NANOMETER AND HIGH ASPECT RATIO PATTERNING BY ELECTRON BEAM LITHOGRAPHY USING A SIMPLE DUV NEGATIVE TONE RESIST

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ABSTRACT

Some DUV resists can be used successfully in the electron beam lithography. In this paper the *micro resist technology*'s ma-N 2400 series DUV negative tone resist is evaluated. This resist has no chemical amplification and therefore a wide process latitude.

The electron beam exposure was done by the Gaussian beam machine LION LV1. We could demonstrate the high resolution capability of this resist and the possibility to delineate dense patterns with high aspect ratios.

Lines and spaces with dimensions down to 150 nm in a 800 nm resist layer and down to 50 nm in a 180 nm resist layer can be resolved. The patterns show steep sidewalls and demonstrate the possibility to generate resist features with high aspect ratios using a simple one layer resist technology. The aspect ratio has at least a value of about 5. Patterns with higher aspect ratios tend to collapse.

The exposure doses for the resist layers in these experiments ranges from 120 µC/cm² to 200 µC/cm² using 20 keV electrons.

Exposures with electron energies less than 20 keV show that the resist sensitivity increases with decreasing electron energy. For 2.5 keV electron energy a dose of only 10 µC/cm² is sufficient. Due to the small penetration depth of low energy electrons only resist layers of less than 100 nm thickness can be used in the low energy range.

INTRODUCTION

In this paper *micro resist technology*'s ma-N 2400 series DUV negative tone resist is evaluated for the electron beam exposure. This resist is composed of a novolak and an aromatic bisazide and has no chemical amplification. Therefore it shows a wide process latitude and a good etch stability. Recently first results of the electron beam exposure of this resist were presented [1,2].

In the new experiments a Gaussian beam machine was used as electron beam exposure tool. Now we could test the resist for resolution capability in thin resist layers (ultimate resolution) and in thick resist layers (high aspect ratio pattern). Further the resist properties at low electron energy exposures were evaluated.

EXPOSURE TOOL

The used exposure tool LION LV1 from *Leica Microsystems Lithography* Jena, Germany, is an e-beam lithography system for nanometer patterning with an accelerating voltage from 1kV to 20 kV. The electron source is a thermal field emitter yielding a high current density and a small energy spread. Therefore the Gaussian beam has a minimum spot size of only 2 nm at 20 kV.

WAFER PREPARATION

Sputtering of 20 nm chromium for better adhesion of the resist.
Spincoating of the ma-N 2400 series DUV negative tone resist.
Bake at 90 °C for 3 min. on a hotplate.
Resist thickness: 800 nm, 180 nm and 70 nm, respectively.

DEVELOPMENT

Developer AZ 726 MIF.
Developing time was 20 s, 30 s, 60 s or 120 s, respectively.

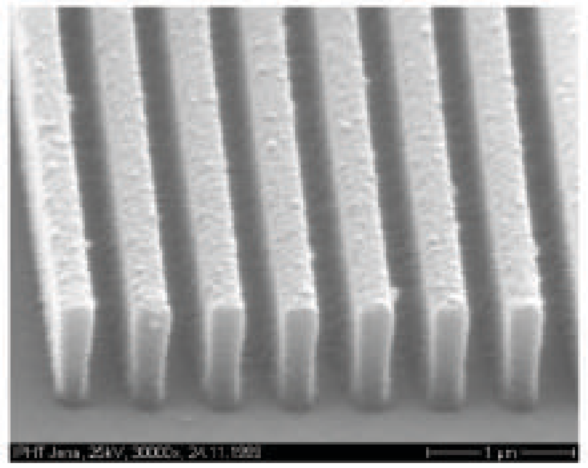
INSPECTION

SEM inspection after sputtering a thin conducting gold film.
Specimen was tilted by 80°.

