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Profile Measurement of Resist Surface Using Multi-Array-Probe System

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Abstract: Semiconductor processing in manufacturing must be fast and highly accurate in the measuring of the surface profile of soft thin films such as photoresist. Since photoresist surface is very smooth and deformable, a device to measure is required that will measure vertical direction with a nanometer resolution in height and not damage the film during the measurement. To do this, we developed an apparatus using multi-array probes and white light interferometer to measure the surface profile. There are 25 probes arranged in the 5 × 5 array with 500 μm interval on the membrane, which covers a wide area at high speed. The probe is 37.5 μm in height with cylindrical diameter of 50 μm, which is attached to the SiC film of 1 μm thickness. Using this device, we made measurements on resist film. The results demonstrated the feasibility of the constructed multi-sensor system for measuring thin film with a high accuracy. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Photoresist measurement, White light interferometer, Multi-array probes, Wide area measurement.

1. Introduction

The development of the semiconductor industry is moving towards miniaturization and high integration. Semiconductor industry with high-performance and low-cost is the motivation of the development of information technology. Lithography plays an extremely important role in semiconductor integration process. The short-wavelength light irradiation method usually used to improve the resolution, but the impact on the exposure is increasing because of the photoresist surface irregularity, which is due to the shallow depth of focus if the wavelength reduced. In traditional lithography, the surface profile of photoresist film need not to be measured, and only controlling the exposure in a required range of accuracy through correcting the measurement system calibration and the measurement systems focus. But as the semiconductor technology moving toward a more accurate direction constantly, the photoresist surface irregularity has a significant impact on the exposure's accuracy even when the difference of surface unevenness is only several 10 nm. Therefore, the surface profile measurement of the photoresist and the corresponding measurement methods are key issues to be studied in the semiconductor industry [1-3]. Photoresist on a wafer is known as a kind of soft thin film about 500 nm thick in future [4]. We want to develop an instrument that can measure this thin film with a vertical resolution of 10 nm within the horizontal range of tens of millimeters.

Usually, we use a light scan method to measure a surface profile quickly with high accuracy without contact, e.g. a con-focal microscope and a white light interferometer. However, the problem is that the thickness of photoresist is known to be less than 500 nm, and when we measure it with the light scan method directly, optical properties of thin films will develop from interference and the reflection. For this reason, we cannot measure the thin film correctly. On the other hand, the general AFM (Atomic force microscopy) can take measurements by a probe with high accuracy, but if the object being measured is softer than the AFM stylus tip, AFM may deform it in the process, and the speed is limited because AFM is used in micro-area measuring[5]. Since the photoresist surface is deformable and smooth, the measurement device is required not to damage the surface in the process, and to have a resolution of tenth of micrometer in horizontal direction [6].

In this research, we want to practice the measurements of thin film by using a contact method just like AFM. We propose a measuring technique by combining optical measure (white light interferometer) and mechanical contact (multi-topo-sensor) [7]. To resolve the above problems, we constructed an apparatus that covers a wide area with a high speed. We proposed a multi-topo- sensor, which is composed of many probes arranged in a reticular pattern on the membrane.

Fig. 1 shows the concept of multi-topo-sensor system. In the measurement process, all probes, set in a 2 dimensional plane, are touched to the sample, and then the upper surface of multi array probes is measured by a white light interferometer with a high resolution.

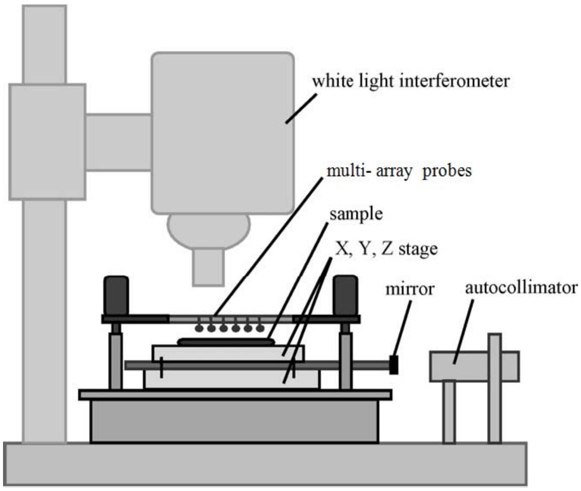


Fig. 1. Construction of multi-topo-sensor system.

