Contrast Enhancement Materials
CEM 388PG

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 388PG

CEM 388PG was specially formulated for use with thick films. It is optimized for films approximately 5µm thickness. The Propylene Glycol Monoethyl Ether Acetate (PGMEA) based solvent system provides excellent water strippability and can be removed by immersion or track processing.
CEM 388PG was developed for 365 nm (i-line), 405 nm (h-line), 436 (g-line) and UV-4 (broadband) exposure tools.

CEM 388PG - 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 388PG.

CEM THEORY

CEM is a photo bleachable solution, which is initially opaque to the exposure wavelength(s) but becomes nearly transparent upon exposure. Figure 1a and Figures 1b show the spectral transmission characteristics of CEM 388PG expososed at 365nm and 405 nm respectively. The Contrast Enhancement Material is spin coated over softbaked positive resist. When the aerial image of a mask incident upon the CEM layer, the regions of highest intensity corresponding to the clear areas of the mask, are bleached at a faster rate than the lower intensity gray and dark areas on 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 the exposure an in-situ contract 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-388PG Spectral characteristics at 405 nm exposure

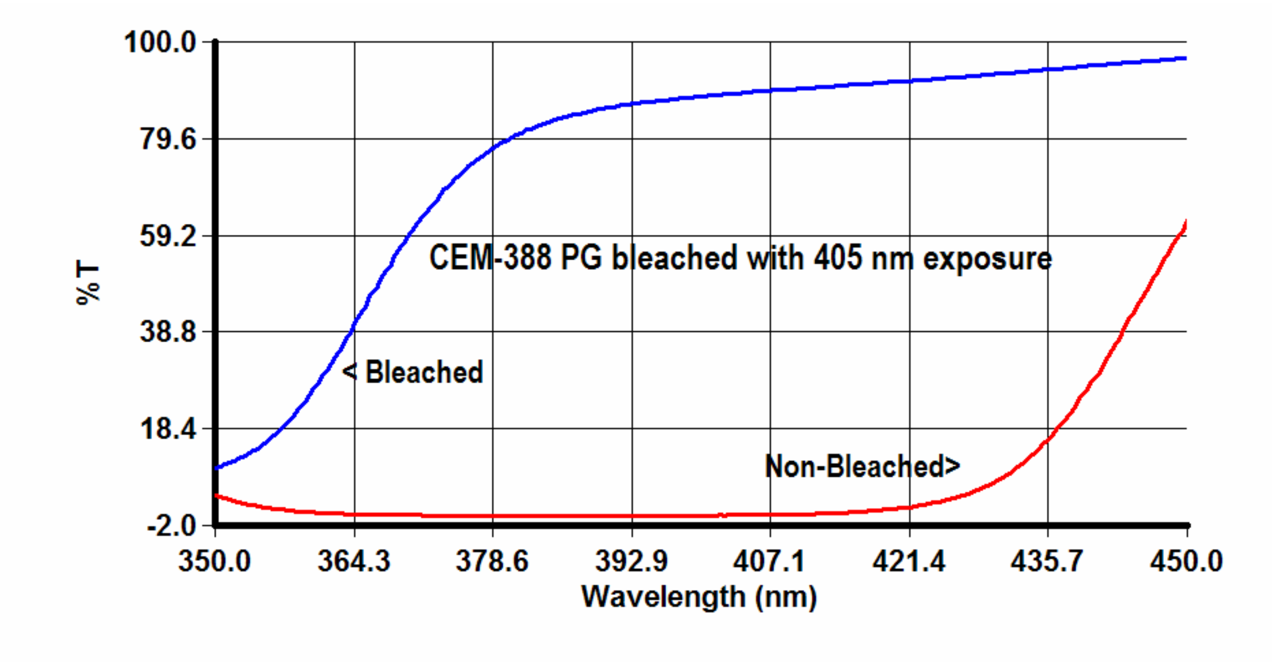
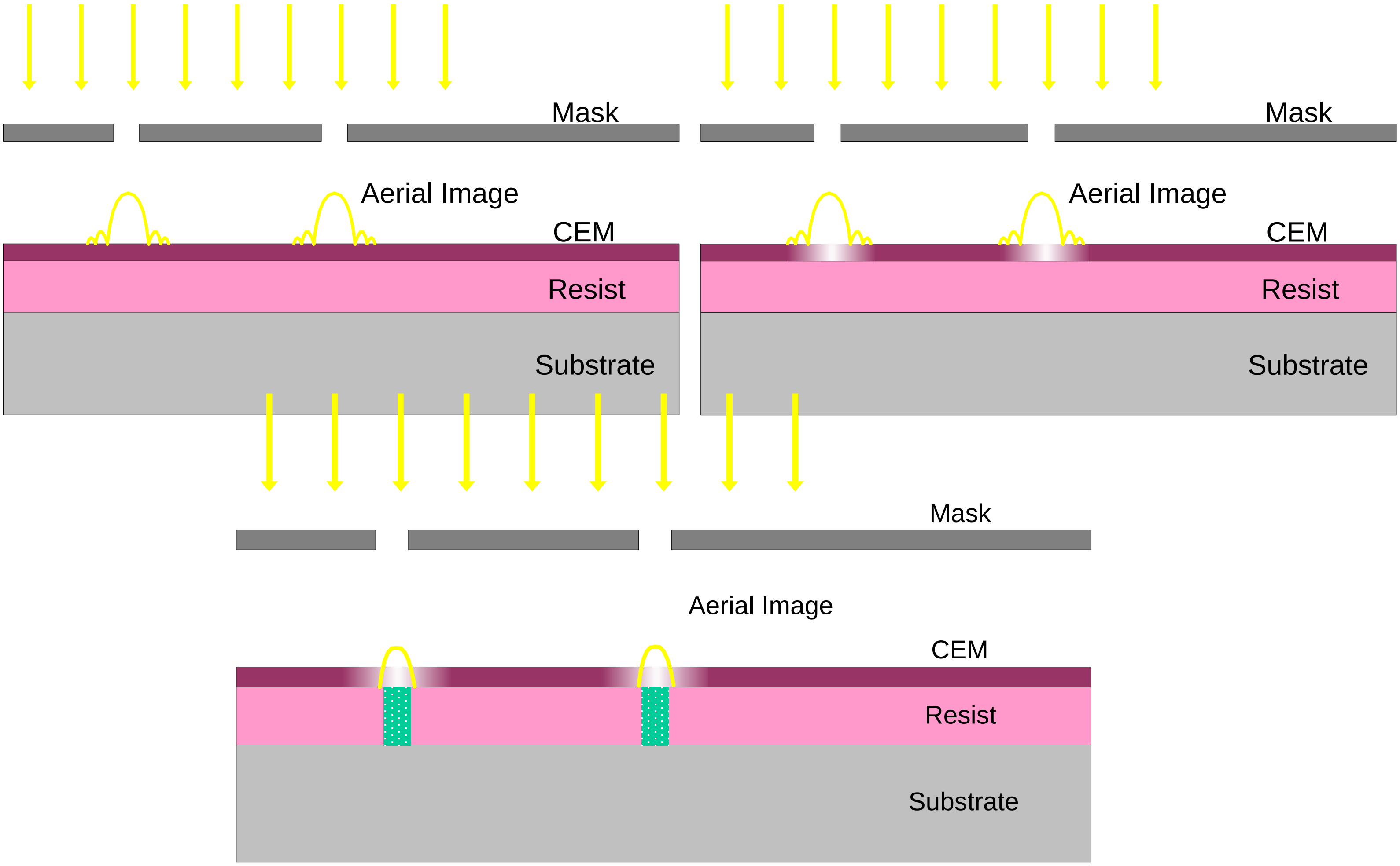


Figure 2: CEM Theory



CEM 388PG 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 388PG Material Properties

Solids	18.5 ± 2.0 %
Viscosity @ 25 Deg C	7.5 ± 0.5 cstks
Refractive index	1.58
Film thickness	6,100Å ± 400Å @ 4,000 rpm
Appearance	Clear, Yellow
Initial transmission (365 nm)	< 2%
Final transmission (365 nm)	> 90%
Cauchy Coefficients	
N_o	1.537
N_1	155.8
K_2	13.743
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

