EUV Patterning Strategy compensating EUV Shot Noise

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It is reported that EUV shot noise has become fundamental issues to deteriorate LWR (Line Width Roughness) and CDU (CD Uniformity). But progress of EUV source power is delayed and not sufficient, we need to develop EUV patterning technology to overcome EUV shot noise. Currently there are four technological strategies and we are investigating them. ; These are (1) resist upgrade, (2) additional LWR / CDU mitigation process, (3) EUV NTD (Negative Tone Development) and finally (4) blend DSA (Directed Self Assembly) rectification. Resist upgrade and additional LWR / CDU mitigation process is matured more or less, so we are using some effects from them already. But EUV NTD and blend DSA rectification is new and potential technology which is introduced recently, so we expect these will become break-through technologies against EUV shot noise.

Keyword: EUV, Shot Noise, LWR, CDU, Source Power, Resist, Mitigation Process, EUV NTD, Blend DSA Rectification

1. Introduction

Recently we gathered patterning result on half pitch 3X nm contact hole by using EUV exposure tool (NXE3100) on which hard mask etch process was applied. From the result of comparison between EUV single and ArFi DPT (Double Patterning Technology), we found both patterning technology can met current device target in view of CDU, but EUV showed 40% larger sensitivity which was compared to ArFi. The effort to improve EUV source power has been ongoing for past several years but progress is not sufficient yet, so dedicated EUV process to improve EUV sensitivity is essentially needed.

The reason why EUV needs relatively high dose sensitivity is on EUV shot noise which is property of EUV photon absorption. EUV has very short wave length of 13.5nm and high energy, so resist matrix cannot absorb photon easily. Actually EUV is recognized as multiple random photons and can be explained by average and distribution. But ArF is recognized as a wave and can be explained by simple average. It is reported that the number of EUV photon absorption is 14 times less than that of ArF under same experimental condition and that is the major reason to

Table 1. Patterning Results on hp 3Xnm C/H

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<thead>
<tr>
<th></th>
<th>EUV Single</th>
<th>ArFi DPT</th>
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<tbody>
<tr>
<td>Top View</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-CDU</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>R-Sensitivity</td>
<td>1.4</td>
<td>1.0</td>
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deteriorate LWR and CDU compared to ArF. As a result, EUV shot noise has became a fundamental issue, so we need strategy for patterning technology to solve it essentially.

2. Experimental

2.1. Additional LWR/CDU Mitigation Process

Several Mitigation Processes were evaluated to overcome EUV shot noise. These are (1) rinse, (2) solvent vapor, (3) plasma treatment, and finally (4) shrink process.

First, rinse process is the optimization method between surfactant which swells resist surface and then improve LWR and additive which protect resist surface against serious swelling. Second, solvent vapor process is the method that vapor swells resist surface and at the same time vapor surface on the resist surface evaporates to the air so that kind of process sequence is optimized and occurred repetitively. Third, shrink process is the method that water soluble polymer is coated on the resist pattern and then attaches on resist surface with regular thickness by using acid-base crosslinking reaction. Finally, plasma treatment is the method that etching and deposition is achieved successively on the resist surface to improve LWR by using etch plasma.

Four kinds of different processes were applied respectively and continuously as shown to Figure 1 and Table 3. As a result of N-CDU, rinse and solvent vapor show less than 1% improvement. And shrink process and plasma treatment show 1.5% and 2.8~3.4% improvement respectively.

2.2. EUV NTD

EUV NTD was evaluated to overcome EUV shot noise. EUV NTD has a concept that hydrophobic solvent developer dissolves hydrophobic and unexposed resist part selectively. It is essential to prepare bright field mask, NTD dedicated resist, solvent developer to be optimized.

2.2.1. Image Contrast (NILS) and Swelling

Image contrast (NILS) on C/H pattern was compared between EUV PTD and EUV NTD by using S-Litho (Synopsys), simulation tool. As shown to figure 2, NTD shows better NILS through all hp C/H and shows especially superior NILS in the range of less than hp 35nm C/H regardless of flare level. Superior NILS means, so to speak, smaller
variation of CD against variation of exposure energy, so we expect EUV NTD shows better on C/H CDU compared to EUV PTD.

Swelling property was also compared between EUV PTD and EUV NTD by using QCM (quartz crystal balance, LTJ). QCM can measure resist thickness as a function of development time and convert to swelling ratio. On the Figure 3 increased thickness was observed on PTD at 19.5mJ and 26mJ respectively which is more than 2 times larger than initial thickness. But no specific thickness change was observed on NTD through energy. As a result of comparison, swelling ratio of PTD shows 200% at 19.5mJ and 26mJ, but swelling ratio of NTD shows nearly Zero.

So we need to develop EUV NTD which is expected as a superior process compared to EUV PTD based on results of image contrast and swelling properties.

Figure 3. Resist Swelling

2.2.2. Patterning Performance on hp 20nm L/S

Patterning performance was compared on hp 20nm L/S between EUV PTD and EUV NTD. Comparable performance was gathered on sensitivity, LWR and resolution even though EUV NTD is not matured yet. Actually EUV NTD L/S resist chase close on the heels of EUV PTD.

And as a result of comparison between PTD and NTD, PTD shows resolution of 19nm and NTD shows resolution of 20nm respectively

Table 4. EUV PTD vs. EUV NTD @ hp 20nm L/S

2.2.3. Patterning Performance on hp 30/32nm C/H

Table 5. shows patterning performance on EUV PTD (hp 30nm C/H) and EUV NTD (hp 32nm C/H). Similar to L/S performance, additional improvement on EUV NTD is needed.

Table 5. EUV PTD vs. EUV NTD @ hp 19~20nm L/S

2.3. DSA (Directed Self Assembly) Rectification

DSA rectification process can be another option to overcome EUV shot noise. C/H guide pattern is made by EUV NTD which has chemical resistance
against organic solvent, and then blend DSA is coated on the NTD C/H guide pattern, annealed with hot plate, and then wet developed by organic solvent. Blend DSA comprises two polymers which show different $\chi$ (degree of incompatibility). So blend DSA process fill C/H guide pattern with blended polymer, separate blended polymer into two different phases with anneal. So we expect blend DSA can mitigate C/H CDU due to the fundamental reason.

Figure 4. Sequence of Blend DSA Rectification

On the table 6. EUV NTD and EUV NTD w/ blend DSA were compared on same DICD. Actually EUV NTD w/ blend DSA shows 9% better CDU compared to EUV NTD.

Table 6. EUV NTD vs. EUV NTD w/ Blend DSA

<table>
<thead>
<tr>
<th></th>
<th>EUV NTD</th>
<th>EUV NTD + Blend DSA</th>
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<tbody>
<tr>
<td><strong>Top View</strong></td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
</tr>
<tr>
<td>hp / DICD</td>
<td>32nm / 34nm</td>
<td>32nm / 34nm</td>
</tr>
<tr>
<td>CDU</td>
<td>4.21nm</td>
<td>3.84nm</td>
</tr>
</tbody>
</table>

Conclusion
EUV shot noise has become fundamental issues to deteriorate LWR and CDU so we need to develop EUV patterning technology to overcome EUV shot noise. Currently we are focusing additional LWR / CDU mitigation process, EUV NTD and blend DSA. We evaluated several kinds of mitigation process but not sufficient so far. EUV NTD shows superior property on image contrast and swelling but resist is not matured until now so we will continue to develop related materials and process. Finally DSA rectification is new and potential process and can be the another option to overcome EUV shot noise.

References