Therefore, the surface profile of the sample is made available.

As shown in Fig. 2, it is possible to measure a large area by scanning the multi array probes with a white light interferometer. Here, we take use of the features of high speed of optical mechanism and less reflection of probes to achieve the demand for a resist surface measurement. During the measurement, the multi array probes are fixed, and the sample is moved to contact the probes. The profiles of touched probes are scanned by the white light interferometer.

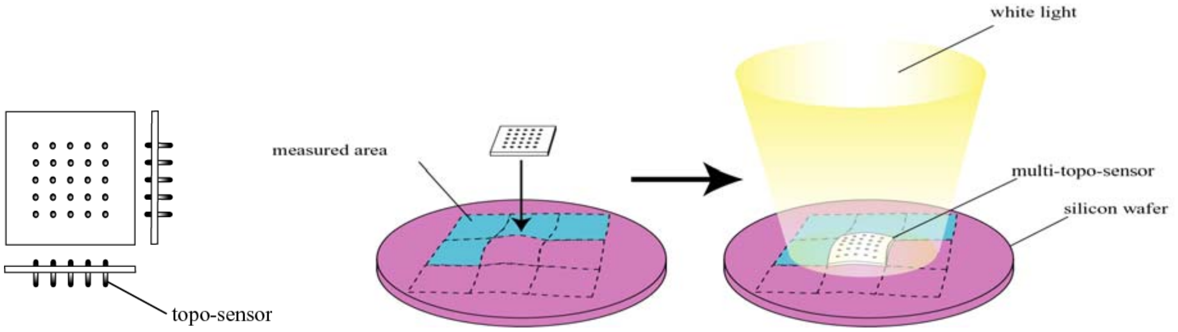


Fig. 2. The concept of multi-topo-sensor system.

2. Construction of Multi-ball-cantilever System

Based on our proposed design, we constructed a multi-array-probe system involving a multi-array probes to measure the surface of resist film, as shown in Fig. 3.

The white light interferometer used for the experimental studies is model ZYGO NewView6300 [8], which can detect height information with height resolution of 0.1 nm and profile heights ranging from 1 nm to 15000 µm.

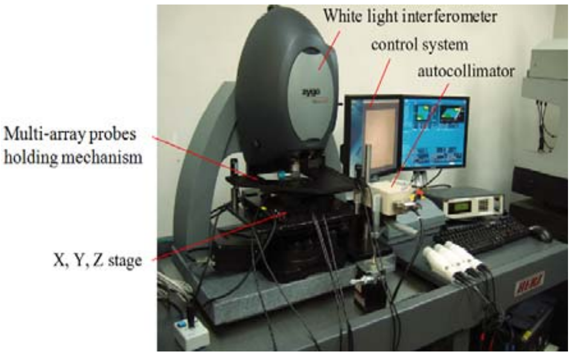
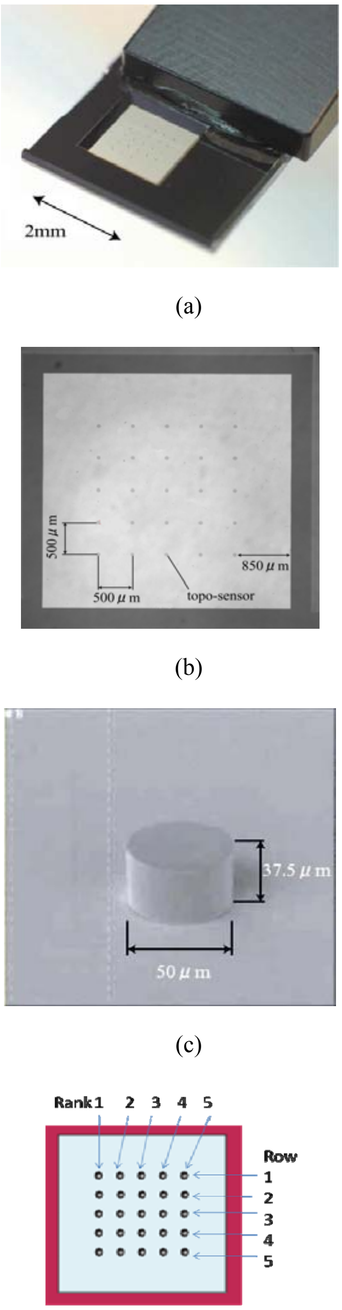


Fig. 3. Photos of multi-array-probes system.

