EE/MSEN 6322 Semi Process Tech Fall 2007

Practice Lithography

5.2. In a particular positive resist process it is sometimes noticed that there is difficulty developing away the last few hundred angstroms of resist in exposed areas. This sometimes causes etching problems because the resist remains in the areas to be etched. Suggest a possible cause of this problem and therefore propose a solution.

Answer:

The most likely cause is that there are standing waves in the resist during the exposure and a minimum of exposure intensity exists in the bottom region of the resist. Thus the resist is not fully exposed and won't clear properly during the develop cycle. The problem could be solved by changing a number of parameters like the resist thickness, the thickness of underlying layers, or by increasing the exposure time. Alternatively, an ARC layer could be added under the resist to minimize standing wave and reflection effects.

Alternative answers are certainly possible. Perhaps the exposure time was too short and because of bleaching effects, the bottom part of the resist was not fully absorbed. Or perhaps the developing time was too short and hence the resist was not developed out at the bottom.

5.7. Lithography often has to be done over underlying topography on a silicon chip. This can result in variations in the resist thickness as the underlying topography goes up and down. This can sometimes cause some parts of the photoresist image to be underexposed and/or other regions to be overexposed. Explain in terms of the chemistry of the resist exposure process why these underexposure and overexposure problems occur.

Answer:

Photoresist exposure occurs with a bleaching process. What this means is that the photons are initially absorbed by the PAC in the top layers of the resist and that is therefore where the initial exposure occurs. As the PAC is reacted in these top layers, the resist becomes more transparent (bleaches) and the light then penetrates to the deeper portions of the resist to expose those regions. The time required for complete exposure all the way to the bottom of the resist will thus depend on the resist thickness. Thus if there are thickness variations, there will be problems with overesposure in the thin regions if the exposure is long enough to expose the thick regions. Alternatively, there will be underexposure problems in the thick regions if the exposure is only long enough to expose the resist in the thin regions.

5.8. As described in this chapter, there are no clear choices for lithography systems beyond optical projection tools based on 193-nm ArF eximer lasers. One possibility is an optical projection system using a 157-nm F_2 excimer laser.

a. Assuming a numerical aperture of 0.8 and $k_1 = 0.75$, what is the expected resolution of such a system using a first order estimate of resolution?

b. Actual projections for such systems suggest that they might be capable of resolving features suitable for the 2009 0.07 μm generation. Suggest three approaches to actually achieving this resolution with these systems.

Answer

a). The simple formula for resolution is

$$R = k_1 \frac{\lambda}{NA} = 0.75 \frac{0.157\mu m}{0.8} = 0.147\mu m$$

b). The calculated resolution in part a is a factor of two larger than required for the 0.07 μm generation. Therefore some "tricks" will have to be used to actually achieve such resolution. There are a number of possibilities:

1. Use of phase-shift masks. This technique, discussed in this chapter, has the potential for significant resolution improvements. It works by designing a more sophisticated mask. Simple masks are digital - black or white. Phase shifting adds a second material to the mask features, usually at the edges which shifts the optical phase and sharpens up the aerial image. Sophisticated computer programs are required to design such masks.

2. Use of optical proximity correction in the mask design. This is another approach to designing a better mask and as discussed in class, can also improve resolution significantly. The approach involves adding extra features to the mask, usually at corners where features are sharp, to compensate for the high frequency information lost to diffraction effects.

3. Off-axis illumination. This allows the optical system to capture some of the higher order diffracted light and hence can improve resolution.