Contrast Enhancement Materials
CEM 420SS

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 420SS

CEM 420SS was specially formulated for use with thick films. It is optimized for films 6µm or greater. The Propylene Glycol Monoethyl Ether Acetate (PGMEA) based solvent system provides excellent water strippability and can be removed by immersion or track processing. CEM-420SS was developed for 405 nm (h-line), 436 (g-line) and UV-4 (broadband) exposure tools.

CEM 420SS - 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.

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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

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 420SS.

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 420SS. 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.

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 420SS Spectral Transmission Characteristics

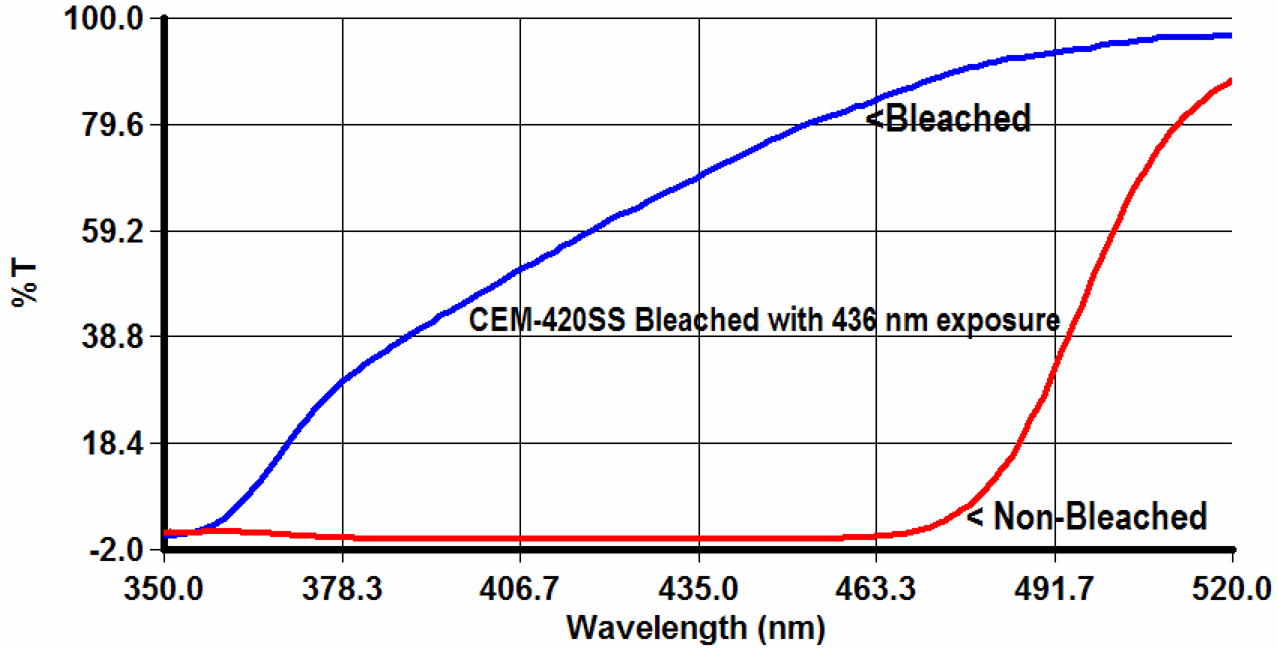

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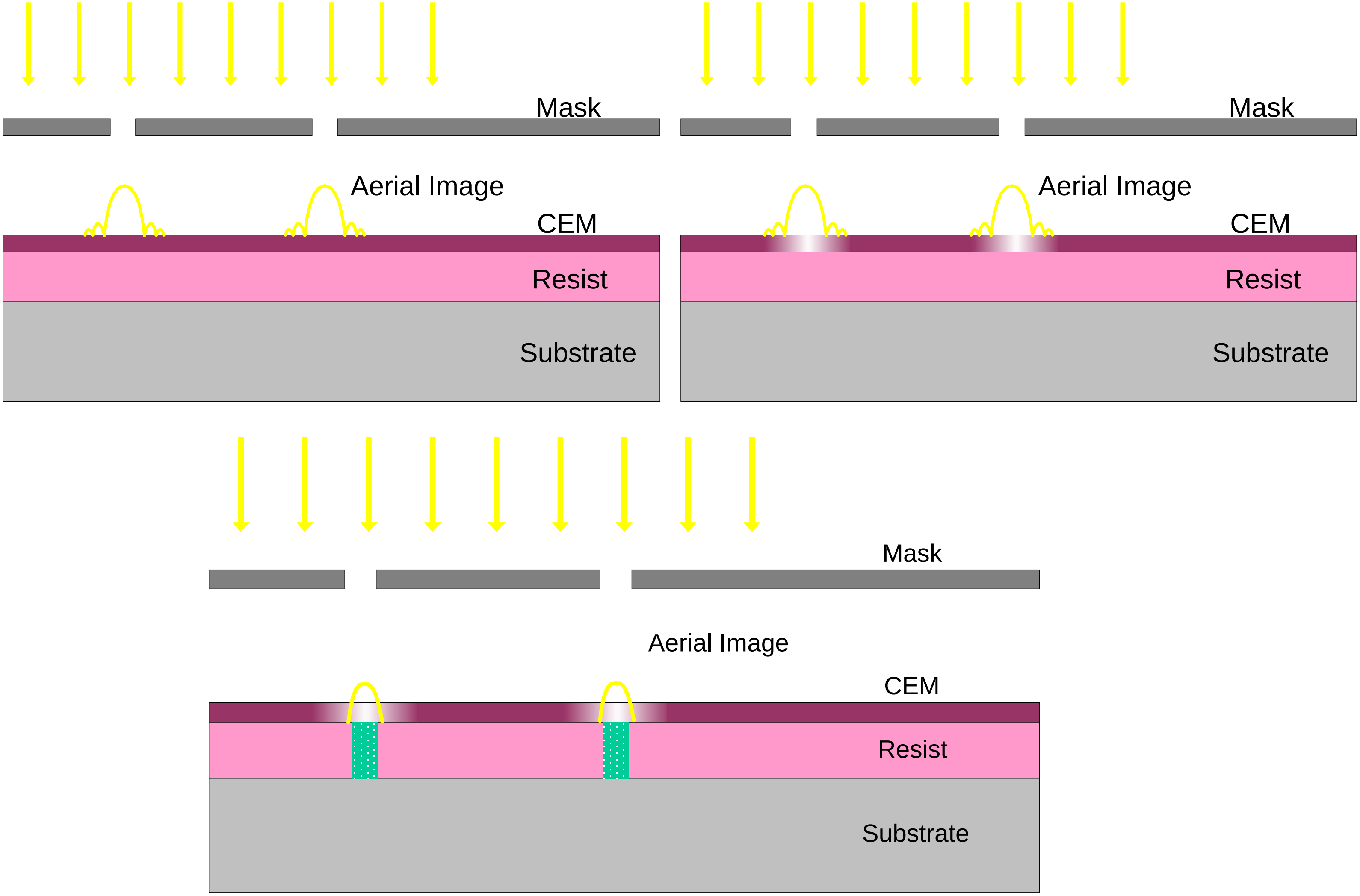
Figure 2: CEM Theory



CEM 420SS is not recommended to be applied directly on top of the photoresist due to interfacial mixing. Therefore, a barrier coat, CEM BC7.5, is required. CEM BC7.5 is a thin transparent polymer film spin coated directly over the photoresist layer after softbake. The recommended CEM BC7.5 coat program includes point-of-use filtration.

