



## ***Contrast Enhancement Materials***

### ***CEM 420WSF***

#### **INTRODUCTION**

In 1989 Shin-Etsu Chemical acquired MicroSi, Inc. and the Contrast Enhancement Material (CEM) technology business from General Electric including a series of patents and technologies\*.

\*Contrast Enhancement Lithography was developed by B.F. Griffing and P. West at General Electric to extend the limit of practical resolution in the field of Microlithography.

#### **CEM 420WSF - PRODUCT PROPERTIES AND PROCESSING GUIDELINES**

Contrast enhancement is a microlithography technique which extends the practical limits of optical lithography systems. This improvement in resolution, depth of focus and reduced interference, allows the fabrication of new and denser integrated circuits without the required capital equipment investment.

Significant benefits of contrast enhancement can be recognized from the following performance features:

- Increase Depth of Focus Latitude
- Reduced Linewidth Change Over Steps
- Extends Resolution Limits
- Generates Vertical Resist Profiles
- Increases Develop/Exposure Latitude
- Reduces Proximity and Interference Effects
- Increased integrity in high aspect ratio features
- Simple/Low defect Process

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## ***CEM 420WSF***

### **GENERAL DESCRIPTION**

The Contrast Enhancement Material (CEM) Process is a unique photolithography technique designed to extend and enhance both the process latitude and resolution limits of optical lithography systems. The purpose of this guideline is to provide information on the theory, characteristics, and use of CEM 420WSF.

### **CEM THEORY**

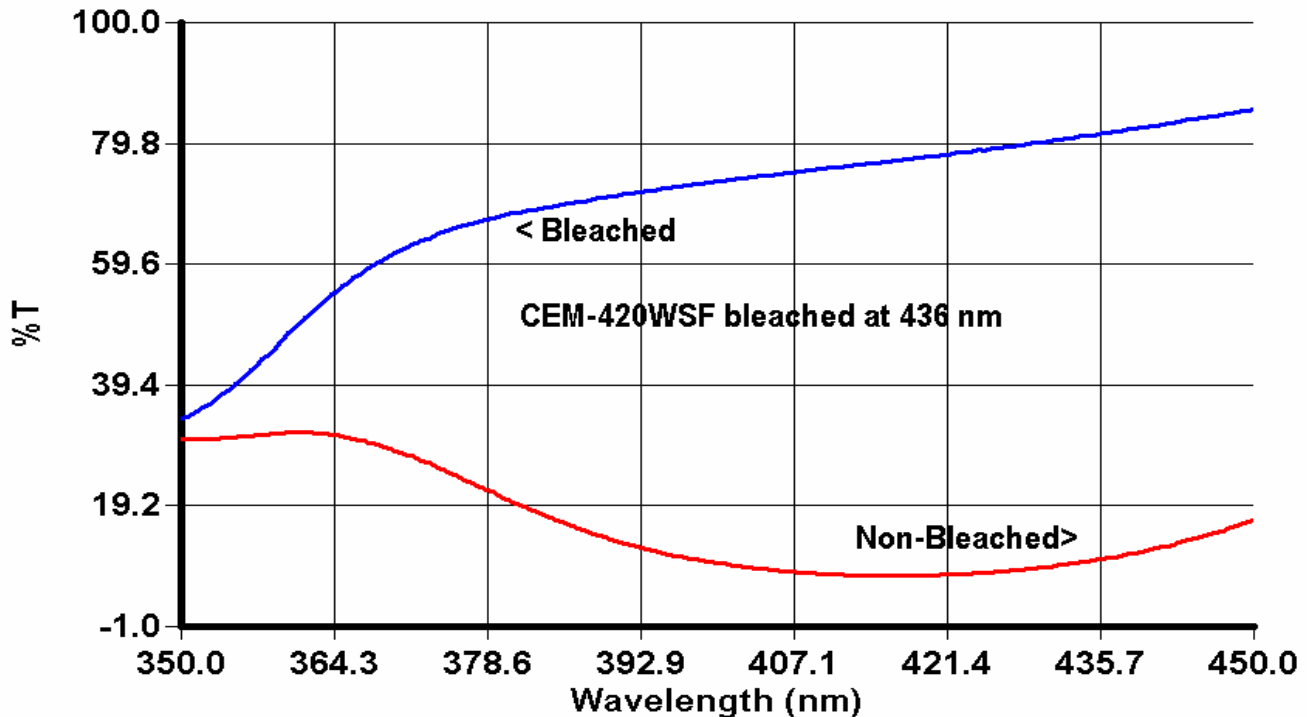
CEM is a photo bleachable solution, which is initially opaque to the exposure wavelength(s) but becomes nearly transparent upon exposure. Figure 1 shows the spectral transmission characteristics of CEM-420WSF. The CEM is spin coated on top of positive photoresist and then exposed. During exposure, the aerial image from the mask hits the CEM layer, where the regions of higher intensity (open areas of the mask) are bleached at a faster rate than the lower intensity regions (closed or dark areas of the mask). By adjusting the bleaching dynamics so that the absorption of the CEM layer is sufficiently high and the photospeeds of the CEM and resist layers are properly matched, it is possible to completely expose the underlying photoresist in the light areas before the CEM is bleached through in the dark areas. Thus, during exposure an in-situ “conformal contact mask” is formed in the CEM layer. The net effect is a higher contrast level of the aerial image used to expose the photoresist (Figure 2). The enhancement of the contrast depends on the photochemical properties of the CEM and the dose required to expose the resist.

