



## ***Contrast Enhancement Materials***

### ***CEM 365iS***

#### **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\*. A concentrated effort in the technology advancement of a CEM led to the development of an aqueous based and completely water soluble material. CEM 365iS is optimized for I-line applications.

\*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 365iS - 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 365iS.

### **CEM THEORY**

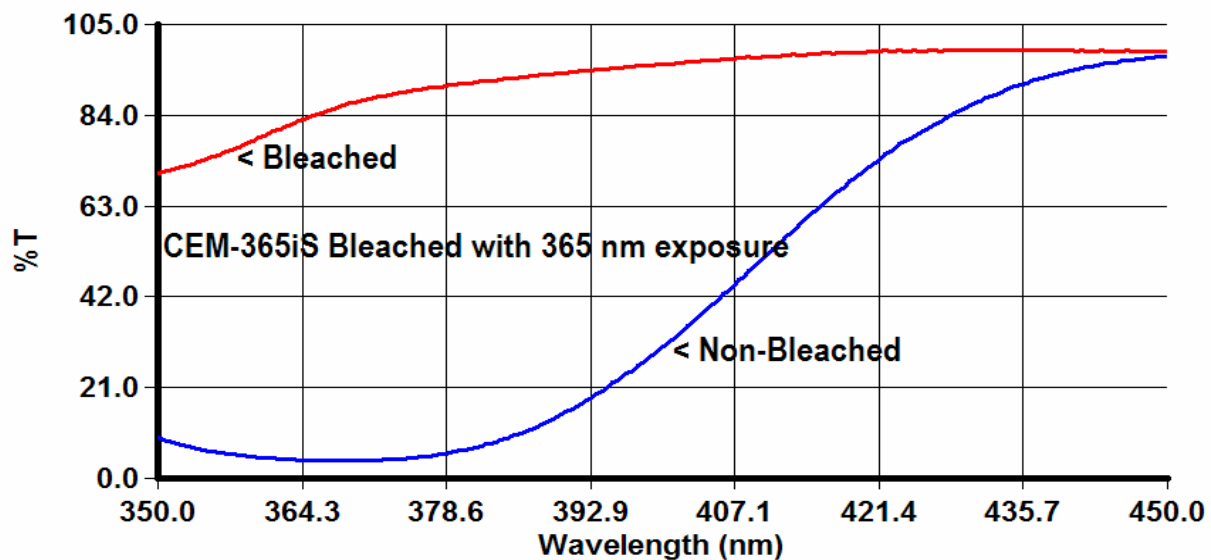
CEM is a photo bleachable solution, which is initially opaque to the exposure wavelength(s) but becomes nearly transparent upon exposure. Figure 1 shows the spectral transmission characteristics of CEM 365iS at I-line exposure. The CEM is spin coated on top of positive photoresist and then exposed. During 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.