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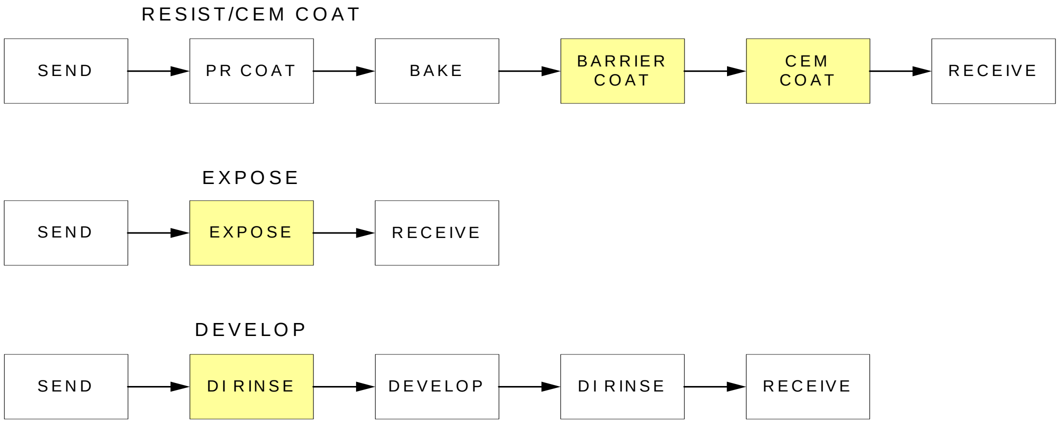
CEM PROCESS CONDITIONS

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 388PG
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.

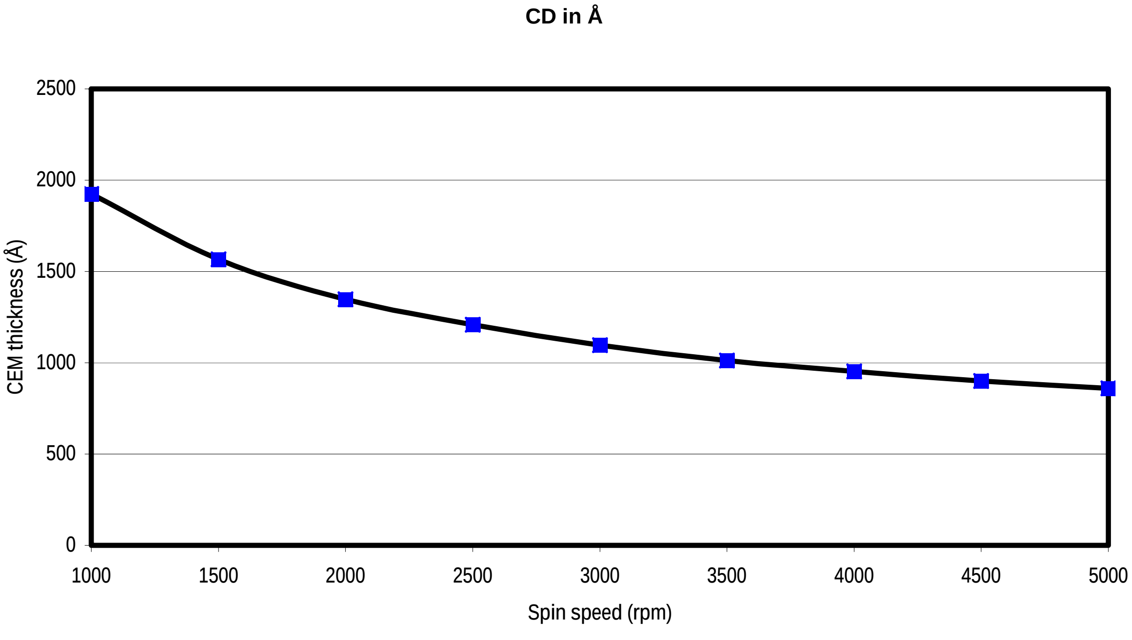
Approximate dispense volume of CEM BC5 by wafer size.

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 of Nowpak using a photoresist pump. For best results, point of use filtration is recommended.

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

1. CEM 388PG 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 388PG by wafer size.

3” & 4”	8 - 10 ml
5” & 6”	10 - 15 ml
8”	12 - 18 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 approximately 6100 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 388PG