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Other conditions such as light scattering and second order aerial image effects shown in Figure 2 also contribute to degradation of desired photoresist performance. With the proper match of CEM and exposure parameters the CEM layer will absorb, in the dark areas, all the light from light scattering and second order aerial image effects before they reach the resist surface. The benefit is much straighter or vertical sidewalls and the elimination of rounding or pointed edges at the tops of features.

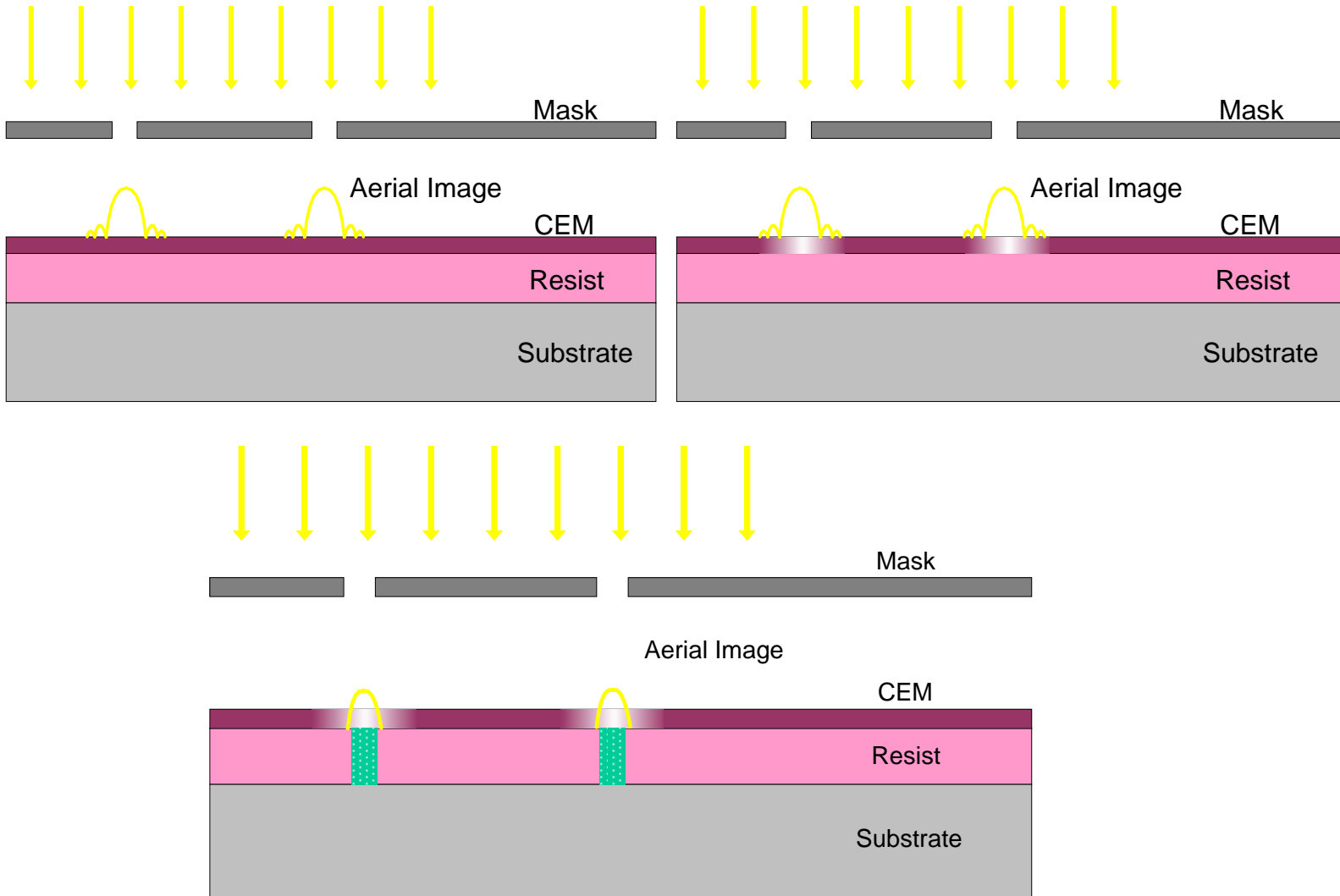
**Figure 1: CEM 420WSF Spectral Transmission Characteristics**



