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Surface Treatment and Adhesion Study

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Abstract

In photolithography, it is often the case that the resist has difficulty adhering to a wafer due to its hydrophobic nature. The purpose of this study was to determine the best method for avoiding such adhesion problems. This study describes that four different surface treatments, (1) No bake before resist coating, (2) Bake at 115ºC before priming, (3) SURPASS coating, and (4) HDMS priming, are examined for UV lithography of sub-ten micron-sized lines and pillar arrays, and that HDMS vapor priming is the most effective surface treatment in promoting adhesion.

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In photolithography, it is often the case that the resist has difficulty adhering to a wafer due to its hydrophobic nature. The purpose of this study was to determine the best method for avoiding such adhesion problems. This study describes that four different surface treatments, (1) No bake before resist coating, (2) Bake at 115ºC before priming, (3) SURPASS coating, and (4) HDMS priming, are examined for UV lithography of sub-ten micron-sized lines and pillar arrays, and that HDMS vapor priming is the most effective surface treatment in promoting adhesion.

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Goal:

To determine the effect of various wafer-surface treatments on the adhesion of the resist film on the substrate after exposure and development.

Experimental Section:

Materials:

- Specially designed mask for lithography resolution (labeled “Etch Test Mask”)
- 100 mm diameter Silicon wafers
- S-1813 photoresist
- SURPASS 4000 primer
- HDMS primer
- MF 319 developer

Equipment:

- Spin Coater
- Hot plate
- SUSS MA6 Contact Printer
- YES Priming Oven
- Zeiss Axio Imager M2m microscope

Protocol:

- Plain wafer undergoes one of the surface treatments indicated below:
  - No treatment
  - Baked at 115ºC for 3 minutes
  - SURPASS 4000 primer is deposited by spin coater at 3500 RPM for 45 se, isopropyl alcohol added at 30 seconds for 5 sec.
  - HDMS is deposited by vapor priming in YES Priming Oven
- S-1813 primer is deposited by spin coater at 3500 RPM for 45 seconds
- Wafer is subjected to 1-minute bake at 115ºC (soft bake)
- Exposed with MA6 Contact Printer, vacuum contact mode, 80 mJ/cm2 exposure dose

- Developed under MF 319 for 1 minute, then rinsed twice in water for approximately 1 minute and blow dried with nitrogen gun
- Optical images of fine features are captured using Zeiss Axio Imager M2m

Results:

Wafer treatment	Result	Comments	Image
No bake before resist coating	Poor adhesion: micron line and pillar array	Poor adhesion of 02/10-micron lines[2] and 2 µm pillar array; 2 µm pillar dots observed deposited across surface; no adhesion of 1 µm pillar array	Fig: 1, 2, 3, 4
Bake at 115ºC before priming	Poor adhesion: micron line and pillar array	Poor adhesion of 02/10-micron, 02/02-micron lines, and 2 µm pillar array; 2 µm pillar dots observed deposited across surface; no adhesion of 1 µm pillar array	Fig: 5, 6, 7, 8
SURPASS coating	Poor adhesion: pillar array	Poor adhesion of 2 µm pillar array; disappearance of pillar dots more gradual than previous two treatments; no dots observed deposited across surface; no adhesion of 1 µm pillar array	Fig: 9, 10, 11, 12
HDMS priming	Good adhesion	No adhesion of 1 µm pillar array; all other features in tact	Fig: 13, 14, 15, 16

[1]All wafers were baked for 1 minute at 115ºC after resist coating
[2]"02/10-micron lines" means line width/space.

