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A New Phase Shifting Method for High Resolution Microlithography

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ABSTRACT

One of the most promising lithographic technique for the future designs of DRAMs is the phase-shifting mask technique. Conventional phase shifting-masks, however, are difficult to fabricate as they require regions of different optical thickness. We present a new phase shifting technique that does not use any phase shifting materials. A special interferometer and a mask that has both transmitting areas and reflective areas accomplish the required phase-shift at the image plane. Using this technique we have demonstrated phase shifting effects using a CCD camera. We also present the results of a computer simulation for the critical resolution of this new method in comparison with the conventional phase shifting approach.

1. INTRODUCTION

This paper reports simulation and experimental details of a novel phase shifting technique based on interferometry. Phase shifting is one of the most promising techniques[1,2] for future DRAM fabrication. In recent years, many kinds of phase shifting methods have been proposed to extend the resolution limit and the contrast of the image of patterns.[3] These phase shifting mask techniques, however, have problems associated with the phase shifting elements on the mask, which need precise placement and exact thickness for a desired amount of phase shifting. Furthermore it is impossible to adjust them once they are made. As a result of this, the manufacturing cost of phase shifting masks is high, which presents a problem for introducing the phase shifting mask into the production line.

2. NEW PHASE SHIFTING TECHNIQUE

Our new phase shifting mask technique does not require any phase shifting elements on the mask, but is based upon a special interferometer, and a mask that has transmitting and reflective areas for the irradiated beam corresponding to the pattern design, shown as Figure 1 and Figure 2. The incoming laser beam is split into two (Laser Beam 1 and Laser Beam 2) by the Beam Splitter 1. These beams irradiate the mask from both the front and back side via Beam Splitter 2 and Beam Splitter 3. The optical paths of the beams are chosen so that the phase of the two beams is different by an odd multiple of π radians at the surface of the mask by adjusting the position of the mask. This means that the electric fields of the reflected and transmitted beams have opposite signs and cancel each other when combined (Figure 2). The combined beams are projected onto the target wafer through a focusing lens which results in the phase shifted image of the pattern of the mask.

3. EXPERIMENTAL RESULTS AND SIMULATION RESULTS

The new phase shifting method was confirmed with a He-Ne Laser as an irradiating beam and a CCD camera system to analyze the image of the mask at the image plane. For the focusing lens we used a microfocus objective lens which has a demagnification index of 20 and a numerical aparture of 0.4. A CCD camera system was used to obtain the image of the mask and analyze it. In order to view the image of the mask we used a microfocus objective lens that has a magnification index of 60 and N.A. equal to 0.8. The resolution of the CCD camera is 11.0 μm. We used a line and

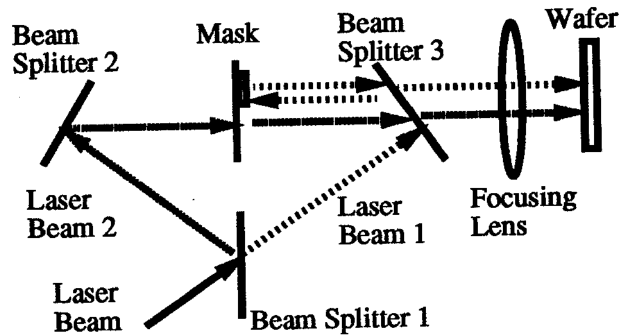

Figure 1: Diagram of New Phase Shifting Method.

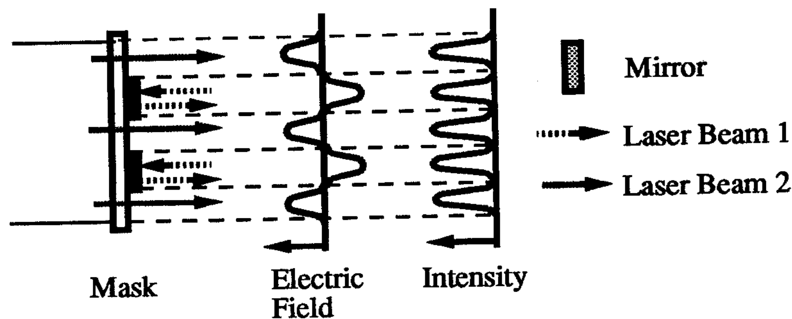

Figure 2: Interferometric Scheme of the New Phase Shifting Method.

space reflective *Al* coating as a mask, with line sizes from 2 μm to 22 μm. For 632.8 nm He-Ne laser light, a feature size of 0.47 μm, or 0.75λ, was achieved with 50 % contrast, and a feature size of 0.50 μm, or 0.79λ, was achieved with 80 % contrast. We used DEPICT-2 to simulate the experiments.[4] The DEPICT-2 program calculates the two dimensional image based on input data on optical properties of the system. The experimental results match well with the simulation performed by DEPICT-2. The calculations show only, considering several optical and electrical noises, about 7 % higher resolution than those of the experiment. The results from the DEPICT-2 simulation for the new phase shifting method show almost the same critical resolution as the Levinson type phase shifting method which are factor of two less than the critical resolution of the transmission type mask. We also confirmed the scalability of this method for shorter wavelengths by computer simulation analyses. A spatial resolution of 0.2 μm should be feasible for 248 nm KrF laser illumination.

Acknowledgments

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