Ultrasonic Sensor for Photoresist Process Monitoring

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***Abstract*—An ultrasonic sensor has been developed to monitor photoresist processing $in\,situ$ during semiconductor manufacturing. Photoresist development, pre-exposure bake, and post-exposure bake were monitored for the Shipley 1800 series I-line resists, and the pre-exposure bake of Shipley APEX-E deep-uv (DUV) resist was monitored as well. Development monitoring was achieved by measuring thickness changes in the resist as it was removed. Data regarding dependence of development rate on exposure dose was obtained for the I-line resist with exposure doses varying from 20 to 68 mJ/cm^2. Measurements showed an increase in average development rate from 0.04 to 0.155 μm/s, with the rate leveling off at around 55 mJ/cm^2. Pre-exposure bake monitoring results demonstrated the ability of the sensor to measure the glass transition temperature of the resist film during prebake as well as the ability to invert out the elastic constants of the film using reflection theory. The glass transition temperature (T_g) is an important parameter in both the pre- and post-exposure bakes and therefore could be useful in monitoring these processes. Results of pre-exposure bake T_g measurements are presented for both I-line and DUV resists. The glass transition temperature during prebake was found to be higher for the DUV resist than for the I-line series. The I-line resist post-exposure bake measurement of glass transition temperature confirmed the reported T_g of 118 °C for the I-line novolac resin. The multiple uses of this sensor make it suitable for integration into a manufacturing setting.**

***Index Terms*— Development, photoresist, postbake, prebake, process monitoring, sensor, softbake, ultrasonic.**

I. Introduction

In current I-line and deep-UV lithography, *in situ* monitoring of photoresist processing is not required to meet design objectives. However, as feature size shrinks below sub-quarter-micron, it is expected that the resist materials will be more sensitive to processing conditions during pre-exposure bake, post-exposure bake, and development. After photoresist has been spin-coated to form a submicron film on a silicon wafer, it is necessary to prebake the freshly spun layer of resist prior to lithographic exposure. The purpose of this step is to evaporate the solvent from the film as well as to relax the resin polymer chains into an ordered array [1]. In order to accomplish this, the resist must be heated beyond its glass transition or softening temperature and held above that temperature during evaporation. The time of prebake is crucial because if the solvent isn't fully evaporated, the resist contrast can be compromised. Along with this, the temperature of prebake is also important since the resist can decompose if it is heated past its decomposition temperature. In either case, the feature size and therefore the device size will not be as expected. A sensor to detect resist cure state across the wafer would be necessary to optimize the process for each new wafer.

After the prebaked resist has been exposed, there is a post-exposure bake (PEB) step designed to produce a uniform image. Heating the resist to the post-exposure bake temperature enables diffusion of the exposed photoactive compound (PAC) within the resist, smoothing the standing waves that result from interference effects. In the case of chemically-amplified resists, the post-exposure bake is especially important since the deprotection reaction and the diffusion of photoactive compound continue throughout the PEB. A measure of this diffusion and the large changes in film properties that accompany it would be useful in characterizing the bake and the effect of its parameters on the final critical dimension of the devices. Once the resist has been through the PEB, it is developed to etch the desired circuit pattern into the resist. It is crucial that all of the soluble resist be removed by developer while the insoluble resist remains to sustain the exposed pattern. Thus, prediction and control of the development rate and time to clearance are necessary for repeatable feature size and device operation.

In the field of resist processing, some research has been completed in endpoint detection of the pre-exposure bake process [7], but the technique provides thickness information only and not information on changing elastic properties. Endpoint detection of photoresist development based on optical monitoring of thickness has been effective for over a decade [1], [8], [9], but this measurement still requires that the development solution be transparent to the incident light. The technique described here provides information on the studied film's elastic properties and thickness and, since it is based on ultrasonic technology, does not depend on optical transparency of the measurement environment. In this paper, ultrasonic measurement and monitoring of the prebake, postbake, and development processes are addressed. Ultrasonic technology has already been applied to the more general task of monitoring semiconductor fabrication processes [2]–[6]. This work involved exciting Lamb waves in silicon wafers and measuring the changes in the velocity of these waves that occurred during wafer processing. Unlike this previous work, the measurement principle of the current sensor involves exciting a high-frequency longitudinal wave in the wafer and monitoring changes in the reflection coefficient of the wave as it reflects from the silicon/photoresist interface. As