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MATERIAL PROPERTIES

CEM 420SS Material Properties

Solids	27.0 ± 2.0%
Viscosity @ 25 Deg C	20.0 ± 2.0 cstks
Refractive index	1.56
Film thickness	1.65 µm ± 0.15µm @ 4,000 rpm
Appearance	Clear, Yellow
Initial transmission (436 nm)	< 4%
Final transmission (436 nm)	> 90%
Cauchy Coefficients	
N_o	1.510
N_1	183.6
K_2	31.233
N_2, K_0, K_1,	0.000

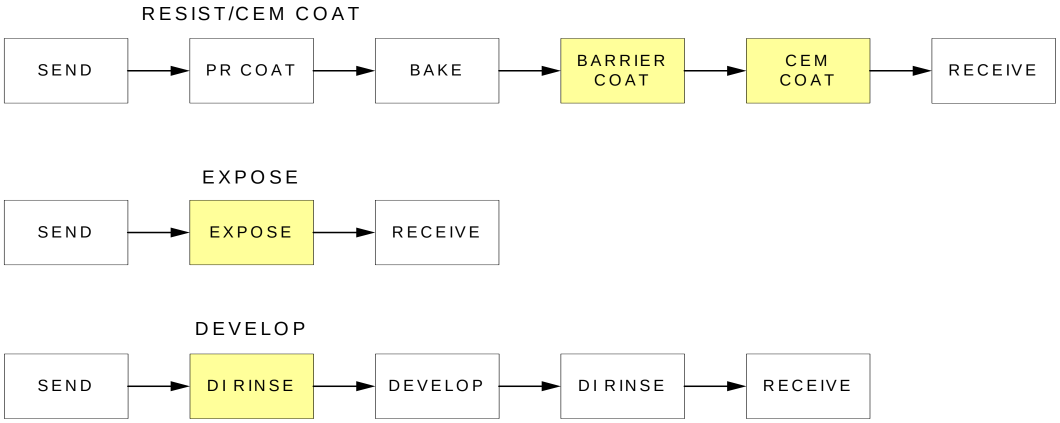
CEM BC7.5 Material Properties

Solids	8.8 ± 0.8%
Viscosity @ 25 Deg C	11.0 ± 1.0 cstks
Refractive index	1.51
Film thickness	4,500 Å ± 500 Å @ 2,000 rpm
Appearance	Clear, Colorless
Cauchy Coefficients	
N_o	1.497
N_1	44.5
N_2, K_0, K_1, K_2	0.000

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 BC7.5. Spin coat CEM 420SS
4. Expose wafer
5. Strip CEM and CEM BC7.5 using a DI water pre-wet
6. Post Exposure bake (if applicable)
7. Develop photoresist according to standard process.

CEM BC7.5 SPIN COATING CONDITIONS

1. CEM BC7.5, static dispense.
2. CEM BC7.5 spread for 2 seconds at 500 rpm.
3. Ramp at 10,000 rpm/sec to 2,000 rpm.
4. Spin dry for 30 seconds.

Sufficient CEM BC7.5 must be dispensed in step (1) above to produce a continuous film during the spread cycle. The following amounts of CEM-BC7.5 are the minimum recommended.

Approximate dispense volume of CEM BC7.55 by wafer size.

3” & 4”	8 - 10 ml
5” & 6”	12 - 15 ml
8”	18 ml

The above sequence yields a CEM BC 7.5 thickness of approximately 4500Å. Figure 4 provides a thickness versus spin speed plot for CEM BC7.5.