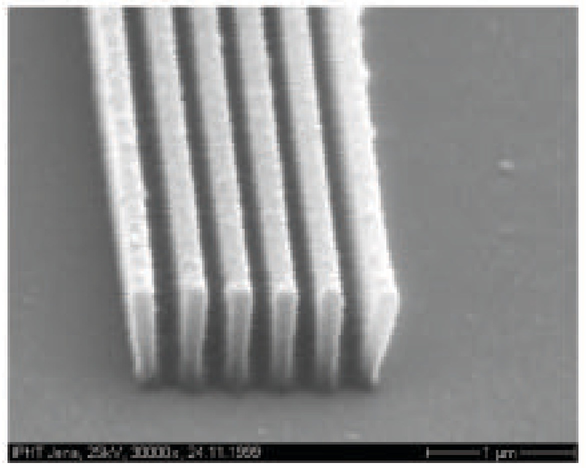
RESULTS

800 nm resist thickness

The patterns have steep sidewalls.
Lines and spaces down to 150 nm in an 800 nm resist layer can be resolved.
The outer lines in the right picture show a weak distortion.
Finer lines are instable, they tend to collapse during the developing process.
This phenomenon restrict the resolution at high resist thicknesses.
The aspect ratio has at least a value of about 5.



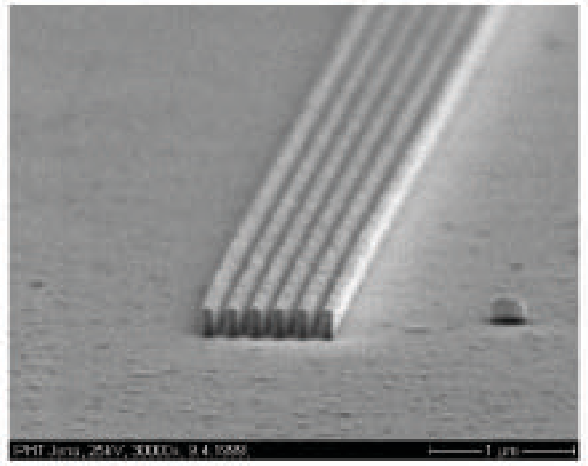
Resist thickness: 800 nm
Dose: 160 µC/cm² at 20 keV
Developing time: 2 min.
Lines and spaces: 250 nm



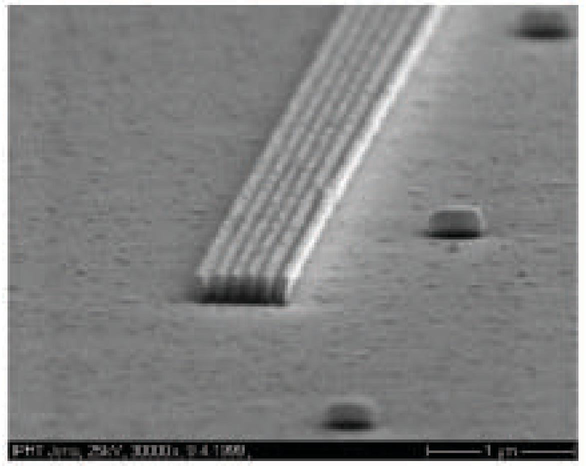
Resist thickness: 800 nm
Dose: 200 µC/cm² at 20 keV
Developing time: 2 min.
Lines and spaces: 150 nm

180 nm resist thickness

The patterns have steep sidewalls.
Up to now lines and spaces down to 50 nm in 180 nm resist layer can be resolved.
The outer lines in the right picture show weak distortions.
Finer lines are instable or did not resolved.
To improve the resolution, dose and developing process must suit correctly.



