SU-8 2000 Permanent Negative Epoxy Photoresist

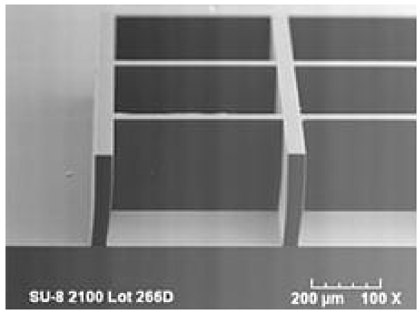
SU-8 2025, SU-8 2035, SU-8 2050, SU-8 2075 and SU-8 2100

Description

SU-8 2000 is a high contrast, epoxy based photoresist designed for micromachining and other microelectronic applications, where a thick, chemically and thermally stable image is desired. SU-8 2000 is an improved formulation of SU-8, which has been widely used by MEMS producers for many years. The use of a faster drying, more polar solvent system results in improved coating quality and increases process throughput. SU-8 2000 is available in twelve standard viscosities. Film thicknesses of 0.5 to >200 microns can be achieved with a single coat process. The exposed and subsequently thermally cross-linked portions of the film are rendered insoluble to liquid developers. SU-8 2000 has excellent imaging characteristics and is capable of producing very high aspect ratio structures. SU-8 2000 has very high optical transmission above 360 nm, which makes it ideally suited for imaging near vertical sidewalls in very thick films. SU-8 2000 is best suited for permanent applications where it is imaged, cured and left on the device.

Features

- High aspect ratio imaging
- 0.5 to > 200 µm film thickness in a single coat
- Improved coating properties
- Faster drying for increased throughput
- i-Line (365 nm) and broadband processing
- Vertical sidewalls



25 µm features in 125 µm thick SU-8 2000 coating

Process Flow

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KAYAKU® ADVANCED MATERIALS

PROCESSING GUIDELINES

SU-8 2000 photoresist is most commonly exposed with conventional UV (350-400 nm) radiation, although i-Line (365 nm) is the recommended wavelength. SU-8 2000 may also be exposed with e-beam or x-ray radiation. Upon exposure, cross-linking proceeds in two steps (1) formation of a strong acid during the exposure step, followed by (2) acid-catalyzed, thermally driven epoxy cross-linking during the post exposure bake (PEB) step. A normal process is: spin coat, soft bake, expose, PEB, followed by develop. A controlled hard bake can be used to further cross-link the imaged SU-8 2000 structures when they will remain as part of the device. The entire process should be optimized for the specific application. The baseline information presented here is meant to be used as a starting point for determining a process.

Substrate Preparation

To obtain maximum process reliability, substrates should be clean and dry prior to applying SU-8 2000 resist. For best results, substrates should be cleaned with a piranha wet etch (using H_2SO_4 & H_2O_2) followed by a deionized water rinse. Substrates may also be cleaned using reactive ion etching (RIE) or any barrel asher supplied with oxygen. Adhesion promoters are typically not required. For applications that include electroplating, a pre-treatment of the substrate with HMDS is recommended.

Coat

SU-8 2000 resists are available in twelve standard viscosities. This processing guideline document addresses four products: SU-8 2025, SU-8 2035, SU-8 2050 and SU-8 2075. Figure 1 provides the information required to select the appropriate SU- 8 2000 resist and spin conditions to achieve the desired film thickness.

Recommended Program

(1) Dispense 1 ml of resist for each inch (25mm) of substrate diameter.
(2) Spin at 500 rpm for 5–10 seconds with acceleration of 100 rpm/second.
(3) Spin at 2000 rpm for 30 seconds with acceleration of 300 rpm/second.