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

Figure 4: CEM BC7.5 Thickness vs. Spin Speed

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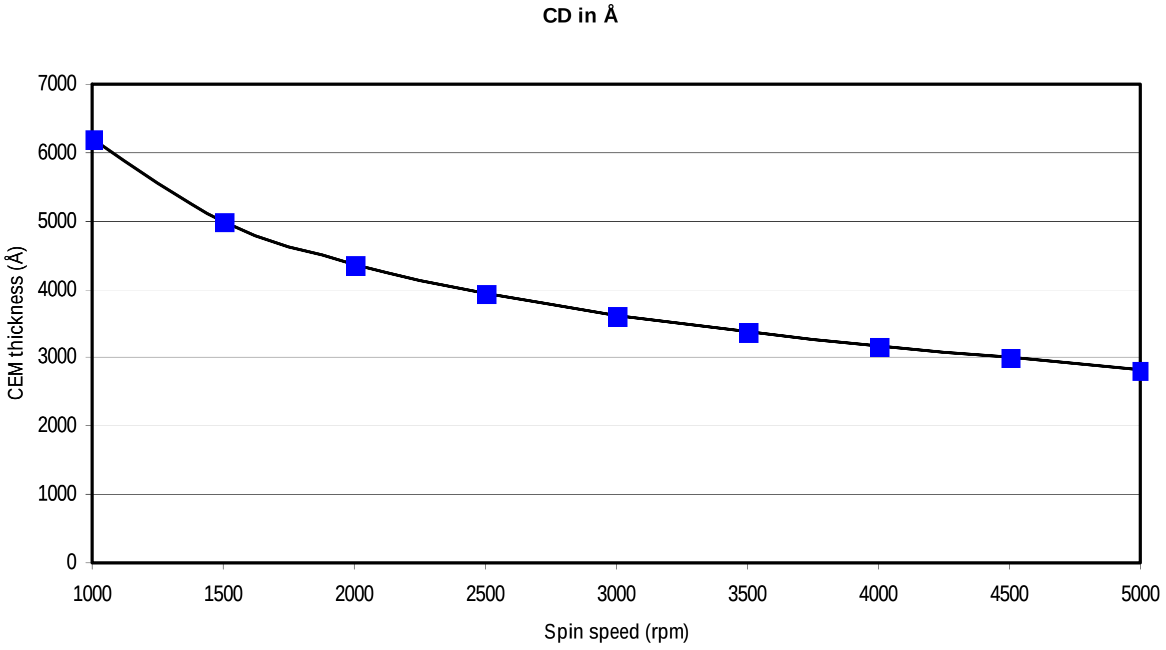


CEM COATING

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 420SS spin coat program is recommended to yield excellent thickness uniformities (< 50 Å variation across the wafer). See Figure #5.

1. CEM 420SS static dispense.
2. Spread for 2 seconds at 500 rpm.
3. Ramp at 10,000-rpm/sec minimum to final spin speed (2,000 rpm nominal).
4. Spin dry for 20 seconds (minimum)

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

3" & 4"	8-10 ml
5" & 6"	10-15 ml
8"	12-18 ml

Note 1: For automated track systems the CEM 420SS material is compatible with the photoresist spin bowl and drain. The Barrier Coat (BC 7.5) material is compatible and can be spin coated in the develop bowl.

Note 2: The volume of CEM used will also depend on the track system used. We have seen acceptable coatings performed on customer track systems with 6" wafers with less than 2ml of material.

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 1.65 µ. A thinner or thicker CEM layer may be optimum for certain resists and applications, and should be characterized by the user (See figure 5).

To measure the thickness of CEM 420SS

1. Coat clean bare silicon with CEM 420SS using the above procedure.
2. Bleach wafer by exposing to UV source for a minimum of 40 seconds.
3. Immediately measure thickness using a refractive index of 1.56.