No bake before coating

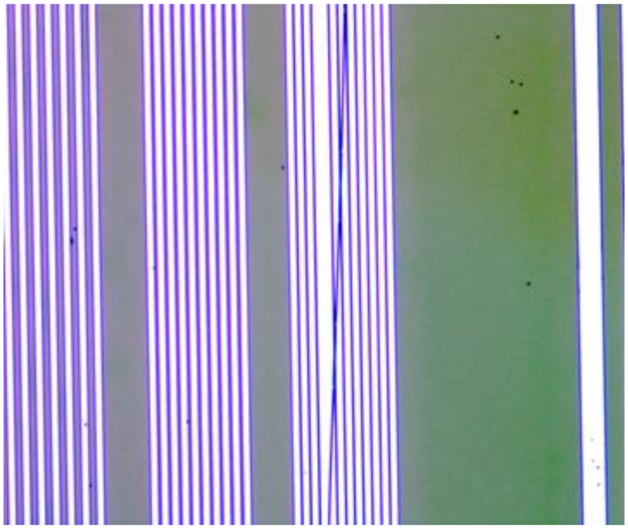

Figure 1: Poor adhesion of 02/10-micron lines

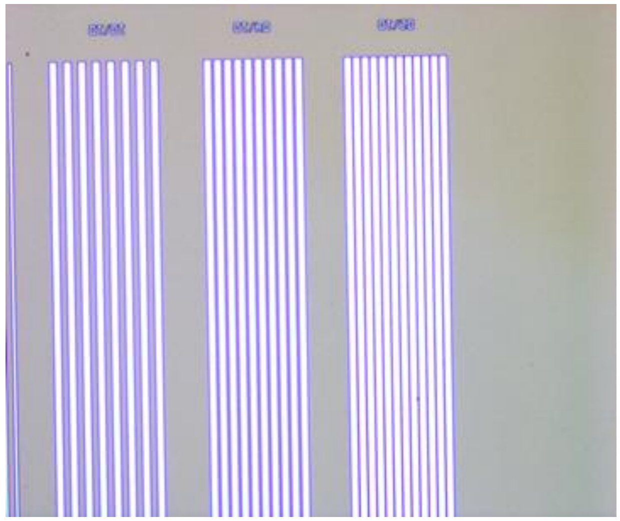

Figure 2: Same 02/10-micron lines on different part of the wafer for comparison

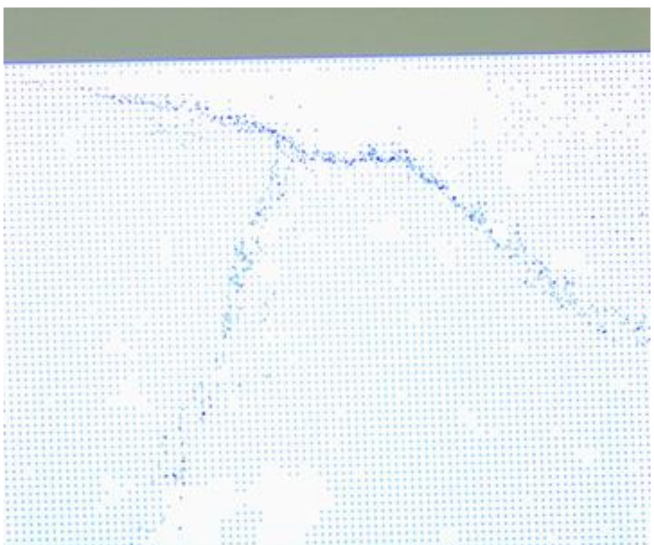

Figure 3: Poor adhesion of 2 µm pillar array

Figure 4: 2 µm pillar array deposited along the surface of the wafer

Bake at 115ºC before coating

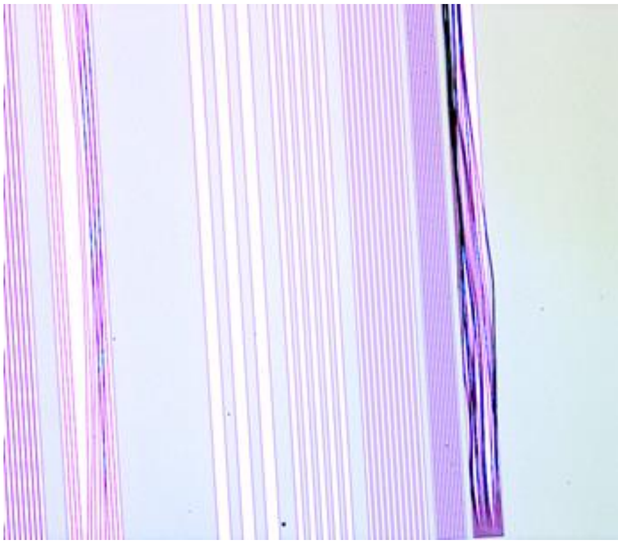

Figure 5: Poor adhesion of 02/10-micron lines (left) and 02/02-micron line array (right)