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Figure 2: CEM Theory



CEM 420WSF is not recommended to be applied directly on top of the photoresist due to interfacial mixing. Therefore, a barrier coat, CEM BC5, is required. CEM BC5 is a thin transparent polymer film spin coated directly over the photoresist layer after softbake. The recommended CEM BC5 coat program includes point-of-use filtration.

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### **MATERIAL PROPERTIES**

#### ***CEM 420WSF Material Properties***

|  |                          |
|--|--------------------------|
| Solids   | 10.0 ± 2.0 %             |
| Viscosity @ 25 Deg C                               | 5.0 ± 0.5 cstks          |
| Refractive index                                   | 1.53                     |
| Film thickness                                     | 3,500 ± 400Å @ 4,000 rpm |
| Appearance   | Clear, Red               |
| Initial transmission (436 nm)                      | < 15 %T                  |
| Final transmission (436 nm)                        | > 90 %T                  |
| Cauchy Coefficients                                |                          |
| N <sub>0</sub>                                     | 1.490                    |
| N <sub>1</sub>                                     | 176.4                    |
| K <sub>2</sub>                                     | 55.041                   |
| N <sub>2</sub> , K <sub>0</sub> , K <sub>1</sub> , | 0.000                    |

#### ***CEM BC5 Material Properties***

|   |                          |
|---|--------------------------|
| Solids  | 5.0% maximum             |
| Viscosity @ 25 Deg C  | 3.5 ± 0.5 cstks          |
| Refractive index  | 1.51                     |
| Film thickness  | 950 Å ± 100Å @ 4,000 rpm |
| Appearance  | Clear, Colorless         |
| Cauchy Coefficients   |                          |
| N <sub>0</sub>  | 1.500                    |
| N <sub>1</sub>  | 34.5                     |
| N <sub>2</sub> , K <sub>0</sub> , K <sub>1</sub> , K <sub>2</sub> | 0.000                    |

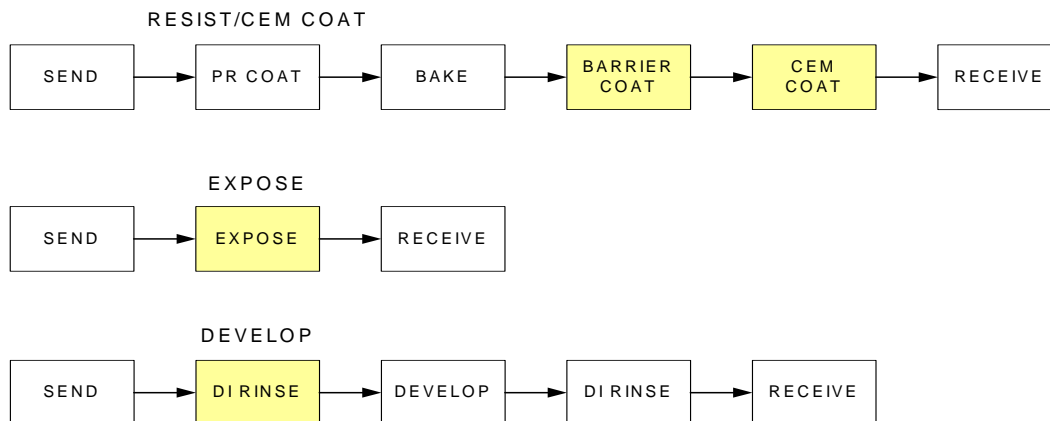
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## CEM 420WSF

### CEM PROCESS CONDITIONS

Figure 3 illustrates the photolithography steps in using CEM. Note that, the CEM process adds only one simple step to the normal positive photoresist processing sequence.

