/cm^2$ at 100 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** | By spinning or dry $N_2$ |
| **Post-Bake** | Not normally necessary. Flow can begin as low as 120℃. 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. |

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**NEB-31**

High resolution chemically amplified negative resist with high sensitivity and contrast

**Characteristics:**

- Negative tone
- Very high resolution (40 nm demonstrated), high contrast
- Dry etch resistance comparable to most photo resists
- Several dilutions available, allowing a wide range of resist thickness
- No shelf life issues for resist solution if stored at room temperature
- Film life issues
- Sensitive to white light

**Basic Processing:**

| | |
|---|---|
| **Surface Preparation** | In general, no surface preparation (aside from normal cleaning) is necessary. Excellent adhesion to most surfaces. For metals, particularly noble metals, dehydration bake @ 170℃ for 15 minutes and apply P2 liquid prime or HMDS vapor prime. |
| **Spin** | Speed 1000-5000 rpm, 60 sec. (100-1000 nm) Coated samples may be stored up to 2 weeks prior to exposure. |
| **Pre-bake** | 110℃ vacuum hotplate (Brewer) for 2 minutes. |
| **Expose** | Dose around 80 $uC/cm^2$ at 100 kV; 10% of PMMA dose requirement. |
| **Post-Bake** | 95℃ vacuum hotplate (Brewer) for 4 minutes - PEB should occur within 24 hours of exposure. |
| **Develop** | MF-321; 10 seconds / 100nm resist thickness. |
| **Rinse** | DI water |
| **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. |
| **Stripping** | Remover 1165 overnight @ RT, or 1165 @ 70°(bath in PG room) for ~ 30 minutes. $O_2$ plasma etches NEB very well. |

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**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:**

| | |
|---|---|
| **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 30 $uC/cm^2$ at 100 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. |

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**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:**

| | |
|---|---|
| **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. |

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**UV-5 Photoresist**

High resolution chemically amplified DUV positive resist with high sensitivity and contrast

**Characteristics:**

- Positive tone
- Resolution at least 150 nm
- Excellent dry etch resistance
- Several dilutions available, allowing a wide range of resist thickness
- No shelf life issues for resist stored at room temperature
- Film life issues
- Sensitive to white light
- Wide process margin

**Basic Processing:**

| | |
|---|---|
| **Surface Preparation** | Plasma clean Si wafer in Branson barrel etcher; Process 3 - 1000W $O_2$ for 3 minutes followed by HMDS P-20 liquid prime. Cover wafer with primer puddle and leave for 1 minute prior to spinning at any speed for ≥ 30 seconds. Proceed to spin on resist immediately. |
| **Spin** | Speed 1000-5000 rpm, 60 sec. (100-1000 nm) |
| **Pre-bake** | 130°C vacuum hotplate (Brewer), 60 seconds. Exposure should occur within 24 hours of pre-bake. |
| **Expose** | Dose 80 $uC/cm^2$ at 100 kV; about 10% of PMMA dose. |
| **Post-Bake** | 130°C vacuum hotplate (Brewer), 60 seconds. PEB should occur within 90 minutes of exposure. |
| **Develop** | CD-26 for 45 - 90 seconds. |
| **Rinse** | DI water |
| **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. |
| **Stripping** | Remover 1165 overnight @ RT, or 1165 @ 70°(bath in PG room) for ~ 30 minutes. $O_2$ plasma etches NEB very well. |

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**Further Reading:**

SPIE Handbook of Microlithography, Microlithography, and Microfabrication - Chapter 2 - Editor: P. Rai-Choudhry, http://www18.cnf.cornell.edu/spiebook/toc.htm

**Resist Sources:**

**NEB-31:**

- SUMIKA Electronic Materials, Inc., Phoenix, AZ
- Customer service 602-659-2590

**ZEP-7000A:**

- Nagase California Corp., 710 Lakeway, Suite 135, Sunnyvale, CA 94086
- Ted Weber / Yuko Loveall, 408-773-0700, http://www.zeon.co.jp/products/imagelec1.html

**UV-5:**

- Shipley Co., 455 Forest St., Marlborough, MA 01752, (508) 229-7251, http://www.shipley.com/
- Mark Wirzbicki, Senior Sales Rep, mwirzbicki@shipley.com, http://www.shipley.com/

**EBR-9:**

- Toray Marketing and Sales, 411 Borel Ave., Suite 520, San Mateo, CA, 94402
- Yuri Okazaki, 650-524-2731, y.okazaki@toray.tomac.com

**PMMA and P(MMA-MAA) Copolymer:**

- MicroChem Corp., 1254 Chestnut St., Newton, MA 02164-1418, (617) 965-5511
- Rob Hardman / Myracle Williamson, http://www.microchem.com/
- Arch Chemicals, Inc., 80 Circuit Dr., North Kingston, RI, 02852, 401-435-2613, http://www.archmicro.com/