As a new feature, the new Film Application is used to measure the thickness of the thin film from 1.5 µm to 50 µm. In this system, an X-Y stage (COMS PT100C-50XY) and a Z stage (PI P-541.TCD) are adopted to move the sample stage. They have solutions of 1 µm and 0.8 nm respectively. The multi-topo sensor was made of SiC membrane.

There are 25 probes (Topo sensor) arranged in the 5 × 5 array with 500 µm interval on the membrane, shown in Figs. 4 (a) and (b).



(a)

(b)

(c)

(d)

Fig. 4. Multi-array probes: (a) Photograph of array probes with holding part; (b) Photograph of array probes; (c) Photograph of one probe; (d) Definition of probe in our measurement.

From SEM picture, we know the probe is 37.5 µm in height and the cylindrical diameter is 50 µm, shown in Fig. 4 (c), which is attached to the SiC film of 1 µm thickness. The shape of the sensor tip that directly contacts with the resist can be confirmed to be substantially flat.

Each probe is created by a hard baked resist for not being deformed upon pressing the sample. In order to properly observe the probe position by white interferometer, as a light shielding film, Ta (tantalum) with approximate 100 nm thickness is sandwiched between the SiC film and the probe. Here, in order to easily show the probes, we definite them by the row and column shown in Fig. 4 (d). For example, the probe in the place of row 1 and column 1 will be marked (1, 1), and the probe in the place of row 2 and column 3 will be marked (2, 3) etc.

3. Measurement Experiment

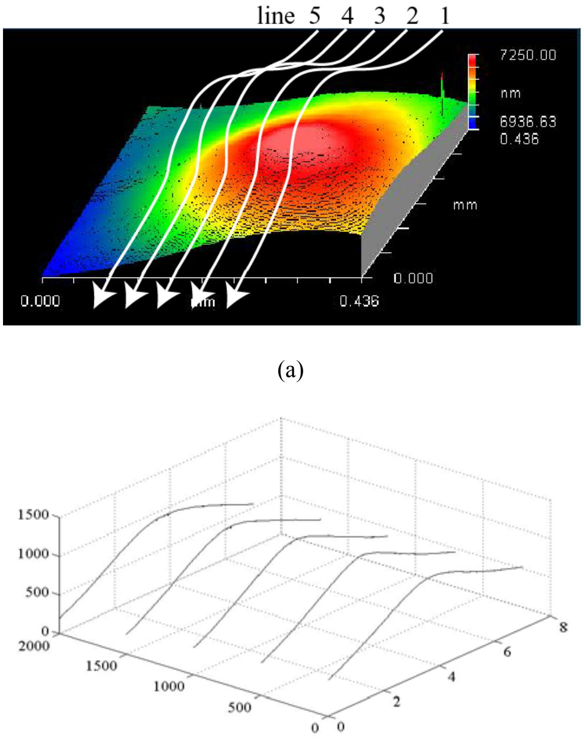
To verify the feasibility of the constructed system, we carried out the scanning experiments on the resist surface. It's necessary to compare the real shape and a profile result measured by the present apparatus. Therefore, each row of shape calculated by multi-probe method will be compared to the cross-sectional profile of the actual shape. After scanning measuring by multi-topo-sensor system, the resist sample is measured by white interferometer. We measured a resist sample applied to the silicon wafer that was around 25 µm thick. Here we derived the resist surface profile as the original profile by the thin film application of NewView6300, which can detect the thickness and surface profiles of thin film thickness from 1.5 µm to 50 µm.

Here, we would calculate the data by two-point method [9]. In general, the two-point method should be used in the wavelength of target shape that was 5 times sensor's interval. Our array probes in design have an interval of 500 µm. That means 2.25 mm or more extra is needed. In the test, more than 4 mm wavelength is selected, so it is possible to accurately reproduce in two-point method. Along the scanning line in Fig. 5 (a), the measurement length is 8 mm.