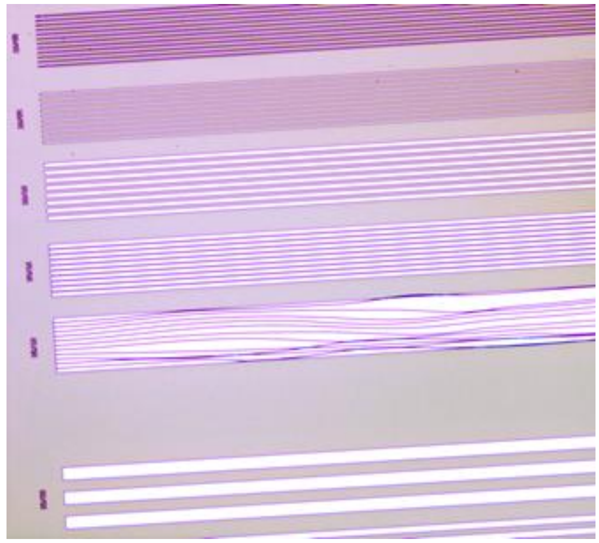

Figure 6: Poor adhesion of 02/10-micron lines on different area of the wafer

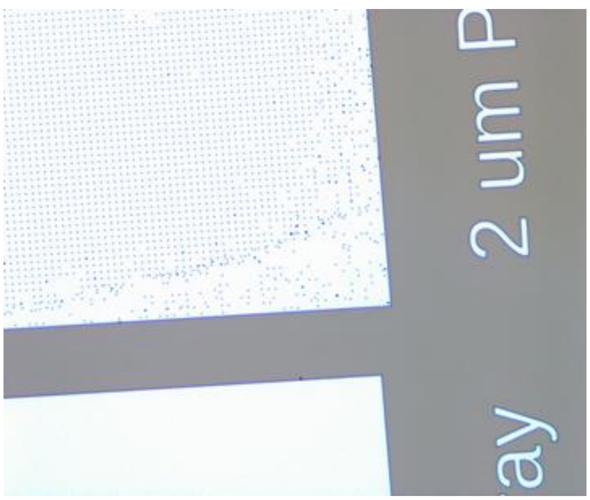

Figure 7: Poor adhesion of 2 µm pillar array

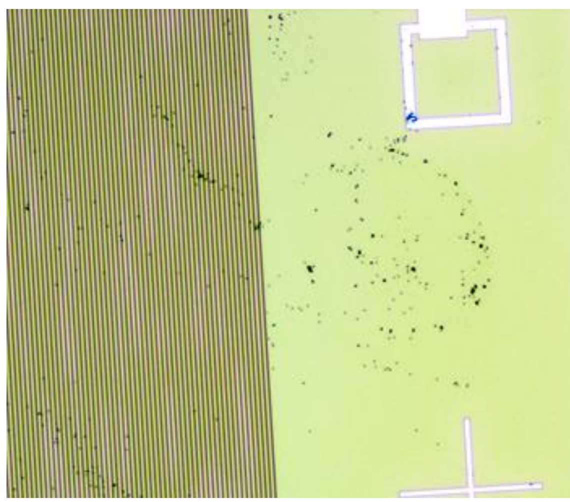

Figure 8: 2 µm pillar array deposited along the surface of the wafer

SURPASS coating

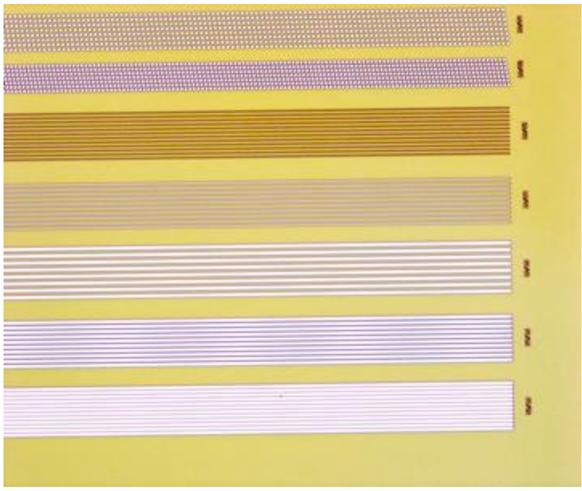

Figure 9: Good adhesion of all line/space arrays, including 02/10 lines (bottom)