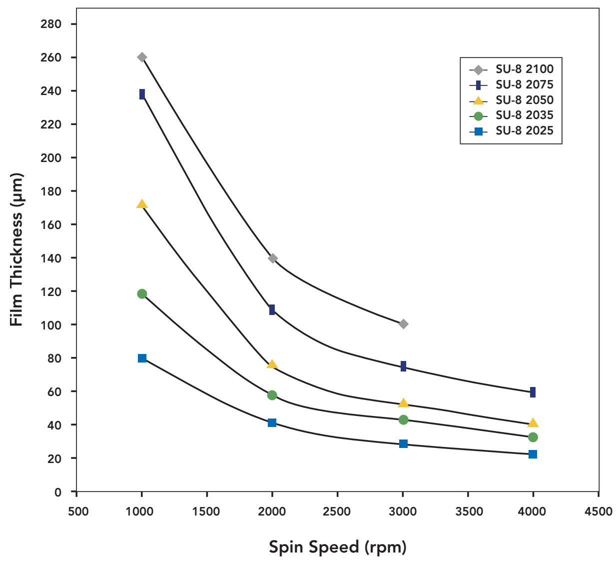

Figure 1. SU-8 2000 Thickness vs. Spin Speed

SU-8 2000	% Solids	Viscosity (cSt)	Density (g/ml)
2025	68.55	4500	1.219
2035	69.95	7000	1.227
2050	71.65	12900	1.233
2075	73.45	22000	1.236
2100	75.00	45000	1.237

Table 1. SU-8 2000 Viscosity

Edge Bead Removal (EBR)

During the spin coat process step, a build up of photoresist may occur on the edge of the substrate. In order to minimize contamination of the hotplate, this thick bead should be removed. This can be accomplished by using a small stream of solvent (Kayaku Advanced Materials’ EBR PG) at the edge of the wafer either at the top or from the bottom. Most automated spin coaters now have this feature and can be programmed to do this automatically.

By removing any edge bead, the photomask can be placed into close contact with the wafer, resulting in improved resolution and aspect ratio.

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Soft Bake

A level hotplate with good thermal control and uniformity is recommended for use during the soft bake step of the process. Convection ovens are not recommended. During convection oven baking, a skin may form on the resist. This skin can inhibit the evolution of solvent, resulting in incomplete drying of the film and/or extended bake times. Table 2 shows the recommended soft bake temperatures and times for the various SU-8 2000 products at selected film thicknesses.

Note: To optimize the baking times/conditions, remove the wafer from the hotplate after the prescribed time and allow it to cool to room temperature. Then, return the wafer to the hotplate. If the film wrinkles, leave the wafer on the hotplate for a few more minutes. Repeat the cool-down and heat-up cycle until wrinkles are no longer seen in the film.

THICKNESS microns	SOFT BAKE TIME minutes @ 65°C	minutes @ 95°C
25–40	0–3	5–6
45–80	0–3	6–9
85–110	5	10–20
115–150	5	20–30
160–225	7	30–45
230–270	7	45–60

Table 2. Soft Bake Times

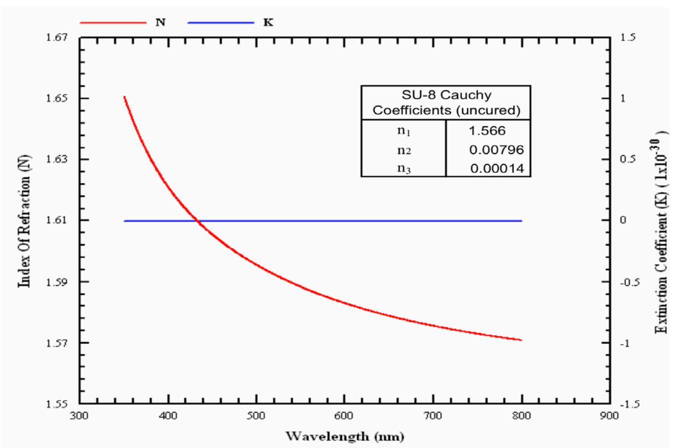

Figure 3. Cauchy Coefficients

Optical Parameters

The dispersion curve and Cauchy coefficients are shown in Figure 3. This information is useful for film thickness measurements based on ellipsomety and other optical measurements.

