Contrast Enhancement Materials

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 optimied for I-line applications but can also be used for broadband exposure tools with strong I-line and h-line wavelength components.

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

*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.

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 1a & Figure 1b shows the spectral transmission characteristics of CEM-365iS at I-line and broadband exposure, 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).

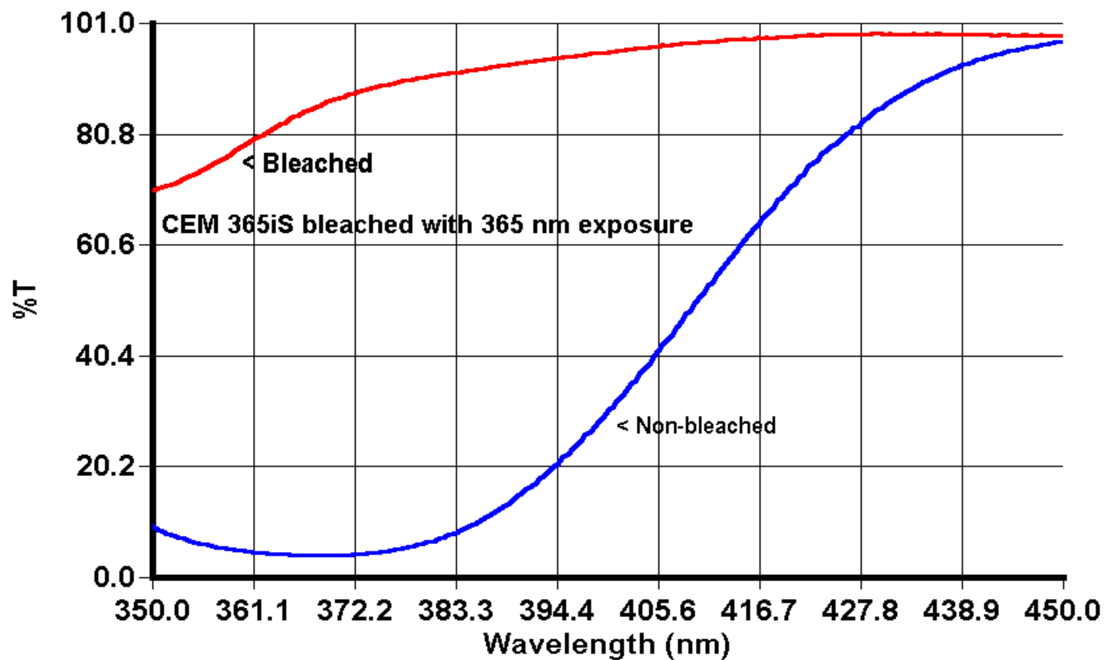


Figure 1a CEM-365iS Spectral Transmission Characteristics with I-line exposure

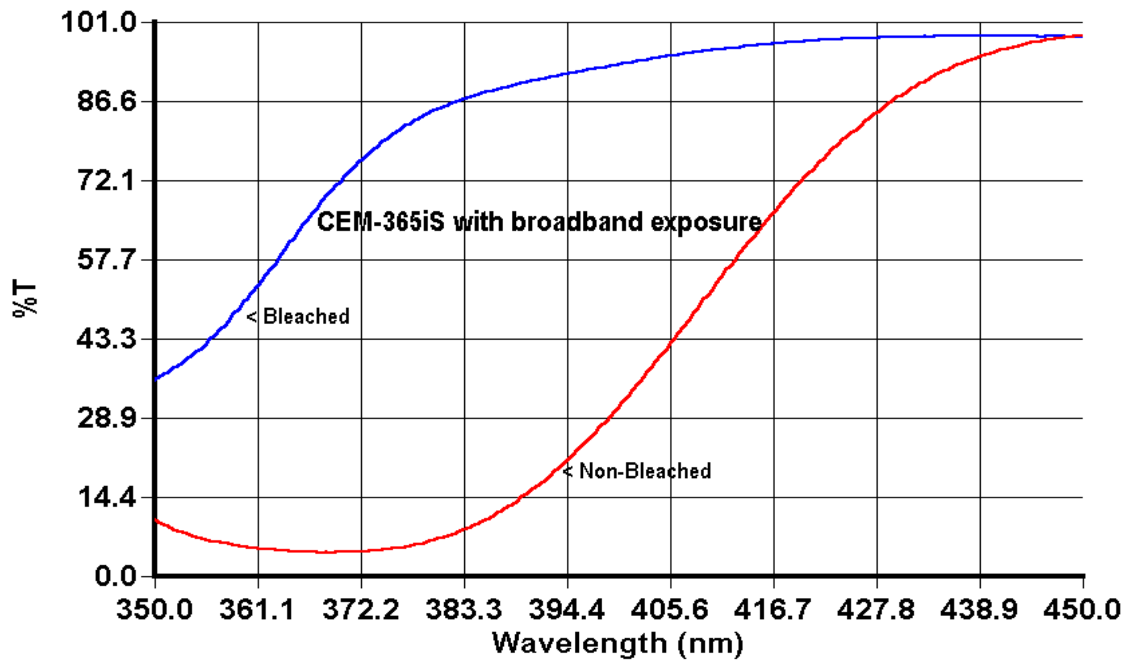


Figure 1b CEM-365iS Spectral Transmission Characteristics with broadband exposure