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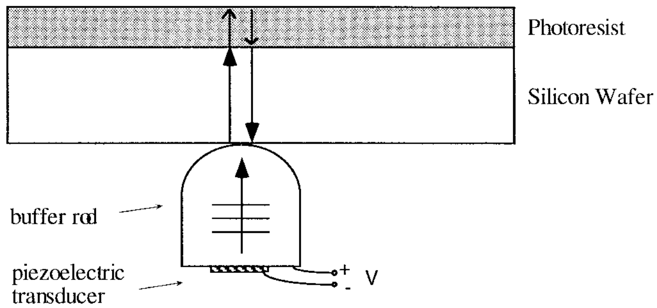

Fig. 1. Illustration of measurement technique (not to scale).

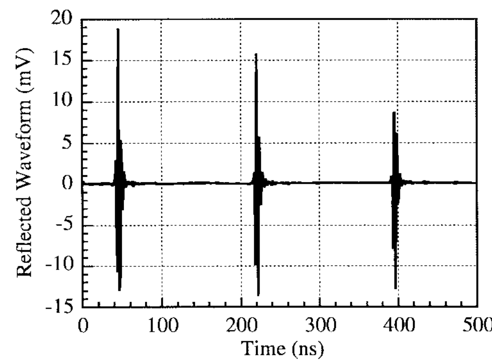

Fig. 2. Multiple reflections from the wafer/photoresist interface used to calculate phase change.

the resist thickness, density, and acoustic velocity change during prebake, the reflection coefficient will be altered in accordance with reflection theory; this will allow *in situ* monitoring of the process. The measurement principle and technique are described first, then the application of the sensor to photoresist development and pre- and post-exposure bake process monitoring is reported.

II. Measurement Principle

The sensor introduced here is based in principle on the measurement of the acoustic reflection coefficient for a wave incident on the interface between silicon and a thin film. This reflection coefficient is dependent upon the elastic properties of the thin film. As with optical reflection, there can be constructive and destructive interference in a thin film that will change as the film thickness and properties change. If the film thickness is of the same order as the wavelength of the incident wave, then these interference changes manifest themselves as measurable changes in the amplitude and phase of the reflection coefficient.

Fig. 1 is an illustration of the reflection measurement [10]. An 8 μm thick zinc oxide (ZnO) film is deposited on a sapphire buffer rod which is placed in contact with the back side of the wafer. The ZnO piezoelectric transducer is excited with a 20–50 V voltage spike, launching a longitudinal wave that is coupled from the buffer rod to the silicon wafer. The reflected wave can then be monitored by the same transducer; it is the change in the amplitude and phase of this reflection that will provide information regarding the resist property changes. The reflected waveform consists of a combination of reflections from both the wafer/resist interface and the resist/air interface, however, if the resist film is about an order of magnitude less than the wavelength, then these reflections will be indistinguishable. Typical wavelengths that will be used here are 20–40 μm.

The reflection coefficient for a longitudinal plane wave incident on a layer separating two semi-infinite media can be calculated using classical reflection theory and is shown in (1) [11]

$$R = \left[\frac{\left(1-\dfrac{z_1}{z_3}\right)\cos k_2L + j\dfrac{z_2}{z_3}\sin k_2L}{\left(1+\dfrac{z_1}{z_3}\right)\cos k_2L + j\dfrac{z_2}{z_3}\sin k_2L}\right] \tag{1}$$

where k_i is the wave number and z_i is the acoustic impedance defined as

$$k_i = \frac{2\pi f}{c_i}, \quad z_i = \rho_i c_i$$

where the subscripts $i = 1, 2, 3$ represent the media of silicon, photoresist, and air, c_i denotes the velocity of longitudinal waves in the medium, and ρ_i is the density. The photoresist thickness is represented by L and frequency is given by f. We also expect a phase change in the reflected signal as the wafer changes temperature. Equation (2) governs the change in phase resulting from this wafer temperature change

$$\Delta\varphi(T) = 4\pi f d\left[\frac{1}{v(T_0)(1-k_v(T=T_0))} - \frac{1}{v(T_0)}\right]. \tag{2}$$

Here, d is the silicon wafer thickness, f is the frequency of the ultrasonic signal, $v(T)$ is the velocity of a longitudinal wave in silicon at temperature T, T_0 is room temperature (25 °C), and k_v is the temperature sensitivity coefficient of the wave velocity in silicon.

