Contrast Enhancement Materials
CEM 388WS

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 388WS - 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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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 388WS.

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 388WS. 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).

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 388WS Spectral Transmission Characteristics

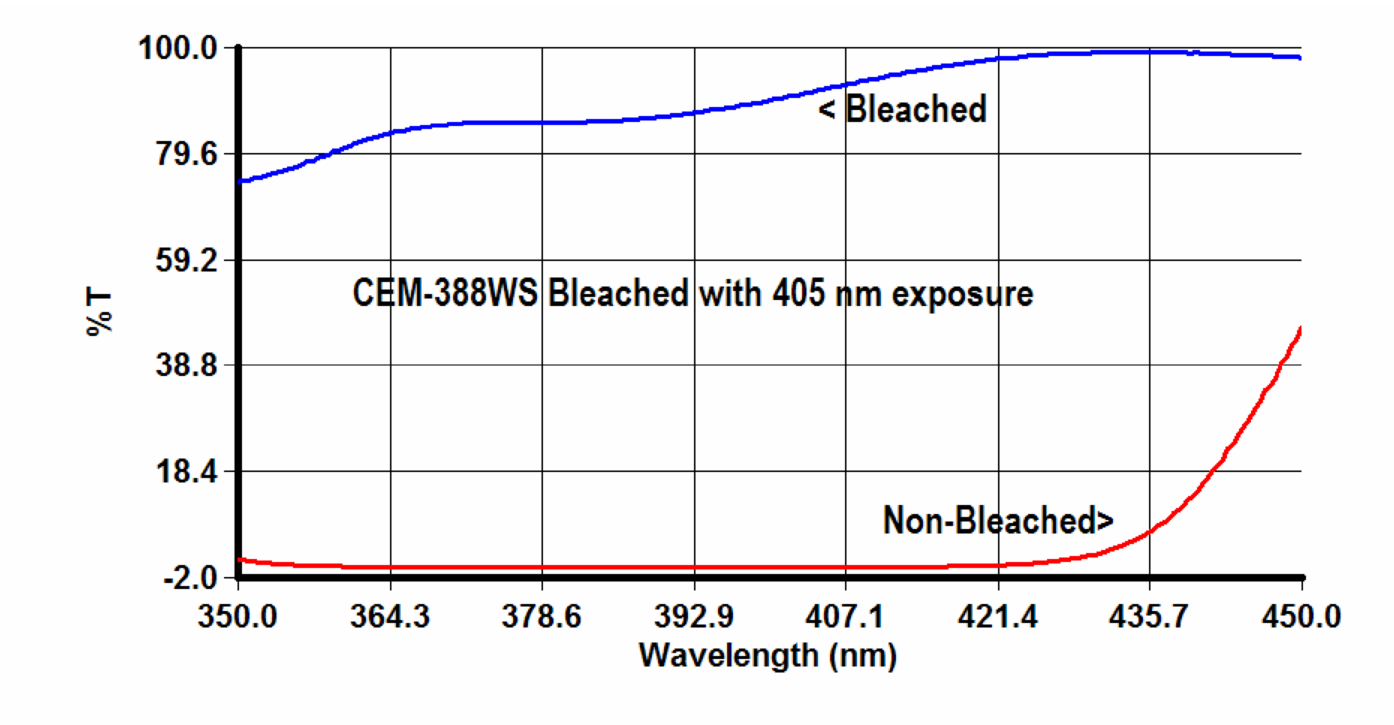
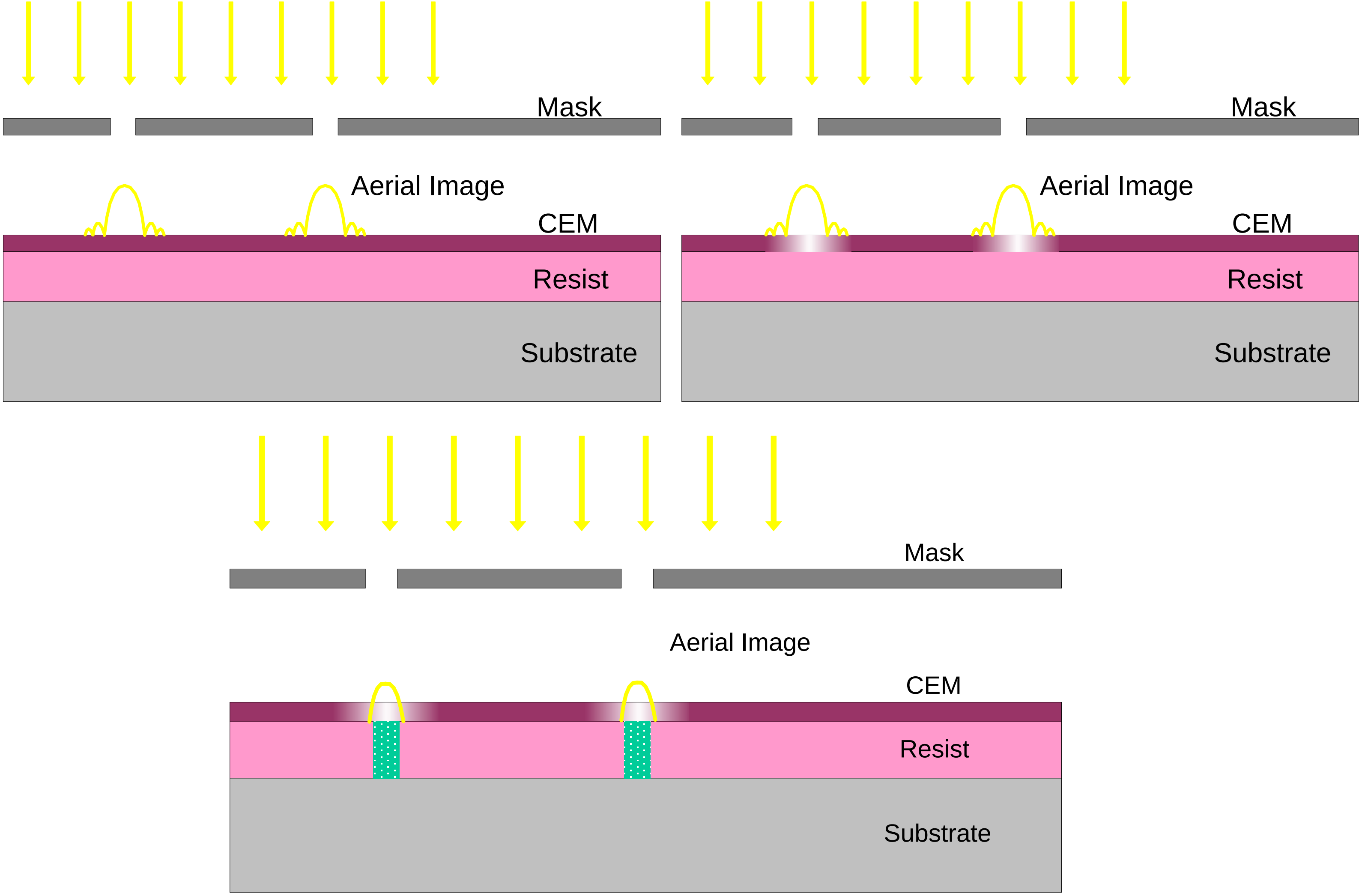