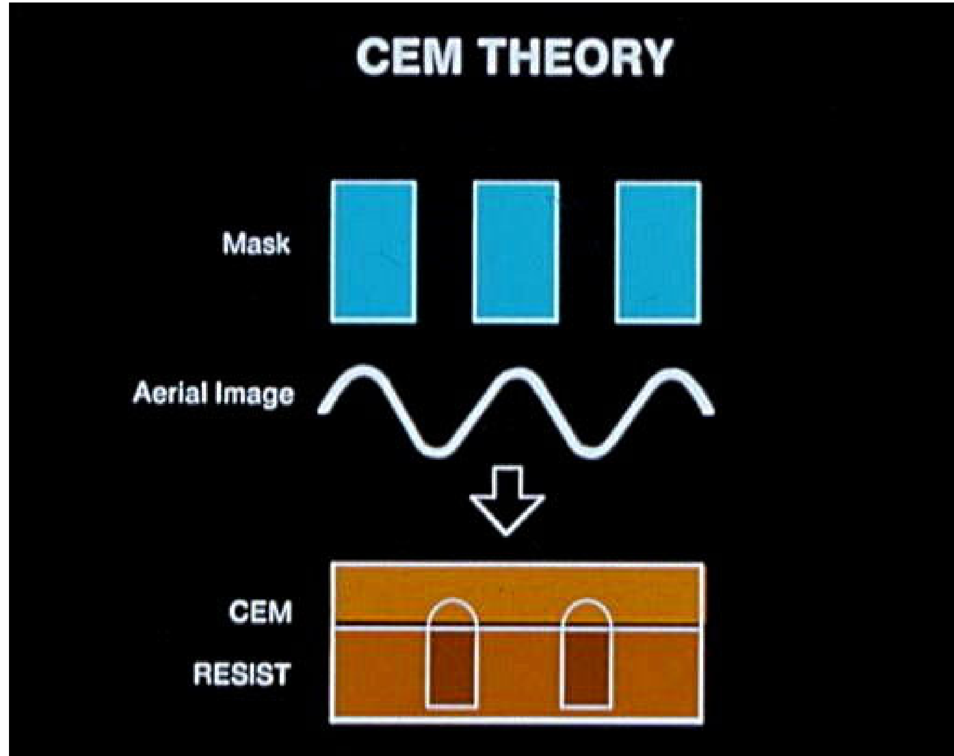


Figure 2 CEM Theory

Properties

Material Properties

Solids	13 ± 1%
Viscosity @ 25 Deg C	5.0 ± 0.5 cstks
Refractive index	1.54
Film thickness	4000 ± 250 Å @ 4000 rpm
Appearance	Clear, Yellow
Initial transmission (365 nm)	≈ 5%
Final transmission (365 nm)	≈ 89%
Initial transmission (405 nm)	≈ 40%
Final transmission (405 nm)	≈ 90%

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.

Sequence of steps in the Contrast Enhancement Process

1. Sin coat positive photoresist on primed wafers.
2. Softbake photoresist according to standard process.
3. Spin coat CEM
4. Expose wafer
5. Post Exposure bake
6. Strip CEM using a DI water pre-wet then develop photoresist according to standard process.