For a given process, we expect a phase change as the impedance and thickness of the resist change. If, along with these impedance and thickness changes, there is a temperature change during the process, an additional phase change corresponding to (2) will be measured. This temperature effect can be characterized and removed from the data, leaving a measure of impedance and thickness changes that can be analyzed to determine at what state the process is and whether or not it has reached completion.

III. Phase Measurement Technique

Once the longitudinal wave is reflected from the interface between the wafer and the resist, it is converted back to an electrical signal by the transducer and monitored on an oscilloscope. Fig. 2 is a plot of a typical reflection signal, consisting of three separate multiple reflections from the silicon/resist interface. Fig. 3 is a block diagram of the experimental setup used. In order to measure the change in phase of this reflected signal, first we digitize the signal using a digital oscilloscope operating at a sampling rate greater than twice the frequency of interest; anti-aliasing filters just above this frequency are applied as needed. Then the data is stored and later processed in software where the

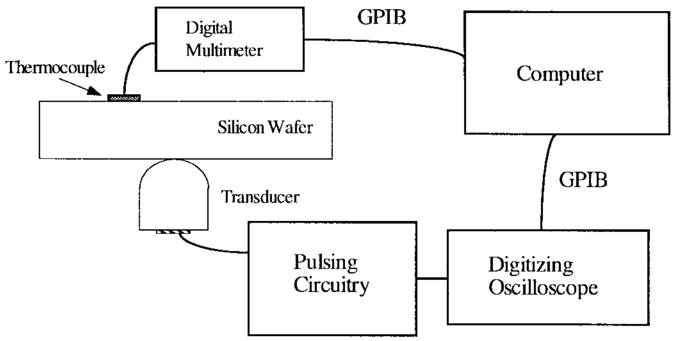

Fig. 3. Block diagram of experimental setup.

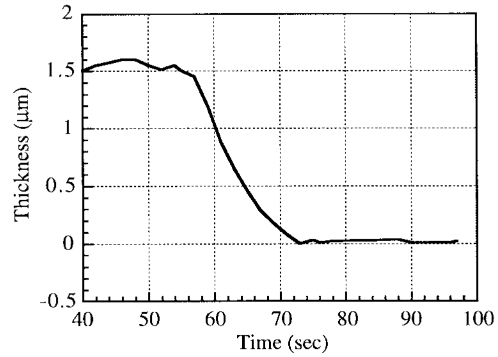

Fig. 4. Inverted thickness of resist during development.

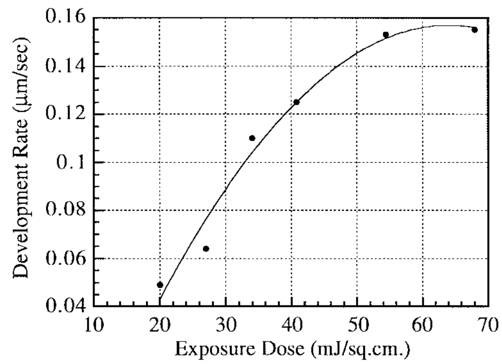

Fig. 5. Average development rate versus exposure dose.

waveform signal is windowed, and the FFT and the phase of the resulting frequency domain signal are calculated. A simple programming routine was written to accomplish this, calculating the phase by subtracting the phases of the first two reflections. In this manner, systematic effects unrelated to changes in the film are removed. This phase calculation is completed for the time sequence of signals digitized by the oscilloscope, allowing the user to track the phase during processing. For each waveform obtained and stored, the wafer temperature is measured and stored using a K-type adhesive thermocouple. The thermocouple is attached to the back-side of the wafer at a location within a centimeter of the monitoring location, and the signal from the thermocouple is fed into a thermocouple converter and then into a digital multimeter setup. The output of the multimeter is obtained through a computer-programmed GPIB interface which sequentially collects data from the thermocouple, the oscilloscope, and then the thermocouple again. The resulting temperature readings are averaged to obtain a close approximation (within 1–2 °C) of the wafer temperature at the time of waveform digitization.

IV. Photoresist Development Monitoring

To demonstrate the use of this transducer as a development process sensor, the change in the phase of the reflection coefficient is monitored during resist removal. A sample resist thickness vs. time during development is shown in Fig. 4. Endpoint was seen to occur in about 75 s, with an average development rate of about 0.1 μm/s. The removal of this 1.5-μm thickness resulted in a phase change of 18° at 283 MHz, which agreed well with the expected phase change at this frequency. A simple calibration was completed to remove the effects of developer addition on the reflection phase. This was done for puddle development here but could be applied to either spray or immersion development too. Two other locations were also developed on the same wafer with similar results. Note that the development rate decreases as the depth into the resist increases. This variation is expected as a result of absorption of the exposure energy as it travels through the resist.