**Figure 3:** Process Steps



### Sequence of steps in the Contrast Enhancement Process

1. Spin coat positive photoresist on primed wafers.
2. Softbake photoresist according to standard process.
3. Spin coat CEM BC5. Spin coat CEM 420WSF
4. Expose wafer
5. Strip CEM and CEM BC5 using a DI water pre-wet
6. Post Exposure bake (if applicable)
7. Develop photoresist according to standard process.

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### CEM BC5 SPIN COATING CONDITIONS

1. CEM BC5, static dispense.
2. CEM BC5 spread for 2 seconds at 500 rpm.
3. Ramp at 10,000 rpm/sec to 4,000 rpm.
4. Spin dry for 30 seconds.

Sufficient CEM BC5 must be dispensed in step (1) above to produce a continuous film during the spread cycle. The following amounts of CEM-BC5 are the minimum recommended.

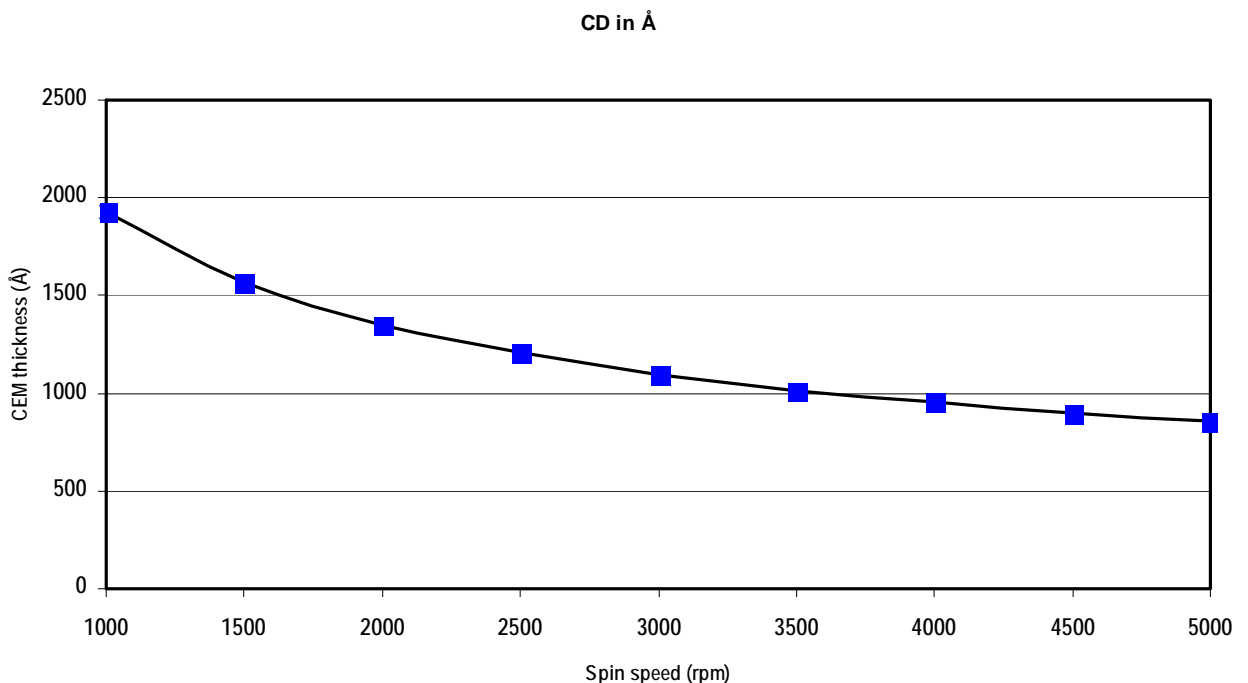
Approximate dispense volume of CEM BC5 by wafer size.

|         |          |
|---------|----------|
| 3" & 4" | 2 - 3 ml |
| 5" & 6" | 4 - 6 ml |
| 8"      | 7 ml     |

The above sequence yields a CEM BC5 thickness of approximately 950 Å. Figure 4 provides a thickness versus spin speed plot for CEM BC5.

**Note:** It is recommended the filtration media is polyethersulfone with a mesh size of 0.1µ.

**Figure 4:** CEM BC5 Thickness vs. Spin Speed



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### CEM COATING

The most common dispensing method is dispensing directly from the bottle or Nowpack using a photoresist pump. For best results, point-of-use filtration is recommended.