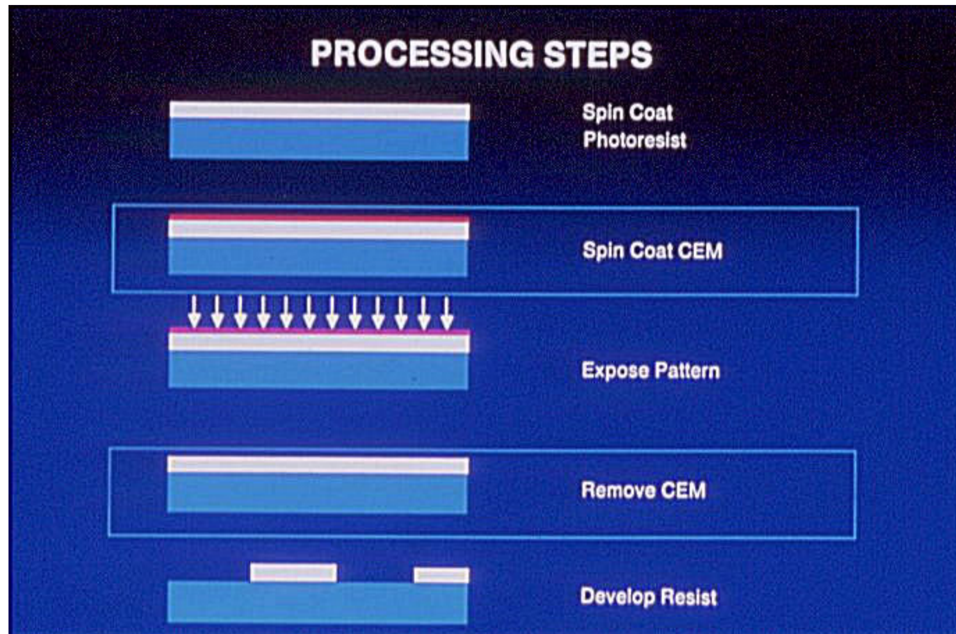


Figure 3 Process Steps

ShinEtsuMicroSi

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 Å 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 (4000 rpm nominal).
4. Spin dry for 20 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

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 between 1850-4000 Å (See Figure 4). A thinner or thicker CEM layer may prove to be optimum for certain resists and applications, and should be characterized by the user.

To measure the thickness of CEM-365iS

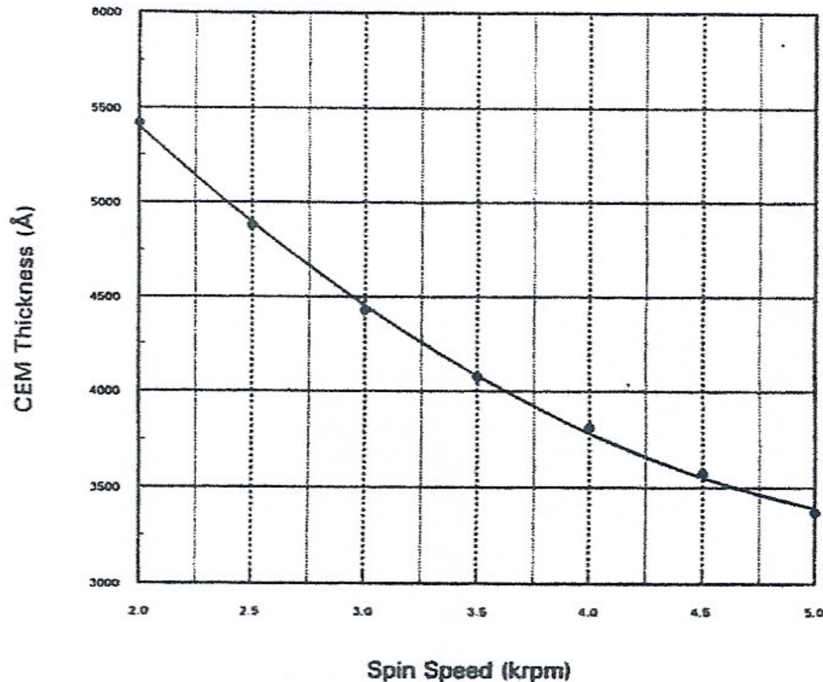
1. Coat clean bare silicon with CEM-365iS using the above procedure.
2. Bleach wafer by exposing to UV source for a minimum of 90 seconds.
3. Immediately measure thickness using a refractive index of 1.54.

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-365iS.

Figure 4 CEM-365iS Thickness vs. Spin Speed



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. 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 1000 rpm.
2. DI water rinse 5-10 seconds @ 1000 rpm.
3. Start standard development process immediately (no spin dry after strip required).
4. DI water flow rate should be ≥ 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 deposal

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.

First Aid for CEM 365iS

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 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

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