Exposure

To obtain vertical sidewalls in the SU-8 2000 resist, we recommend the use of a long pass filter to eliminate UV radiation below 350 nm. With the recommended filter (PL- 360-LP) from Omega Optical (www.omegafilters.com) or a 365 nm cut off filter, an increase in exposure time of approximately 40% is required to reach the optimum exposure dose.

Note: *With optimal exposure, a visible latent image will be seen in the film within 5–15 seconds after being placed on the PEB hotplate and not before. An exposure matrix experiment should be performed to determine the optimum dosage.*

THICKNESS microns	EXPOSURE ENERGY mJ/cm^2
25–40	150–160
45–80	150–215
85–110	215–240
115–150	240–260
160–225	260–350
230–270	350–370

Table 3. Exposure Dose

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SUBSTRATES	RELATIVE DOSE
Silicon	1X
Glass	1.5X
Pyrex	1.5X
Indium Tin Oxide	1.5X
Silicon Nitride	1.5–2X
Gold	1.5–2X
Aluminum	1.5–2X
Nickel Iron	1.5–2X
Copper	1.5–2X
Nickel	1.5–2X
Titanium	1.5–2X

Table 4. Exposure Doses for Various Substrates

Post Exposure Bake (PEB)

PEB should take place directly after exposure. Table 5 shows the recommended times and temperatures.

Note: After 1 minute of PEB at 95°C, an image of the mask should be visible in the SU-8 2000 photoresist coating. If no visible latent image is seen during or after PEB this means that there was insufficient exposure, heating or both.

THICKNESS microns	PEB TIME (65ºC)* minutes	PEB TIME (95ºC) minutes
25–40	1	5–6
45–80	1–2	6–7
85–110	2–5	8–10
115–150	5	10–12
160–225	5	12–15
230–270	5	15–20

*Optional step for stress reduction

Table 5. Post Exposure Bake Times

Development

SU-8 2000 photoresist has been designed for use in immersion, spray or spray-puddle processes with Kayaku Advanced Materials' SU-8 developer. Other solvent based developers such as ethyl lactate and diacetone alcohol may also be used. Strong agitation is recommended when developing high aspect ratio and/or thick film structures. The recommended development times for immersion processes are given in Table 6. These development times are approximate, since actual dissolution rates can vary widely as a function of agitation.

Note: The use of an ultrasonic or megasonic bath may be helpful when developing out via or hole patterns or structures with tight pitch.

THICKNESS microns	DEVELOPMENT TIME minutes
25–40	4–5
45–75	5–7
80–110	7–10
115–150	10–15
160–225	15–17
230–270	17–20

Table 6. Development Times for SU-8 Developer

Rinse and Dry

When using SU-8 developer, spray and wash the developed image with fresh solution for approximately 10 seconds, followed by a second spray/wash with developer for another 10 seconds if required. Air dry with filtered, pressurized air or nitrogen.

Note: A white film produced during IPA rinse is an indication of underdevelopment of the unexposed photoresist. Simply immerse or spray the substrate with additional SU-8 developer to remove the white film and complete the development process. Repeat the rinse step.

The use of an ultrasonic or megasonic bath will energize the solvent and allow for more effective development of the unexposed resist.