The following CEM 420WSF spin coat program is recommended to yield excellent thickness uniformities ( $< 50 \text{ \AA}$  variation across the wafer).

1. CEM 420WSF static dispense.
2. Spread for 2 seconds at 500 rpm.
3. Ramp at 10,000-rpm/sec minimum to final spin speed (4,000 rpm nominal).
4. Spin dry for 30 seconds (minimum)

**Note: For automated track systems the CEM 420WSF material is compatible with the photoresist spin bowl and drain. The Barrier Coat (BC 5) material is compatible and can be spin coated in the develop bowl.**

Approximate dispense volume of CEM-420WSF by wafer size.

|         |              |
|---------|--------------|
| 3" & 4" | 1.0 – 1.5 ml |
| 5" & 6" | 2.0 – 2.5 ml |
| 8"      | 3.0 – 3.5 ml |

The resulting film will be somewhat tacky, but at no time should the film be subjected to a softbake process including momentary hot plate contact.

The above coating sequence should yield a film thickness of approximately  $3500 \text{ \AA}$ . A thinner or thicker CEM layer may prove to be optimum for certain resists and applications, and should be characterized by the user (See Figure 5).

To measure the thickness of CEM 420WSF

1. Coat clean bare silicon with CEM 420WSF using the above procedure.
2. Bleach wafer by exposing to UV source for a minimum of 30 seconds.
3. Immediately measure thickness using a refractive index of 1.53.

**Note: It is important that the film is completely bleached. Partially bleached films can contribute to high readings (up to  $+200 \text{ \AA}$ ) and poor uniformity.**

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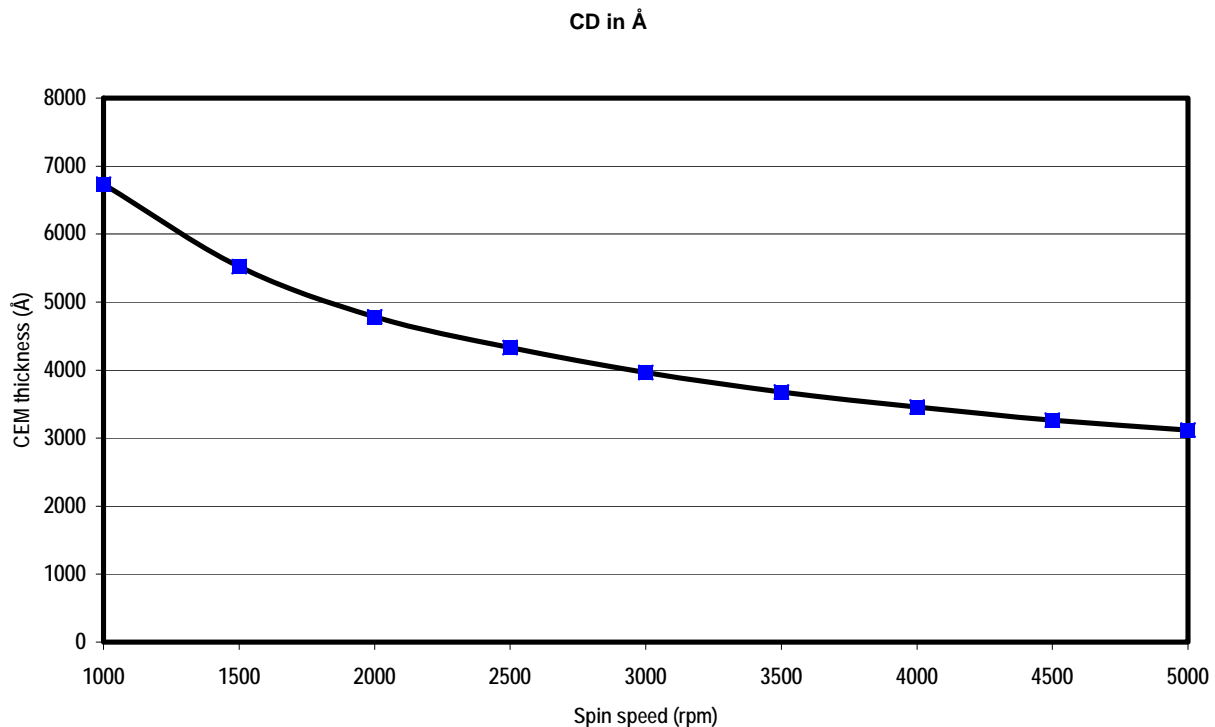
## *CEM 420WSF*

Good linewidth control is dependent upon the uniformity of the CEM layer thickness. It is important to use a photoresist thickness that provides adequate planarization of the topography being coated. Normally this is 2 to 2.5 times the greatest step height. One of the benefits of CEM is that it provides a high aspect ratio. Therefore, thicker photoresist films can be used with no loss in resolution.