To measure the difference in development rate that results from different exposure levels, resist thickness changes were monitored during development of four samples [12]. The results are shown in Fig. 5, where the measured development rates are plotted versus exposure dose. As the exposure dose was increased from 20 to 68 mJ/cm^2, the dissolution rate initially increased sharply but then leveled off above at a dose of around 55 mJ/cm^2. The filled circles in the figure represent the actual datapoints while the solid line represents a curve that was fit to the data.

One consideration in designing a sensor to monitor development or any other wafer processing step is whether or not topography on the wafer will interfere with the measurement. In a previous paper [12], this issue was addressed and it was shown that the sensor could monitor development on multi-layered three-dimensional PMOS devices with topographical dimenstions on the order of the thickness of the resist film (0.1–1.0 μm). Another consideration was the sensitivity of the measurement to development of a resist pattern instead of the blanket film removal studied above. Calculations indicated that if a pattern of lines was developed, the change in phase would be measurable if the total area of the lines removed was greater than 1/20 the original area of resist coating.

This sensor is capable of monitoring the thickness of photoresist during lithographic development, differentiating between development rates, and monitoring development of photoresist deposited over layered topography. This technique can be applied to *in situ* monitoring of lithographic photoresist development in a manufacturing setting.

V. Pre-Exposure Bake Monitoring

During the pre-exposure bake process of semiconductor fabrication, it is important that the temperature exceed the glass transition temperature (T_g) of the resist/solvent mixture.

This ensures the diffusion of solvent molecules and polymer chains that is necessary for prebake to occur [1]. If the solvent isn't fully evaporated or if the prebake time is too long, then feature sizes in exposed and developed photoresist may not be congruent to those on the mask. Several techniques are available to measure T_g, but none of them has been applied in situ for endpoint detection of photoresist softbake [13], [14]. Endpoint detection based on optical monitoring of the thickness of the photoresist has been used [7], but the prebake process involves more than a simple film thickness change. The high-frequency reflection method applied here monitors not only the effect of thickness change, but also the effect of the change in the elastic properties of the photoresist.

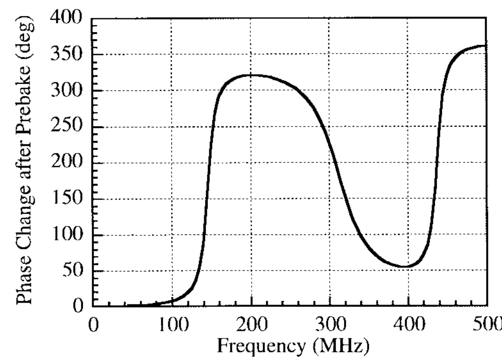

Fig. 6. Reflection coefficient phase change versus frequency for resist film, from before to after prebake.

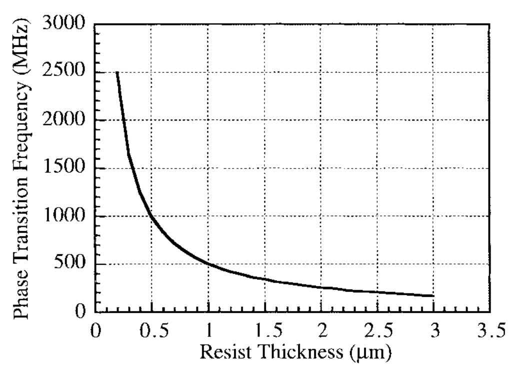

Fig. 7. Required transducer frequency versus resist thickness measured.

A. Theoretical Change in Phase During Prebake

As indicated previously, the reflection coefficient of a longitudinal plane wave incident from a medium on a layer can be calculated using (1). We expect a phase change during prebake as the photoresist layer properties change and as the wafer changes temperature. The phase change accompanying photoresist thickness and impedance changes is expected as a result of thin film interference effects. For the films of interest, the thickness of the layer is less than a wavelength, and we do not expect separate reflections from the front and back of the layer.