Resist thickness: 180 nm
Dose: 120 µC/cm² at 20 keV
Developing time: 30 s
Lines and spaces: 80 nm



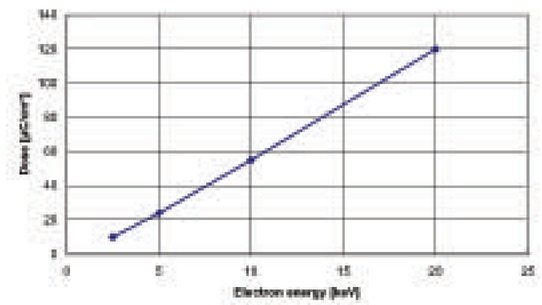
Resist thickness: 180 nm
Dose: 140 µC/cm² at 20 keV
Developing time: 30 s
Lines and spaces: 50 nm

LOW ENERGY ELECTRON BEAM EXPOSURE

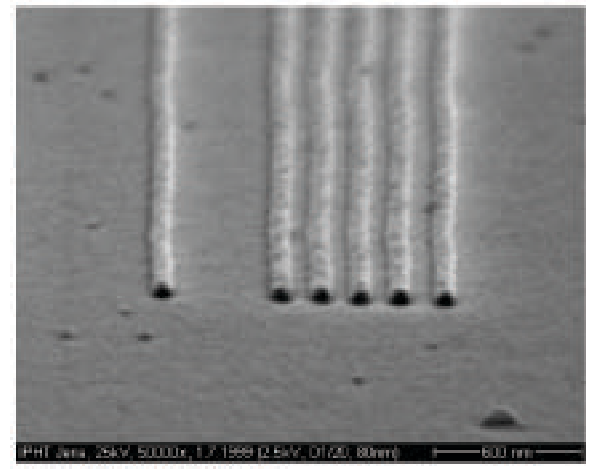
Electron beam exposures with energies of 10 keV, 5 keV and 2.5 keV were made to determine the influence of the electron energy on the resist sensitivity. These experiments were carried out on wafers with a thin resist film (only 70 nm thickness) due to the small penetration depth of low energy electrons.

The exposure doses for the resist layers in these experiments were varied from 1 µC/cm² to 100 µC/cm². The other conditions were similiar to the previous experiments.

Analysing these experiments we found that the resist sensitivity is drastically increased with decreasing electron energy (see Fig. below). For 2.5 keV electron energy a dose of only 10 µC/cm² is sufficient. The sufficient doses were estimated from the SEM pictures of a line and space group exposed with various dose values. As an example in the SEM picture below features of 80 nm width are shown, exposed with 2.5 keV electrons and a dose of 10 µC/cm² in a resist layer of 70 nm thickness. The developing time was 20 s.



Exposure dose for ma-N 2400 resist vs. electron energy



Resist thickness: 70 nm
Dose: 10 µC/cm² at 2.5 keV
Developing time: 20 s
Lines and spaces: 80 nm

CONCLUSIONS

Using a simple DUV negative tone resist and electron beam lithography we can generate high aspect ratio patterns with values of about 5 in resist layers of a thickness of 800 nm.

In thinner resist layers we can produce dense lines and spaces in the sub-100 nm region. Up to now we could generate features of 50 nm linewidth.

Probably the resolution limit is at much finer structures but to find out the right working point is more critical.

The resist technology is very simple because no chemical amplification takes place in the resist. Therefore no post exposure bake is necessary and we got a wide process latitude.

Further the resist samples have a longer shelf life in comparison with resists with chemical amplification.

No susceptibility to poisoning was observed.

For the low voltage electron beam lithography this resist has a good sensitivity and for all energies a high resolution capability.

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[1] "Evaluation of the ma-N 2400 Series DUV Photoresist for the Electron Beam Exposure", H. Elsner and H.-G. Meyer, A. Voigt and G. Gruetzner, MNE '98, Leuven, Belgium. 22-24 Sept. 1998. Microelectronic Engineering 46 (1999) 389-392.

[2] "Nanometer Patterning Using ma-N 2400 Series DUV Negative Photoresist and Electron Beam Lithography", A. Voigt, H. Elsner, H.-G. Meyer, G. Gruetzner, Proceedings of SPIE Vol. 3676, 485-491.