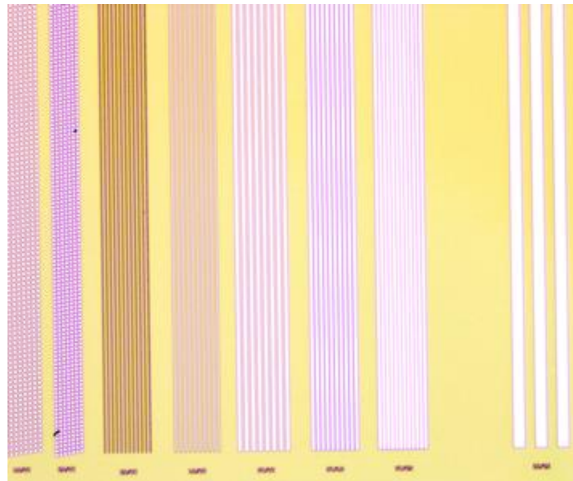

Figure 10: Good adhesion of line arrays on different portion of the wafer

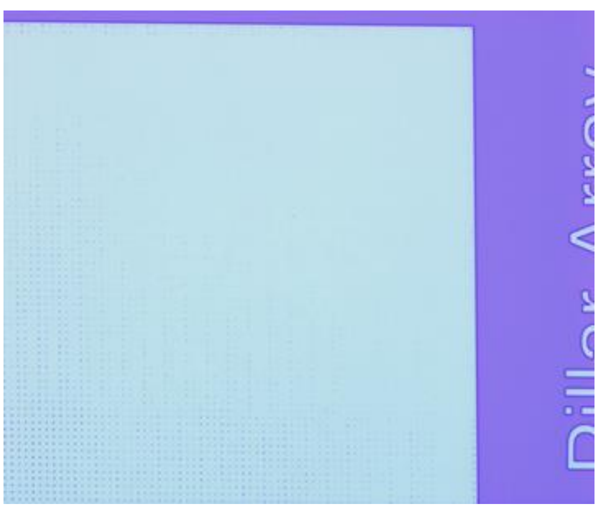

Figure 11: Poor adhesion of 2 µm pillar array, dots gradually decrease in upper right corner