Figure 2: CEM Theory



CEM 388WS 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 388WS Material Properties

Solids	16.0 ± 2.0 %
Viscosity @ 25 Deg C	7.0 ± 0.5 cstks
Refractive index	1.58
Film thickness	6,500 ± 400Å @ 4,000 rpm
Appearance	Clear, Yellow
Initial transmission (405 nm)	< 2%
Final transmission (405 nm)	> 90%
Cauchy Coefficients	
N_o	1.534
N_1	168.6
K_2	13.489
N_2, K_0, K_1,	0.000

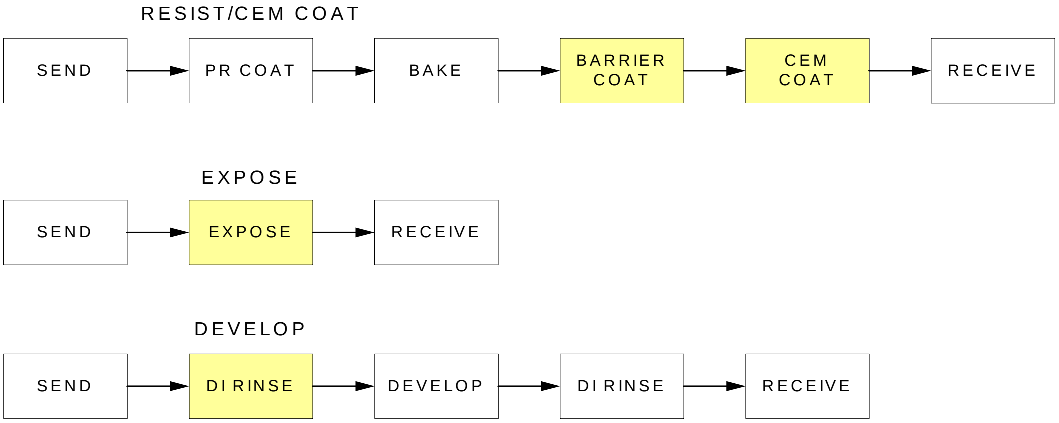
CEM BC5 Material Properties

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_o	1.500
N_1	34.5
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 BC5. Spin coat CEM 388WS
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.

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.

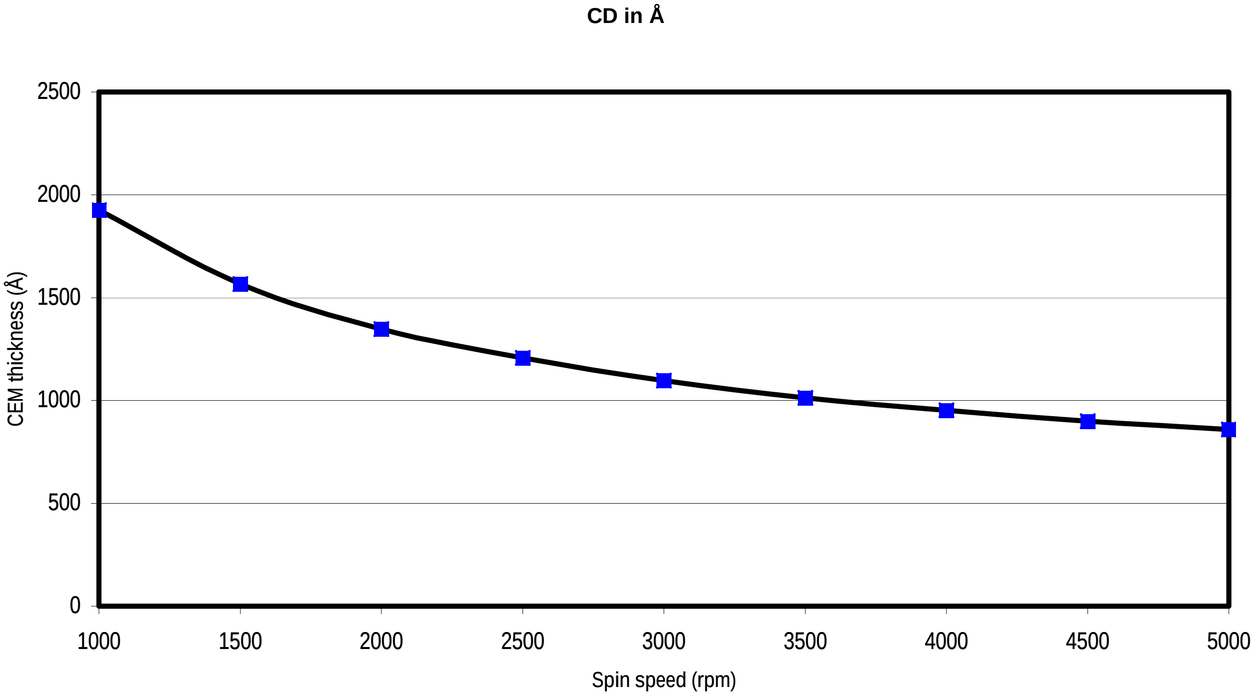
Approximate dispense volume of CEM BC5 by wafer size.

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



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 388WS spin coat program is recommended to yield excellent thickness uniformities (< 50 Å variation across the wafer).

1. CEM 388WS 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 20 seconds (minimum)

Approximate dispense volume of CEM 388WS by wafer size.