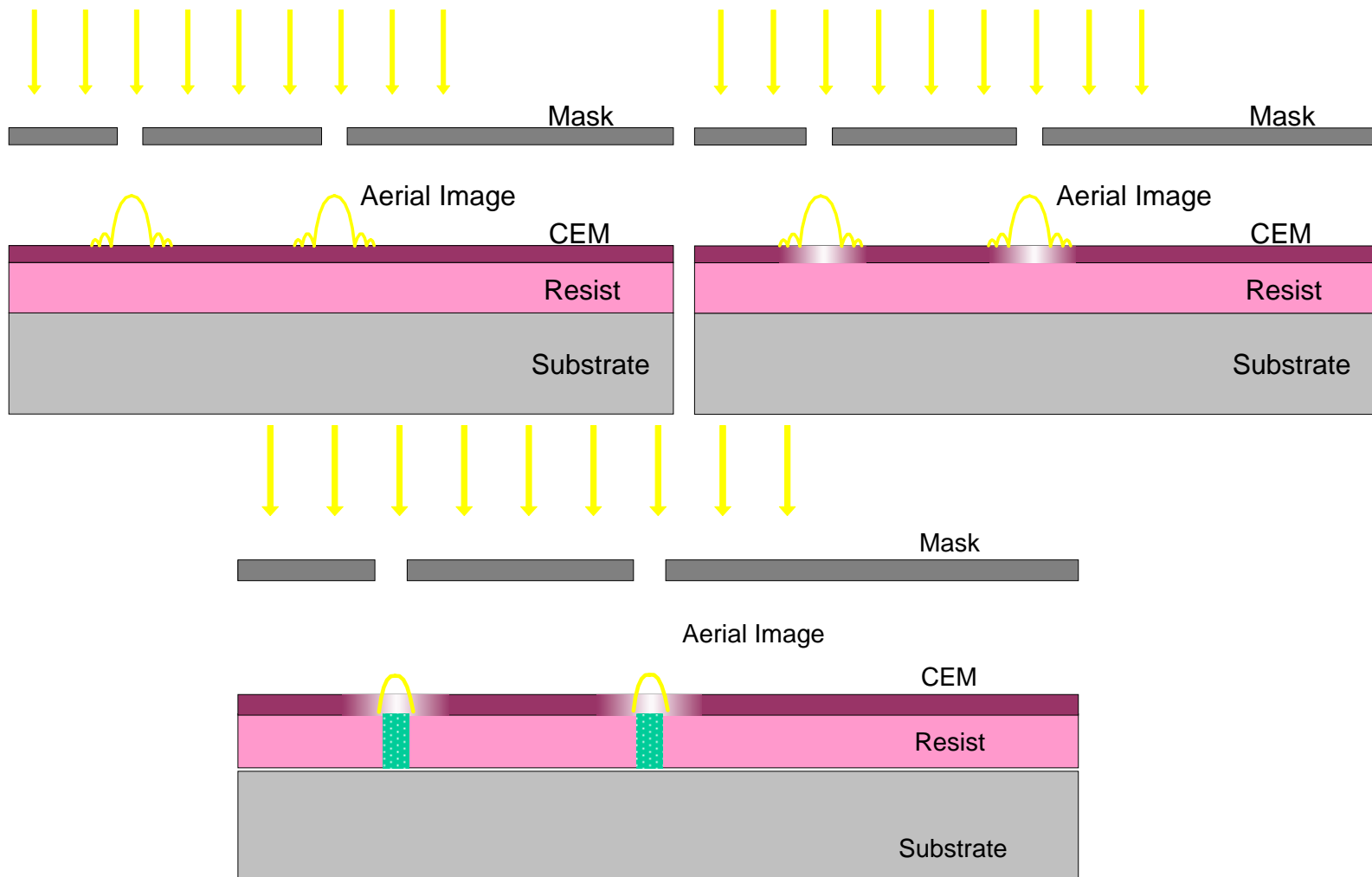
**Figure 1a:** CEM-365iS Spectral Transmission Characteristics with I-line exposure



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## CEM 365iS

Figure 2: CEM Theory



### MATERIAL PROPERTIES

Solids	14 ± 1%
Viscosity @ 25 Deg C	5.4± 0.5 cstks
Refractive index	1.55
Film thickness	3,900 ± 200 Å @ 4,000 rpm
Appearance	Clear, Yellow
Initial transmission (365 nm)	< 6.5
Final transmission (365 nm)	> 83.5
Cauchy Coefficients	
N <sub>0</sub>	1.524
N <sub>1</sub>	120.7
N <sub>2</sub> , K <sub>0</sub> , K <sub>1</sub> , K <sub>2</sub>	0.000

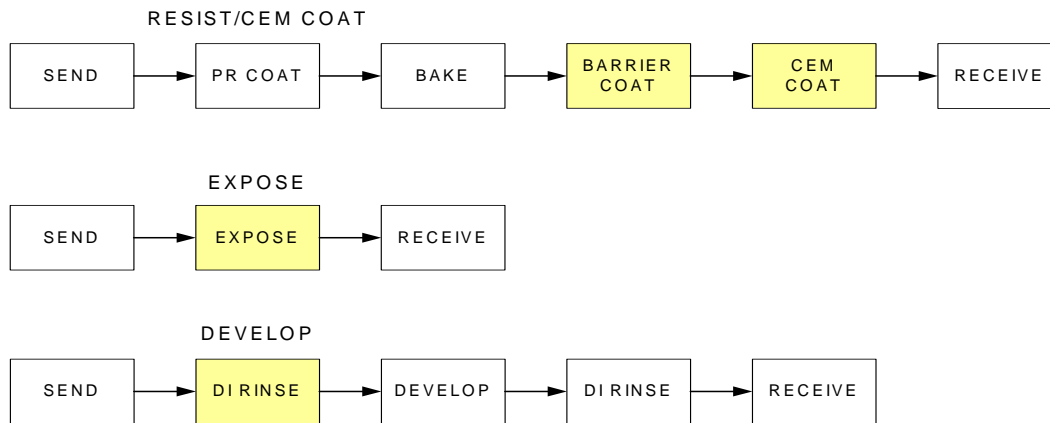
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### CEM PROCESS CONDITIONS

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

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### **CEM COATING**

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

The following CEM 365iS spin coat program is recommended to yield excellent thickness uniformities ( $< 50 \text{ \AA}$  variation across the wafer).

