Chapter 1

Introduction

In December 1947 three researchers - William Shockley, John Bardeen, and Walter Brattain - demonstrated a device called transistor that changed the way humankind work and play in the second half of the twentieth century. After the early paper-clip-size transistors, miniaturizing and integration became the main streamline for inserting more and more transistors into the same place.

Today's advanced computer chips contain millions of transistors on a surface not even half the size of a postage stamp. In 1965, seven years after the integrated circuit (IC) was invented, Gordon Moore observed that the number of transistors that semiconductor makers could put on a chip was doubling every year. In 1975 the pace slowed to a doubling of transistors every 18 months. The National Technology Roadmap for Semiconductors developed by the Semiconductor Industry Association extrapolates current trends to the year 2010, when 0.07 μm minimum feature size enable 64Gb DRAM chip production. The question is what technology can provide such resolution?

Integrated circuits or chips are probably the most complex of man-made products. These three-dimensional structures are the result of a multi-step process. Each step, from design to packaging must be executed perfectly if the chip is to work. Optical lithography is a crucially important and critical step in the present IC manufacturing process. During this process the patterns on the mask are imaged into a photo-resist by means of a computer controlled machine called stepper. The system and process parameters determine the obtainable critical feature size (CD). Reduction of the illumination wavelength and/or the use of higher numerical aperture projection lens are two traditional methods to enhance the resolution of the optical system. However, these techniques significantly decrease the depth of focus (DOF) of the image. This issue can be addressed by means of new methods and technological processes that could enhance both the spatial resolution and the depth of focus. This thesis focuses on a comparative study of five resolution enhancement methods. The first technique to be discussed is an advanced phase shifting technique called **interferometric phase shifting combined with off-axis illumination**. This technique does not require any phase shifting layers on the mask, and therefore it is free from any undesirable effects caused by the phase shifting layer. The second (**annular illumination**) and third (**coated objective**) techniques are historically used to enhance optical resolution in various areas of science from microscopy to astronomy. Here they are studied and evaluated from the lithography point of view. The fourth technique (**image duplication by means of a birefringent plate**) utilizes the fact that a birefringent plane-parallel plate inserted behind the projection lens shifts the foci generated by the ordinary and extraordinary rays to different extents. The final image is the superposition of these images. The fifth technique (**coherent multiple imaging by means of a Fabry-Perot etalon**) uses a Fabry-Perot etalon between the mask and the projection lens. The etalon generates multiple virtual 1x images of the mask along the optical axis, and the projection lens creates their superimposed image. The resolution and depth of focus could be enhanced simultaneously using appropriate initial system parameters.