The alteration in the interference pattern of the reflected waveform will depend on both the thickness and impedance changes in the resist during a process. During prebake, the resist thickness is expected to change by about 0.15–0.40 μm, depending on the initial thickness after coating [7]. For a sample calculation, it was assumed that the initial resist thickness was 2.4 μm and the final thickness after prebake was 2.0 μm. The expected density change as the resist changes from liquid to solid is from 1080–1150 kg/m^3, approximated values from water and polyimide, respectively. At the same time, the velocity is expected to change from about 1400–2500 m/s, resulting in a significantly greater effect on the impedance than the smaller change in density. To determine the overall effect of prebake on the reflection coefficient, the changes in impedance and thickness were combined in the calculation of phase to obtain the results in Fig. 6. From this figure, the maximum sensitivity of the sensor to prebake-induced changes in phase is expected to occur in the range of 160–260 MHz. Optimum choice of frequency is necessary to get maximum sensitivity from the sensor design. To predict the frequency necessary to monitor the prebake of other resist thicknesses, Fig. 7 is a plot of the calculated phase transition frequency (or frequency of film resonance) versus resist thickness. Notice the increase in frequency necessary to measure thinner films; it is reasonable to allow for 1–2 GHz frequency requirements since acoustic microscopy transducers have been designed beyond this range.

B. Temperature Effects

There will also be a phase change in the reflected signal as the wafer changes temperature. During prebake, the wafer temperature typically increases from room temperature to 90 °C. The two-way phase change for a given temperature variation can be calculated as was given in (2). The calculated phase correction has been multiplied by two to compensate for wave travel to and from the wafer surface. It has been shown experimentally for silicon that this relationship is linear within the temperature range of the bake [15]; thus, it can easily be applied to removing the effect of temperature on the phase.

C. I-Line Resist Characterization

The phase change was measured during resist prebake to identify a significant and repeatable trend in the results that could be used to determine the state of cure at a given time. The expected change in phase during the bake was predicted to be a steady increase due to decreasing thickness and increasing density of the resist. The actual value of phase change would depend on the starting and ending point conditions of the film, including thickness, density, and velocity. This excludes the slowing effects of wafer heating, which are expected to be linear, as well as the changes in the elastic properties of the resist due to its softening. To measure the change in phase during prebake, first the temperature coefficient of a bare wafer was found, then the change in phase during prebake of a resist-coated wafer was monitored, subtracting off the effects on the phase due to wafer heating.

D. Temperature Compensation

A typical experiment involved cleaning a 200-mm wafer and measuring the increase in phase as the bare wafer was heated to

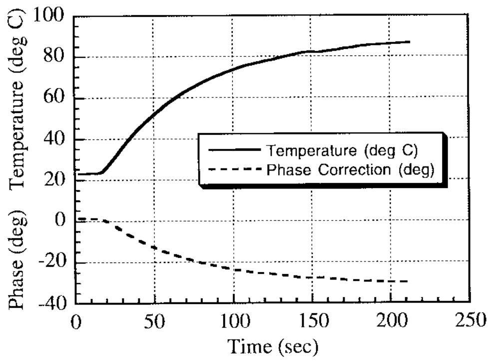

Fig. 8. Sample phase change calculation (lower) given temperature trajectory (upper).

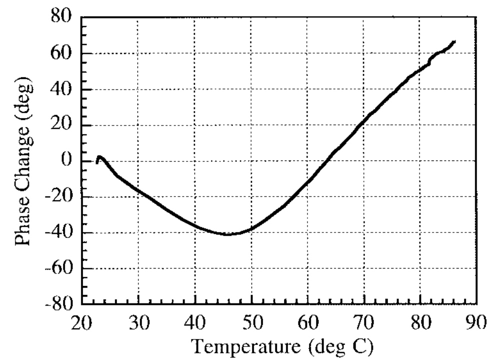

Fig. 9. Phase change versus temperature during prebake.

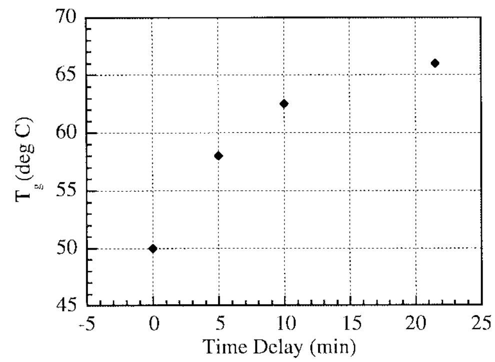

Fig. 10. Change in glass transition temperature as the prebake is delayed.

a typical prebake temperature of 90 °C. In this way, the slope of the linear relationship between phase and temperature was obtained. The results of two runs on the same wafer indicated a kv of about $-30 \times 10^{-6}/°C$, corresponding with expected results [15]. This slope was used to remove the temperature effects from the total phase change during a cure involving that wafer; a sample calculation of the phase change due to temperature effects is shown in Fig. 8, with the upper plot representing data taken from a thermocouple attached to the wafer as the wafer was heated. The lower plot, then, is the phase change due to that temperature change.