We scanned to measure the resist thin film along the line with the constructed system. Measurement results are shown in Fig. 6 (a) and (b).

By every two probes in the first row, we all obtained the shape just like the actual file as shown in Fig. 6 (a). It shows that the probes contact the sample well because measured shape is not with high frequency wave in this measurement. In Fig. 6 (b), Rows 1, 2, 3, 4 reflected the right shape compared to the real file. The result demonstrated the feasibility of the constructed multi-topo-sensor system for measuring thin film with high accuracy.

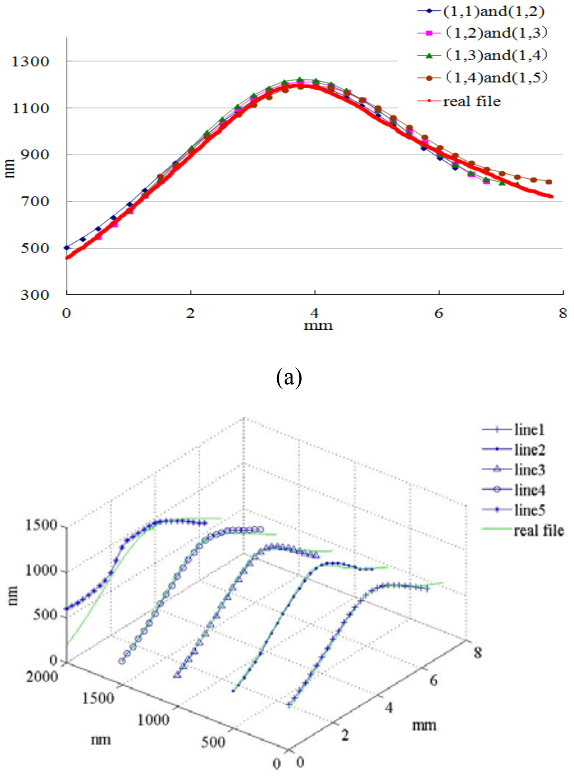
Fig. 7 shows the bias of row 1 and row 2 and the error is maximum 50 nm. In measurement, row 5 didn't give the good shape in Fig. 6 (b).



(a)

(b)

Fig. 5. Resist profile scanning by the film application of NewView6300. Scanning length is 8 mm.



(a)

(b)

Fig. 6. Measurement results by constructed system. (a) Line 1 result calculated by probes in one row with two-point method. (b) 5 lines results calculated by probes of column 1 and column 2 with two point method.

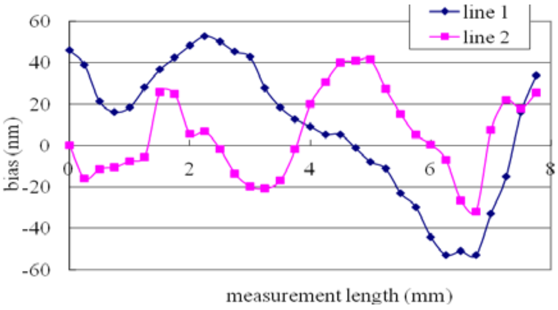


Fig. 7. Bias of line 1 and line 2 in measurement.

There are two reasons in our experiment. One is due to the dust and the some other probes were not contacting well on the sample surface. The solution to the dust is placing the system in the clean room or adding the self-cleaning structure in the system. Another reason for bad contact is because array probes are all attached to only one membrane. The edge probes will contact well but the middle ones are easy to be dumping during the scanning process. This will be an influence to the measurement accuracy. According to this scenario, the independent supporting structure for every probe is needed in the future system design.

4. Summary

In order to measure the surface profile of thin film such as photoresist for a high accuracy, we proposed a new methodology by combining the light scanning with multi-array probes guided by the mechanical moving stage of autocollimator. For the errors from the scanning stage and system sensor, the error separation method was discussed regarding the operation of the multi-array probes. Using the white light interferometer, multi-array probes and autocollimator, we designed a new measurement mechanism with multiple probes--multi-topo-sensor system, and applied the design on the resist film profile measurement. The result demonstrated the advantages of the multi-topo-sensor system for measuring thin film with a high accuracy. On the error and bad contact of probes in measurement, we also discussed the possible methods for the solution.

Acknowledgements

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