1. Coat clean bare silicon with CEM 388PG 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.

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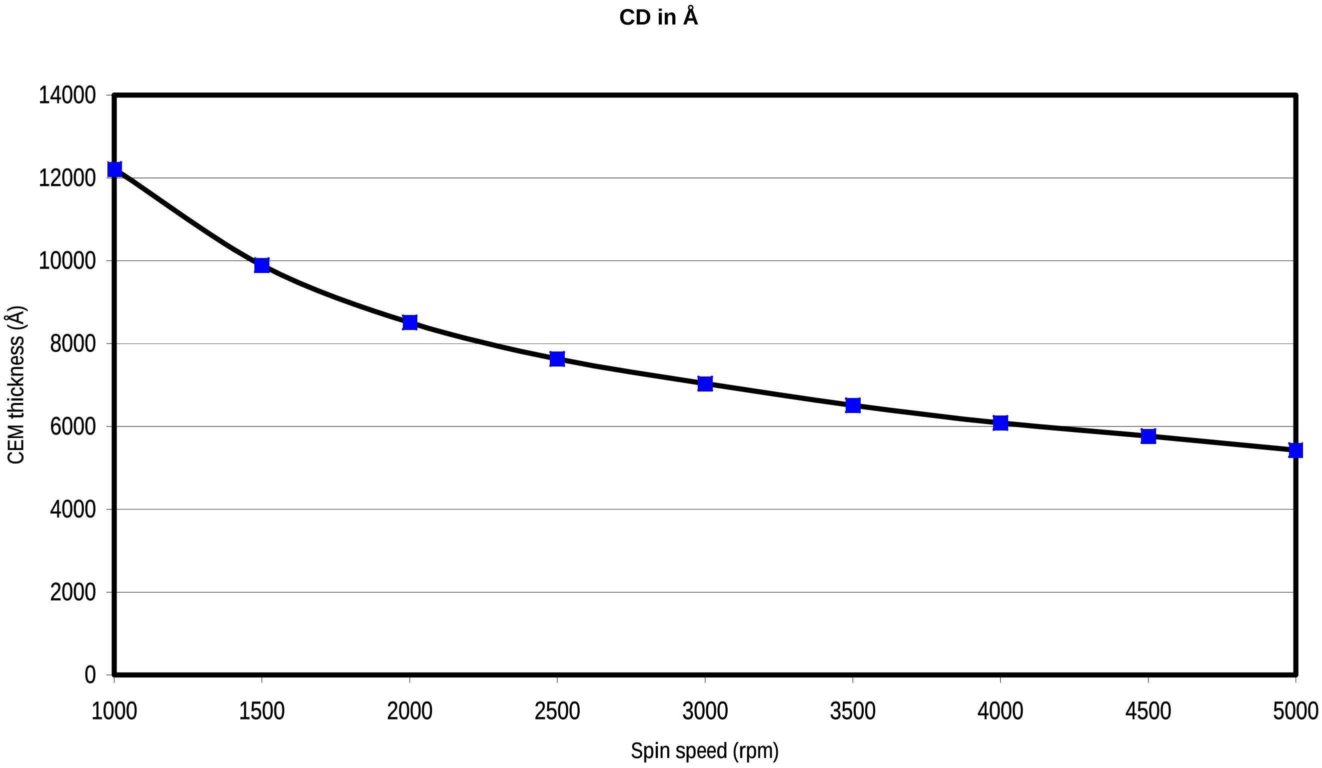
Good linewidth control is dependent upon the uniformity of the CEM layer thickness. It is important to use a photoresist thickness that provides adequate planarization of the topography being coated. Normally this is 2 to 2.5 times the greatest step height. One of the benefits of CEM is that it provides 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 388PG.

Note: **It is recommended the filtration media is Teflon with a mesh size of 0.05µ.**

Figure 5: CEM 388PG Thickness vs. Spin Speed



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CEM 388PG EXPOSURE

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

CEM 388PG 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 388PG layers. The CEM must be stripped prior to PEB.

Track process

Removal is performed by a water rinse which removes both the CEM-388PG and CEM-BC5.

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 388PG and CEM BC5 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 3500 rpm in a SRD

CEM 388PG PRODUCT HANDLING AND STORAGE PROCEDURES

Handling Precautions

CEM 388PG is light sensitive and should only be processed under yellow light. CEM 388PG is a flammable liquid. Use adequate ventilation. Avoid breathing of vapors. Keep away from heat sparks or open flame. CEM-388PG 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 18 to 24 ° C for CEM-BC5 and 18 to 24 °C for CEM 388PG are recommended to insure optimum quality and shelf life. CEM 388PG and CEM BC5 should be allowed to stabilize at ambient temperature before use.

Waste disposal

CEM 388PG is a hazardous waste due to its flammability and must be disposed of in accordance with all Federal, State and local regulations.

FIRST AID FOR CEM 388PG

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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