1. CEM-365iS 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)

Approximate dispense volume of CEM 365iS 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 365iS is compatible with aqueous materials. It is recommended it is spin coated in the develop bowl or a separate spin bowl from the photoresist spin 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 approximately  $3,900 \text{ \AA}$ . 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 4).

To measure the thickness of CEM 365iS

1. Coat clean bare silicon with CEM 365iS 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 1.55.

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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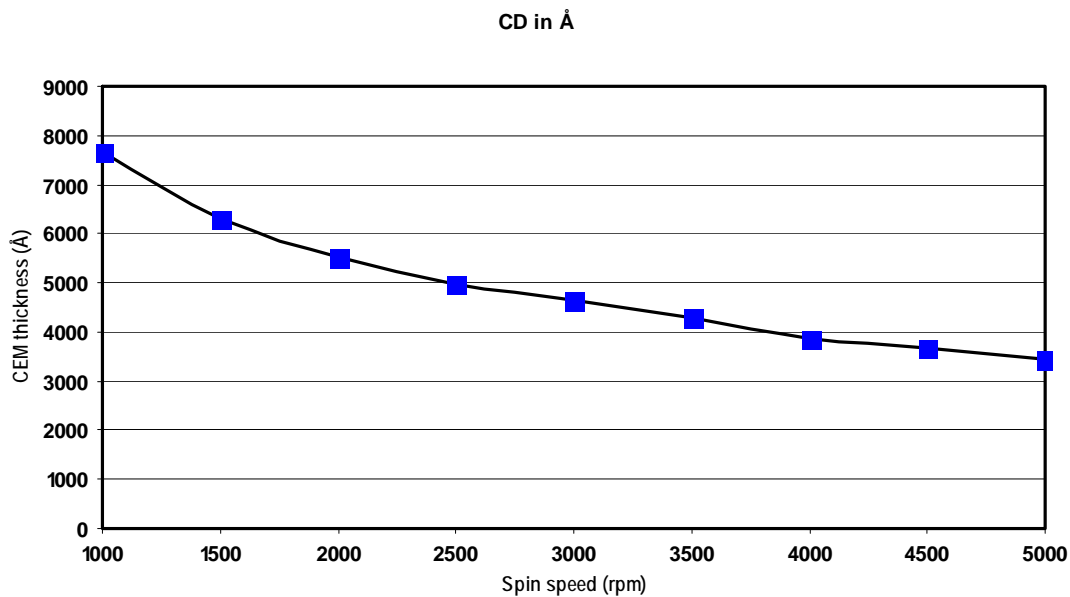
### CEM 365iS

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 365iS.

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

**Figure 4:** CEM-365iS Thickness vs. Spin Speed



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### **CEM 365iS EXPOSURE**

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 10-30% higher for I-line exposure and the center of focus will shift from the center to the top of a standard photoresist process. Broadband exposure will require slightly higher exposure depending on the exposure tool.

### **CEM 365iS STRIP/DEVELOPMENT**

CEM 365iS is a water strippable formulation. A develop pre-wet is all that is necessary to strip the CEM layer. CEM must be stripped prior to PEB.

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.

CEM 365iS is aqueous based and is compatible with developer.

### **CEM 365iS PRODUCT HANDLING AND STORAGE PROCEDURES**

#### **Handling Precautions**

CEM 365iS is light sensitive and should only be processed under yellow light. 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 0 to 5 ° C is recommended to insure optimum quality and shelf life. CEM 365iS should be allowed to stabilize at ambient temperature before use.

#### **Waste disposal**

CEM 365iS is soluble in alkaline water. The developers used for positive photoresist are alkaline. The CEM waste can be treated the same as the photoresist developer. All disposal is to be done in accordance with Federal, State and local regulations.

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### **First Aid for CEM 365iS**

Take action as follows:

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| 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 physician. Wash clothing before re-use.                       |
| 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    | • Liquid Underfill Materials |
| • KJR Liquid Coating Materials   | • Barrier Coats              |
| • Contrast Enhancement Materials | • Pellicles                  |
| • Mask Blanks                    | • Flexible Copper Laminate   |
| • PBN Crucibles                  | • Epoxy Molding Compounds    |
| • Photoresists / Developers      | • Adhesion Promoters         |
| • Quartz Substrates & Wafers     |                              |

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