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Extreme ultraviolet lithography

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INTRODUCTION

EUV (Extreme Ultraviolet) lithography uses an EUV light of the extremely short wavelength of 13.5 nm. It allows exposure of fine circuit patterns with a half-pitch below 20 nm that cannot be exposed by the conventional optical lithography using an ArF excimer laser. Putting it into practical use requires a variety of element technologies, including the light source, optics, masks, photoresist, and lithography tools.

Today, EUV lithography technology including the light source is still under development; it is expected to be put into practical use within several years. The output power required for high-volume production is 350 W or more. But, the present EUV light source for production use has the output power of approx. 100 W, which is still at a low level. The EUV light source for high-volume production requires a great enhancement of the output power and high reliability that allows non-stop operation without maintenance for several months.

How it works

The droplet generator is a small vessel. In operation, tin is loaded into the droplet generator and then heated. At that point, a train of tiny tin droplets flow out from the droplet generator, through a filter and into the vacuum chamber in the source. The droplets are 25 microns in diameter and are falling at a rate of 50,000 times a second. In the vessel, there is a camera. A droplet passes a certain position in the chamber. Then, the camera tells the seed laser in the sub-fab to fire a laser pulse into the main vacuum chamber. This is called the pre-pulse. Then comes the really hard part. The pre-pulse laser hits the spherical tin droplet and turns it into a pancake-like shape. Then the laser unit fires again, representing the main pulse. The main pulse hits the pancake-like tin droplet and vaporizes it. At that point, the tin vapor becomes plasma. The plasma, in turn, emits EUV light at 13.5nm wavelengths.The goal is to hit a droplet with precision. This determines how much of the laser power gets turned into EUV light, which is referred to as Conversion Efficiency (CE). Meanwhile, once the EUV light is generated, the photons hit a multi-layer mirror called the collector. The light bounces off the collector and travels through an intermediate focus unit into the scanner. In the scanner, the light bounces off a complex scheme of 10 surfaces or multi-layer mirrors. First, the light goes through a programmable illuminator. This forms a pupil shape to illuminate the right amount of light for the EUV mask. Then, EUV light hits the mask, which is also reflective. It bounces off six multi-layer mirrors in the projection optics. Finally, the light hits the wafer at an angle of 6%. Each multi-layer mirror reflects about 70% of the light. Based on various calculations, the EUV scanner itself has a transmission rate of only 4%. The light then hits the photoresist on the wafer.

Resist

The basic requirements for EUVL resist are sensitivity, resolution, Line Width Roughness (LWR) or Line Edge Roughness (LER), outgassing, a pattern cross-sectional aspect ratio and profile, etch resistance, defect density, and reproducibility. Among them, it is a critical challenge to meet the requirements simultaneously on resolution, LWR, and sensitivity (RLS).

EUVL uses Chemically Amplified Resist (CAR) due to the advantages of high sensitivity and resolution, but its LWR is relatively high, which becomes a significant issue. For the 22 nm feature, LWR should be controlled below 2 nm (3σ), which is about half of the current best available values.

Necessity

Lithography with 193 nanometer light has been pushed further than many would have thought possible, but it has come at a cost: the industry has had to reach deep into a bag of tricks to continue shrinking chip features. With EUV lithography, we are offering the industry a fineliner. Chipmakers will be able to continue making smaller, faster and more powerful chips while keeping costs in check.

CONCLUSION

EUV lithography has gone through intensive global studies since proposed. Original critical technological challenges in EUVL reflective optics have been overcome; resist resolution was pushed down to 13 nm feature size; EUVL exposure tools now have better alignment accuracy, better optics, and 40–55 W EUV in-band light at the IF position. The EUVL mask significantly improved the defect level with an advanced inspection tool. It is generally expected that volume production will soon come despite several delays in its adoption.