E. Pre-Exposure Bake

Once the temperature coefficient was determined, the wafer was coated with Shipley resist, either 1813, 1811, or 1805 at a spin speed of about 3500 r/min. The coated wafer was immediately placed on the setup and a heating lamp was turned on to begin the prebake. The reflected waveforms and temperature data were obtained every 3 s for about 200 s, well beyond the usual bake time of 90 s. The total phase change was calculated versus time and temperature and the temperature effects subtracted using the slope determined in the first part of the experiment. The measured phase vs. wafer temperature is plotted for a typical run in Fig. 9, with the temperature effect on phase removed. The resist monitored was Shipley 1813 spin-coated to a thickness of about 2 μm. There is a repeatable phase minimum occurring at about 48 °C. The temperature of this minimum represents the characteristic glass transition temperature of the resin/solvent mixture [10]. The rapid increase in phase shown following the minimum is likely due to the onset of solvent evaporation. To support this hypothesis, a separate study was conducted in which the solvent was allowed to evaporate without heating the wafer and resist. In this case, there was just a small monotonic increase in phase due to solvent evaporation, with no decrease measured. Thus, we know that the initial decrease in phase is a heating effect, and we believe it to be a measure of the resist softening. To support the assertion that this phase minimum is the glass transition temperature, a study was designed to show the effect of decreased solvent concentration on the temperature of minimum phase. Fig. 10 shows the effect of increasing the time delay between coating and prebaking the wafer; it was expected that a longer delay would allow more solvent to evaporate and increase T_g [16]. As seen in this figure, this effect was confirmed.

F. Thinner Resist Films

As indicated earlier, in order to predict the transducer frequency which will provide the highest sensitivity to a given thickness measurement, it is necessary to find the frequency of the phase transition for that film thickness. Fig. 7 showed the predicted behavior of frequency required vs. film thickness. To verify this curve experimentally, measurements of prebake at final film thicknesses of 2.2–0.6 μm were conducted and the phase transition frequency determined. Shipley 1813, 1811, and 1805 resists were applied for this purpose, with the 1813 resist being the most viscous and 1805 the least. The less viscous the material, the lower the spun film thickness will be. Fig. 11 shows the results of this study with phase transition frequency plotted versus resist film thickness. A 500-MHz transducer was designed to obtain the data at less than 1 μm thicknesses. The design of this transducer was essentially the same as that of the 260 MHz transducer with the exception of the zinc oxide thickness which was approximately halved in order to achieve resonance at twice the original frequency. As can be seen from the plot, the trend follows that of the predicted curve. Note that the resist thickness here represents the initial thickness following the coat process but before the prebake. In order to obtain these values, the film thickness was measured after prebake and appropriate changes were made to account for the thickness lost due to solvent evaporation. For example, a change of about 0.40 μm is expected when a 2.6-μm film is prebaked, resulting in a

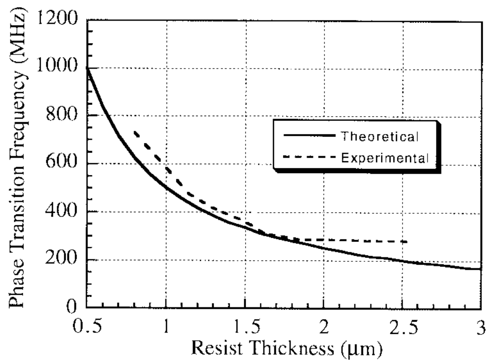

Fig. 11. Theoretical and experimental phase transition frequency versus resist film thickness.