3” & 4”	1.0 – 1.5 ml
5” & 6”	2.0 – 2.5 ml
8”	3.0 – 3.5 ml

Note: For automated track systems the CEM 388WS 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.

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 6500 Å. 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 388WS

1. Coat clean bare silicon with CEM 388WS 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 1.58.

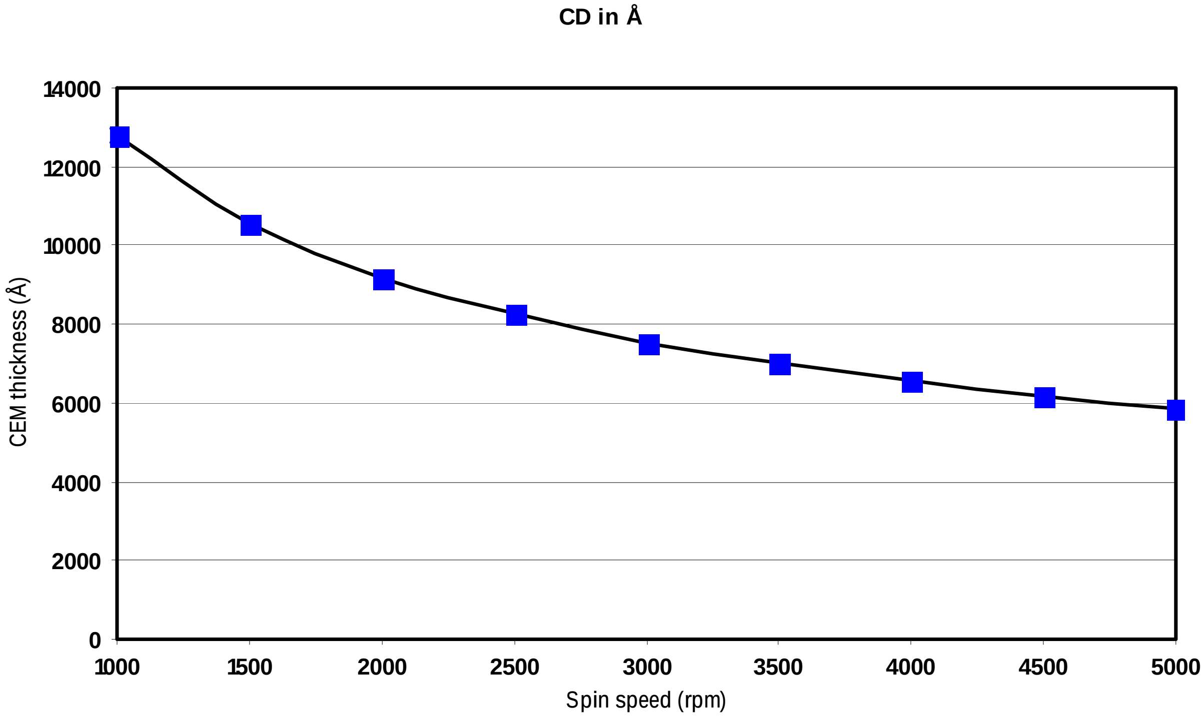
Note: It is important that the film is completely bleached. Partially bleached films can contribute to high readings (up to +200 Å) and poor uniformity.

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 388WS.

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

Figure 5: CEM 388WS Thickness vs. Spin Speed



CEM 388WS EXPOSURE

CEM 388WS was developed for 365 nm (i-line), 405 nm (h-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 2 to 3 times longer than for the photoresist layer alone and depend upon the CEM-388WS layer thickness and other process conditions. After exposure, a latent pattern is visible in the CEM-388WS 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 388WS STRIP/DEVELOPMENT

CEM 388WS 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 388WS 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 ≥ 10 ml/sec.

CEM 388WS 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 388WS 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 388WS PRODUCT HANDLING AND STORAGE PROCEDURES

Handling Precautions

CEM 388WS is light sensitive and should only be processed under yellow light. CEM 388WS is a flammable liquid. Use adequate ventilation. Avoid breathing of vapors. Keep away from heat sparks or open flame. CEM-388WS 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 388WS are recommended to insure optimum quality and shelf life. CEM 388WS and CEM BC5 should be allowed to stabilize at ambient temperature before use.

Waste disposal

CEM 388WS 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 388WS

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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ShinEtsuMicroSi
www.microsi.com (888) 642-7674