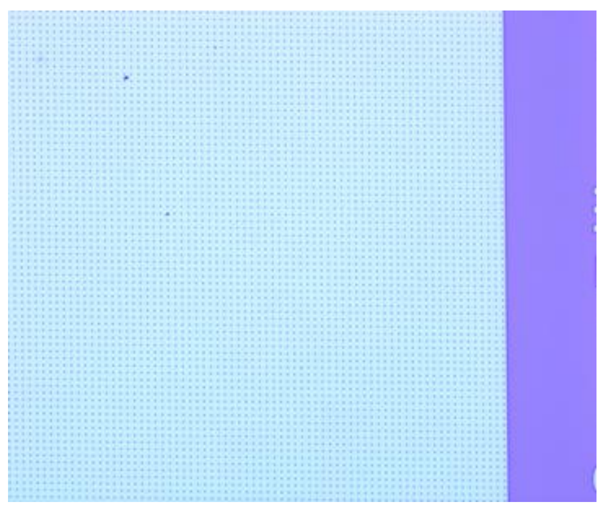

Figure 12: Good adhesion of 2 µm pillar array on different portion of the wafer

HDMS priming

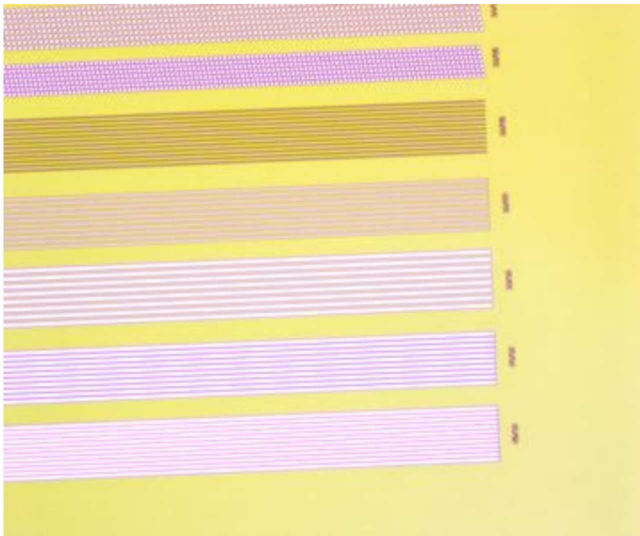

Figure 13: Good adhesion of all micron line arrays

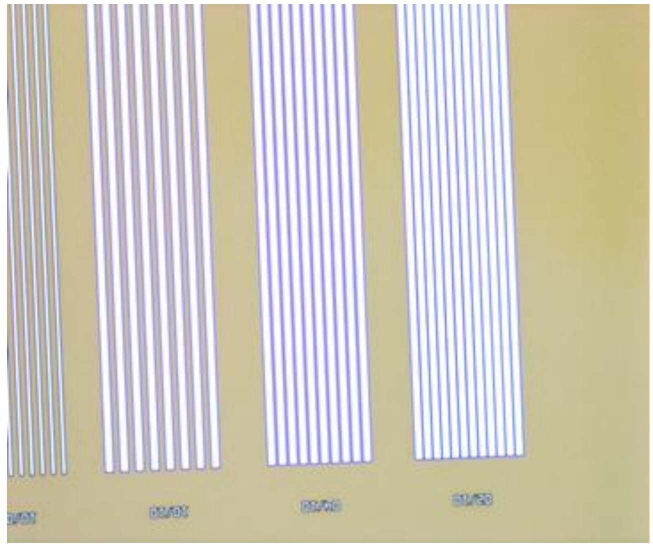

Figure 14: Good adhesion of line arrays on different portion of the wafer

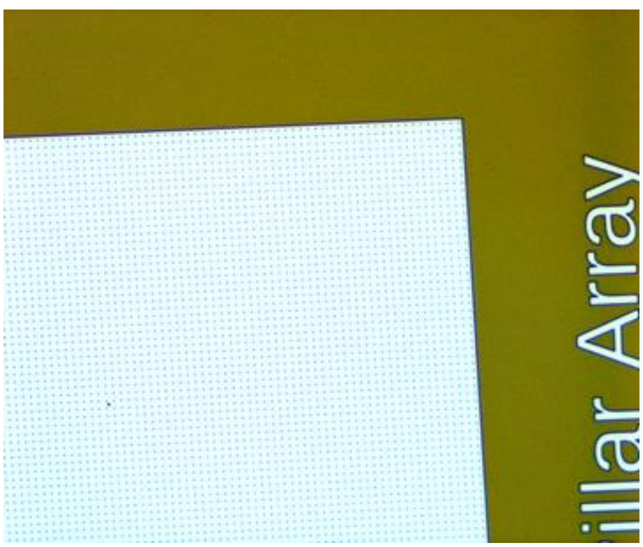

Figure 15: Good adhesion of 2 µm pillar array

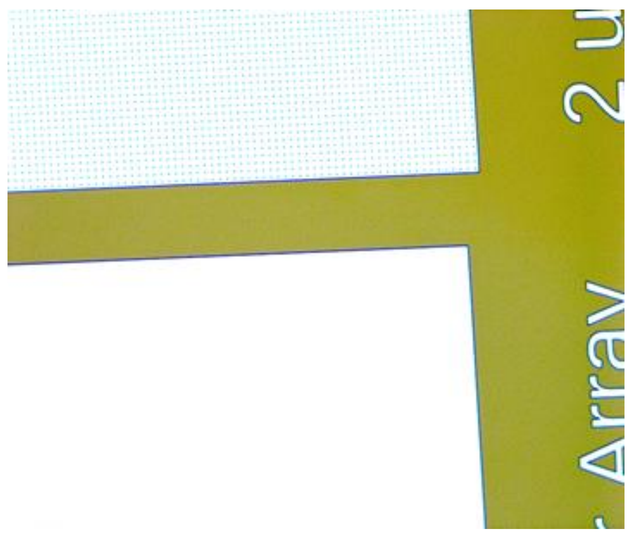

Figure 16: Absence of 1 µm pillar array, with 2 µm array for comparison (consistent feature across all wafers)

Discussion:

First, this study showed that developed features are often subject to adhesion problems. 2 to 10 µm width lines as well as 2 µm diameter pillar arrays were observed to have variable degrees of adhesion depending on the wafer-surface treatment; in wafers produced through less effective surface treatments, the developed features adhered poorly. 1 µm diameter pillar arrays were missing on all wafers, regardless of surface treatment, suggesting that the process conditions and/or photomask properties were inappropriate for features of this size.

The results detailed above indicate that the surface treatments of “no bake before priming” and “bake at 115ºC before coating” are the least effective adhesion-promoting; both treatments produced wafers with poor adhesion of 2 µm pillar arrays and 02/10 or 02/02-micron lines. SURPASS priming was the next best effective surface treatment; while the developed features showed poor adhesion of some 2 µm pillar arrays, there was good adhesion of all micron lines. HDMS vapor priming was observed to be the most effective wafer-surface treatment; no lack of adhesion was observed across any micron lines or 2 µm pillar arrays.

Steps for future inquiry would be to replicate this experiment with the addition of buffered or dilute hydrofluoric acid etching. After etching is complete, the wafers would be analyzed in the same way to observe adhesion of developed features.

Summary

It is the recommendation of this study that HDMS vapor priming be used to treat wafer surfaces in photolithography, as this surface treatment is expected to achieve the most effective adhesion of developed features.

It should be noted, however, that in this experiment, due to the large size of the YES Priming Oven, establishing a vacuum took approximately 40 minutes. This increased the time required for the entire process, and made vapor priming somewhat inconvenient. Time constraints of an experiment should be taken into consideration before using HDMS vapor priming as a wafer-surface treatment.

Acknowledgements

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