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Physical Properties
(Approximate values)

Adhesion Strength (MPa) Silicon/Glass/Glass & HMDS	38/35/35
Glass Transition Temperature (Tg °C), tan δ peak	210
Thermal Stability (°C @ 5% wt. loss)	315
Thermal Conductivity (W/m.K)	0.3
Coefficient of Thermal Expansion (CTE ppm)	52
Tensile Strength (MPa)	60
Elongation at break (ξb %)	6.5
Young's Modulus (GPa)	2.0
Dielectric Constant @ 10MHz	3.2
Water Absorption (% 85°C/85 RH)	0.65

Table 7. Physical Properties

Optical Properties

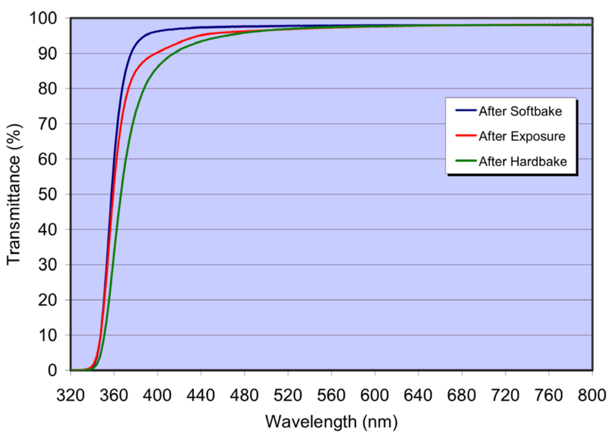

Figure 4. Optical Transmittance

Process conditions for Figure 4
Soft bake: 5 minutes at 95°C
Exposure: 180 mJ/cm^2
Hard bake: 30 minutes at 300°C

Hard Bake (cure)

SU-8 2000 has good mechanical properties. However, for applications where the imaged resist is to be left as part of the final device, a hard bake can be incorporated into the process. This is generally only required if the final device or part is to be subject to thermal processing during regular operation. A hard bake or final cure step is added to ensure that SU-8 2000 properties do not change in actual use. SU-8 2000 is a thermal resin and as such its properties can continue to change when exposed to a higher temperature than previously encountered. We recommend using a final bake temperature 10°C higher than the maximum expected device operating temperature. Depending on the degree of cure required, a bake temperature in the range of 150°C to 250°C and for a time between 5 and 30 minutes is typically used.

Note: The hard bake step is also useful for annealing any surface cracks that may be evident after development. The recommended step is to bake at 150°C for a couple of minutes. This applies to all film thicknesses.

Removal

SU-8 2000 has been designed as a permanent, highly crosslinked epoxy material and it is extremely difficult to remove it with conventional solvent based resist strippers. Kayaku Advanced Materials' Remover PG will swell and lift off minimally crosslinked SU-8 2000. However, if OmniCoat (30-100 nm) has been applied, immersion in Remover PG can effect a clean and thorough lift-off of the SU-8 2000 material. Fully cured or hard baked SU-8 2000 cannot be removed without the use of OmniCoat.

To remove minimally crosslinked SU-8 2000, or when using Omnicoat: Heat the Remover PG bath to 50-80°C and immerse the substrates for 30-90 minutes. Actual strip time will depend on resist thickness and crosslink density. For more information on Kayaku Advanced Materials' Omnicoat and Remover PG please see the relevant product data sheets.

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To re-work fully crosslinked SU-8 2000: Wafers can be stripped using oxidizing acid solutions such as piranha etch, plasma ash, RIE, laser ablation and pyrolysis.

PLASMA REMOVAL

RIE 200W, 80 sccm O_2, 8 sccm CF_4, 100 mTorr, 10°C. For more information, refer to the SU-8 / KMPR® Removal applications note on the website www.kayakuAM.com. Also see www.r3t.de or www.pvatepla.com for microwave plasma tools for high throughput without damaging other microstructures.

Storage

Store SU-8 2000 resists upright and in tightly closed containers in a cool, dry environment away from direct sunlight at a temperature of 40-70°F (4-21°C). Store away from light, acids, heat and sources of ignition. Shelf life is thirteen months from date of manufacture.

Disposal

The material and its container must be disposed in accordance with all local, state, federal and/or international regulations.

Handling

Consult Safety Data Sheet (SDS) for details on the handling procedures and product hazards prior to use. If you have any questions regarding handling precautions or product hazards, please email productsafety@kayakuAM.com.

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