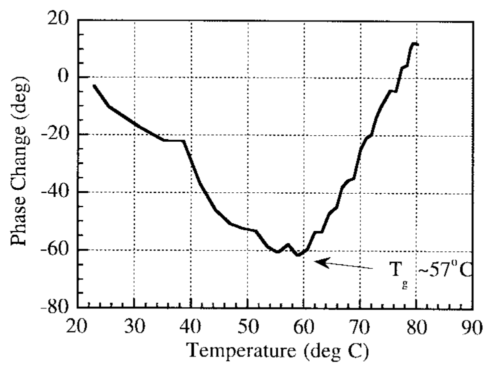

Fig. 12. Phase change versus temperature during prebake, 0.6 μm Shipley 1805 film, 750 MHz.

final thickness measurement of 2.2 μm. A 0.8-μm film is expected to lose about 0.2 μm to result in a final measured value around 0.6 μm; thus, the lowest thickness represented by the experimental data corresponds to 0.6 μm final thickness, levels currently used in DUV lithography.

To obtain better signal to noise ratio at the thinner film thicknesses, a higher frequency transducer was designed similarly to the others, this time using a zinc oxide thickness of about 2.7 μm for a target resonant frequency of 750 MHz. Due to loading effects of the sapphire buffer rod, the peak resonance frequency was 600 MHz, but the 6-dB bandwidth was 100% which provided significant signal for measurement at 750 MHz. Results of a prebake study on a 0.6-μm film of Shipley 1805 resist are shown in Fig. 12. The T_g of about 57 °C shown here is higher than expected, likely because of placement of the thermocouple too far from the sensor contact. From this figure, it was concluded that the transducer was capable of evaluating films with thicknesses in the range of 0.5–0.8 μm, typical thicknesses of deep-uv chemically amplified resists used in semiconductor manufacturing today.

G. Chemically-Amplified (DUV) Resists

Current manufacturing systems are in place to fabricate electronics with 0.25 and 0.18 μm technology. Exposure wavelengths must then decrease from I-line to deep-ultraviolet levels in order to allow delineation of features this size. The photoresists employed to accomplish this are generally chemically-amplified deep-uv range resists. Processing of these resists is more complex than that of I-line resists in that there are more chemical reactions to consider, causing the final critical dimensions to be highly dependent on processing conditions. This is especially true of the post-exposure bake process. The goal of working with these resists is first to study the pre-exposure bake properties, including T_g and elastic property changes during the bake, and then to study changes in the elastic properties during the post-exposure bake as well. We expect significant changes in phase during these processes. Because the deep-uv range resists are generally applied in thickness ranges from 0.5 to 0.8 μm, the 750-MHz transducer was used (see Fig. 7).

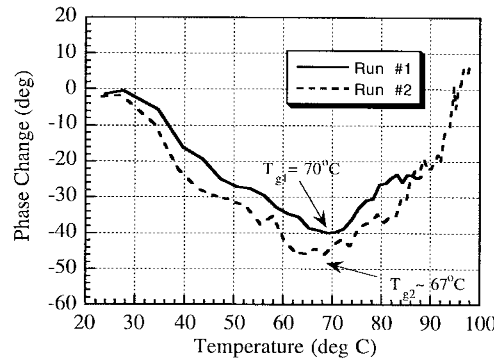

Fig. 13. Phase change versus temperature during two prebake experiments, 0.8 μm Shipley APEX-E films, 750 MHz.

The first DUV prebake experiments were conducted on Shipley APEX-E 2048 photoresist. The temperature coefficient determined in the previous section was used to subtract the temperature effects from the measured phases during prebake. The resist was spun on the wafers at 3500 r/min for 40 s. Results of two studies on 0.8 μm films are shown in Fig. 13 with phase change plotted versus wafer temperature during prebake. The plots indicate that the glass transition temperature occurs at about 67 and 70 °C in the separate experiments. These measured prebake glass transition temperatures are higher than those measured for I-line resist films, as expected [17].

VI. Post-Exposure Bake

In order to confirm the claim that the minimum in phase corresponds to the glass transition temperature, a postbake glass transition temperature measurement was completed. Once postbaked, the novolac resin of the Shipley 1800 series resists is expected to have its glass transition at 118 °C. As shown in Fig. 14, this result was confirmed with the phase minimum occurring at 118 °C. In some photoresist postbake processes, it is important not to exceed this temperature since the features will lose sharpness as they become fluid; in others, the goal is to exceed T_g in order to minimize contaminant diffusion. This measurement can be used as a monitoring technique for post-exposure bake of materials whose T_g is unknown; the process would be stopped once the phase curve began to flatten.