Coater exhaust also can contribute to coat uniformity. For best results, the exhaust should be adjusted for the low viscosity and high vapor pressure of CEM 420WSF.

**Note: It is recommended the filtration media is Teflon with a mesh size of 0.10 $\mu$ .**

**Figure 5:** CEM 420WSF Thickness vs. Spin Speed



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### **CEM 420WSF EXPOSURE**

CEM 420WSF was developed for g-line (436 nm) and UV-4 (broadband) exposure tools.

As with conventional resists, a focus/exposure matrix should be run to determine the parameters which will yield optimum results.

The exposure required will be 30% to 100% longer than for the photoresist layer alone and depend upon the CEM 420WSF layer thickness and other process conditions. After exposure, a latent pattern is visible in the CEM-420WSF coating that disappears after strip.

The center of focus will shift in comparison to the standard photoresist process. A shift of 0.5 micron is typical.

### **CEM 420WSF STRIP/DEVELOPMENT**

CEM 420WSF is a water strippable formulation that does not require a separate solvent strip prior to the photoresist development step. A develop pre-wet is all that is necessary to strip the CEM BC5 and CEM 420WSF layers. In some cases the CEM must be stripped prior to PEB. This is dependent on the resist and process conditions (primarily the softbake temperature).

1. Spin wafer at 1,000 rpm.
2. DI water rinse 5-10 seconds @ 1,000 rpm.
3. Start standard development process immediately (no spin dry after strip required).
4. DI water flow rate should be  $\geq 10$  ml/sec.

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CEM 420WSF and CEM BC5 are compatible with positive photoresists and their solvents (including edge bead removal). The two in combination with photoresist will not contribute to any problems with solvent drain systems. If CEM 420WSF is applied on the coater track, no changes with standard photoresist cup clean procedure (an acetone soak) are required. However, with the CEM BC5 an additional DI water rinse may be required since the CEM BC5 is a barrier to many solvents.

### **CEM 420WSF PRODUCT HANDLING AND STORAGE PROCEDURES**

#### **Handling Precautions**

CEM 420WSF is light sensitive and should only be processed under yellow light. CEM 420WSF is a flammable liquid. Use adequate ventilation. Avoid breathing of vapors. Keep away from heat sparks or open flame. CEM-420WSF and CEM BC5 are harmful if swallowed. Avoid contact with skin and eyes. Handle with care. Wear chemical goggles, rubber gloves and protective clothing.

#### **Storage**

Store in sealed, original containers, in a dry area away from light. Cold storage at 4 to 27 ° C for CEM BC5 and 0 to 5 °C for CEM 420WSF are recommended to insure optimum quality and shelf life. CEM 420WSF and CEM BC5 should be allowed to stabilize at ambient temperature before use.

#### **Waste disposal**

CEM 420WSF is a hazardous waste due to its flammability and must be disposed of in accordance with all Federal, State and local regulations.

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### **FIRST AID FOR CEM 420WSF**

Take action as follows:

- If Eye contact: Flush with water for at least 15 minutes. Contact physician.
- If Skin contact: Wash affected areas with soap and water. Remove contaminated clothing. If irritation persists, contact a physician. Wash clothing before re-use.
- If Inhaled: Move into fresh air, if not breathing give artificial respiration.
- If Ingested: If swallowed do not induce vomiting. Give large quantities of water and seek emergency attention immediately. Never give anything by mouth to an unconscious person.

**Refer to Safety Data Sheets for more information**

### **Shin-Etsu MicroSi**

Shin-Etsu MicroSi, Inc. is a wholly owned subsidiary of Shin-Etsu Chemical Co., Ltd., a global leader in research, development and the manufacture of chemicals used in the semiconductor industry. From its headquarters in Phoenix, Arizona, Shin-Etsu MicroSi provides high performance products and materials including:

- Thermal Interface Materials
- KJR Liquid Coating Materials
- Contrast Enhancement Materials
- Mask Blanks
- PBN Crucibles
- Photoresists / Developers
- Quartz Substrates & Wafers
- Liquid Underfill Materials
- Barrier Coats
- Pellicles
- Flexible Copper Laminate
- Epoxy Molding Compounds
- Adhesion Promoters

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