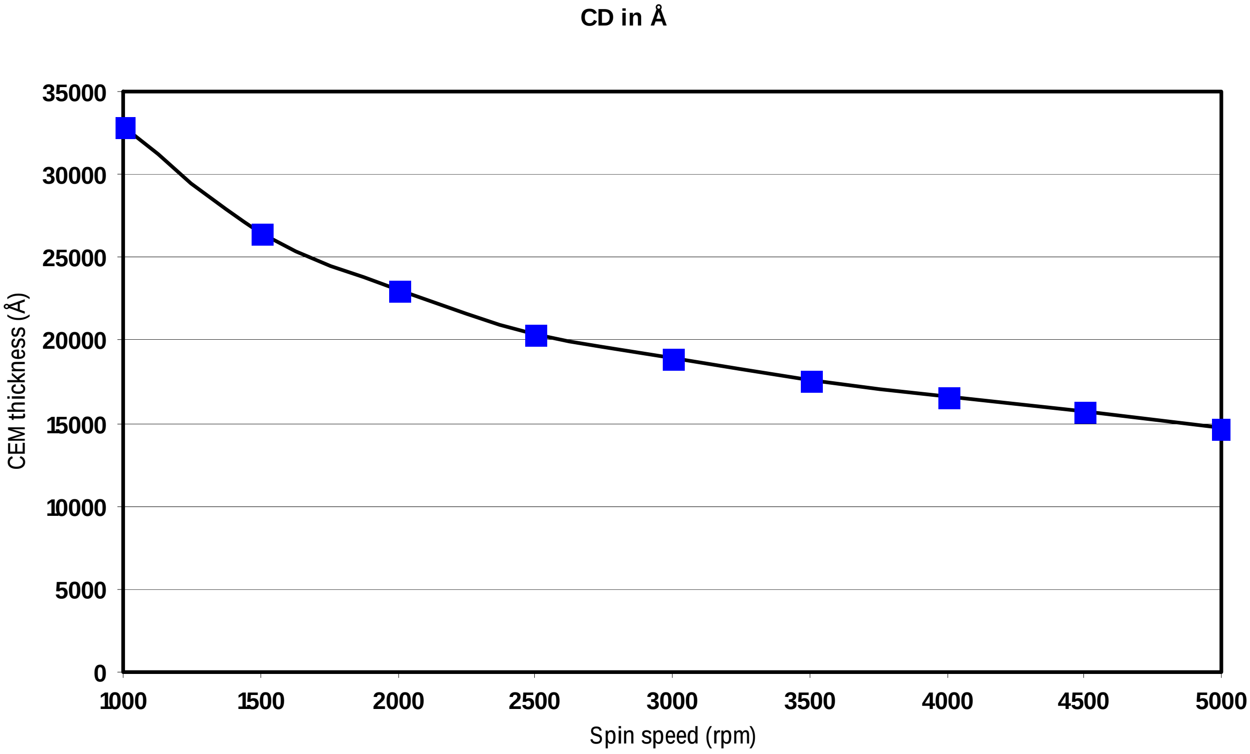
Note: It is important that the film is completely bleached. Partially bleached films can contribute to high readings (up to +200 Å) and poor uniformity.

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 420SS.

Note: It is recommended the filtration media is Teflon with a mesh size of 0.10µ.

Figure 5: CEM 420SS Thickness vs. Spin Speed



CEM 420SS EXPOSURE

CEM 420SS was developed for 405 nm (h-line), 436 nm (g-line) 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 approximately 30% to 100% higher and the center of focus will shift from the center to the top of a standard photoresist process. The increase in dosage is dependent on the photoresist and thickness, CD's being printed and the exposure tool.

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

CEM 420SS STRIP/DEVELOPMENT

CEM 420SS 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 BC7.5 and CEM 420SS layers. The CEM must be stripped prior to PEB.

Track process

Removal is performed by a water rinse which removes both the CEM 420SS and CEM BC7.5.

1. Spin wafer at 700 rpm
2. DI water rinse 10-20 seconds at 700 rpm.
3. DI water flow rate should be ≥ 10 ml/sec.
4. Spin dry, 15-25 sec at 5,000 rpm.

Immersion process

CEM 420SS and CEM BC7.5 may be stripped using a water immersion bath. For immersion stripping, the preferred equipment is a dump-rinse type of bath which provides vigorous agitation and rinses the wafers with copious amounts of water.

1. Program bath for 3 dump-rinse cycles, 40 seconds per cycle
2. Bath temperature: 20-25 °C (room temperature)
3. Water flow rate: 6-7 gallons/minute at 25 psi
4. Spin dry for 5 minutes at 3,500 rpm in a SRD

CEM 420SS PRODUCT HANDLING AND STORAGE PROCEDURES

Handling Precautions

CEM 420SS is light sensitive and should only be processed under yellow light. CEM 420SS is a flammable liquid. Use adequate ventilation. Avoid breathing of vapors. Keep away from heat sparks or open flame. CEM-420SS and CEM BC7.5 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 BC7.5 and 0 to 5 °C for CEM 420SS are recommended to insure optimum quality and shelf life. CEM 420SS and CEM BC7.5 should be allowed to stabilize at ambient temperature before use.

Waste disposal

CEM 420SS 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 420SS

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 Coast
- Pellicles
- Flexible Copper Laminate
- Epoxy Molding Compounds
- Adhesion Promoters

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