VII. Parameter Inversion

Besides moving to lower resist thicknesses and more recent resist types, research has also been completed on extraction

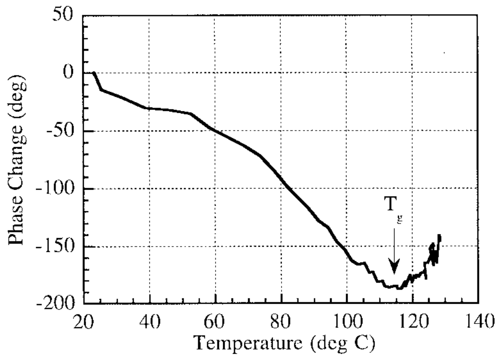

Fig. 14. Determination of postbake T_g phase change is plotted versus postbake temperature.

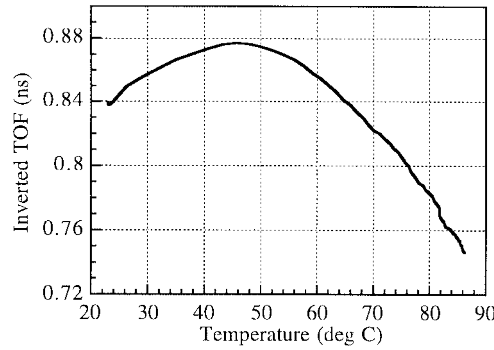

Fig. 15. Time of flight inversion results, TOF plotted versus prebake temperature.

of the elastic constants of photoresist during pre-exposure bake. The reflection coefficient at the silicon wafer/photoresist interface can be written in terms of two main parameters, the resist time of flight and the resist acoustic impedance. The acoustic impedance equals the density times the velocity of sound in the resist, and the time of flight is equal to the thickness of the film divided by the velocity of sound in the resist. Knowing the phase and amplitude of the reflection coefficient, the time of flight and resist impedance can be determined. Then, knowing one of the three properties that these parameters are dependent upon, the other two can be determined. For example, if the thickness of the resist is known throughout the prebake, then the corresponding density and velocity changes can be determined. These properties can be correlated to the state of the prebake and the process can be stopped based on their reaching a given threshold level.

Results of the parameter inversion show that the time of flight and acoustic losses reach a maximum at the glass transition temperature. This indicates that, as expected, the resist softens to the greatest extent at this temperature, causing the velocity of the resist to decrease and the thickness to increase slightly due to volume expansion. Fig. 15 illustrates the time of flight inversion results for a 2-μm film of Shipley 1813 resist. The time of flight plotted versus prebake temperature. The time of flight maximum is shown to occur at about 48 °C in this figure, corresponding to the phase minimum measured by the sensor. This confirms that the resist is acoustically slowest at the glass transition temperature. The imaginary part of the inverted impedance was used to determine where maximum losses occurred. These inversion results are plotted in Fig. 16 versus prebake temperature. Maximum losses occurred at the same temperature as the time of flight maximum, indicating that the attenuation coefficient for propagation is highest around the glass transition temperature.

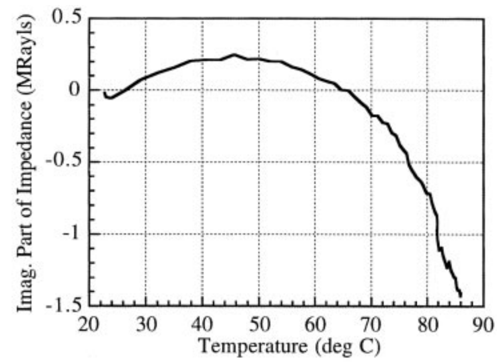

Fig. 16. Impedance inversion results, imaginary part of impedance plotted versus prebake temperature.

VIII. Conclusions

This research has provided an ultrasonic sensor than can be used for *in situ* photoresist process monitoring during semiconductor manufacturing. It was applied to monitor resist thickness changes during photoresist development, introducing a method for development monitoring that is independent of developer optical transparency. The presented sensor can measure nondestructively the glass transition temperature of prebaking and postbaking photoresist. This is an important step in determining pre-exposure bake cure state of the resist since it is at the glass transition temperature that the resist softens and the diffusion and evaporation of the solvent molecules in the resist becomes significant. Since photoresist prebake involves removal of excess solvent as well as relaxation of the polymer molecules into an ordered matrix, the glass transition temperature gives us a measure of the cure state of the resist during prebake.

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