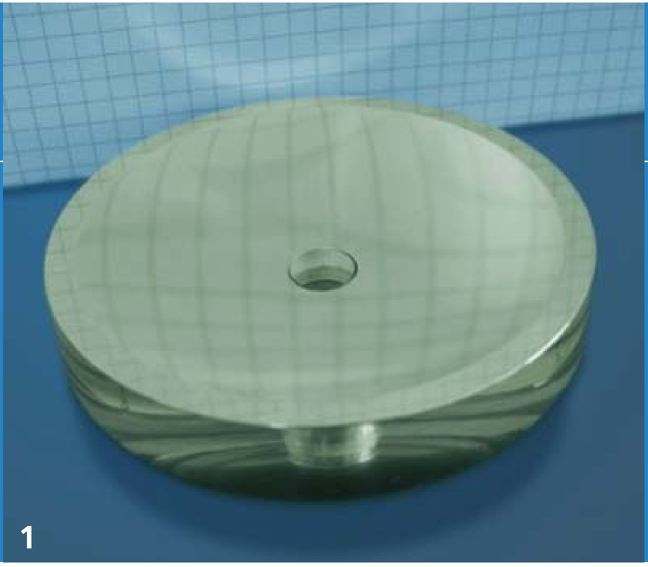


EUV MIRROR LAYERS FOR 7 NM LITHOGRAPHY

THE TASK

Several semiconductor manufacturers currently expose significantly more than 1000 wafers per day by means of EUV lithography. Thus, it makes sense to introduce this “unusual“ vacuum technology into microelectronics – not only for technical, but also for economic reasons.

In all photolithographic configurations, the optical device plays a key role. In EUV lithography, the mask structure is mapped on the wafer by means of mirrors (Fig. 1). The reflective layers deposited must fulfill the highest requirements in terms of the reflection coefficient, smoothness, precision of lateral thickness distribution and low internal stresses. The requirements increase still more as a function of further structure reduction so that a continuous improvement of the coating properties is still necessary.

In the SeNaTe (Seven Nanometer Technology) European research project coordinated by the ASML company, the IWS is responsible for the exploration of EUV reflective layers for future optical devices for lithography. The highest priority requirements in terms of layer development consist in:

- reducing stray light from the reflective layers
- engineering high precision coatings on sculptured surfaces
- diminishing internal layer stresses while maintaining consistently high optical performance

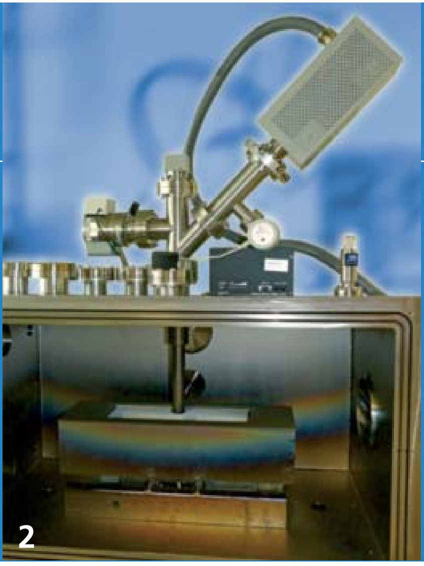
The special challenge is to develop a coating process enabling the production of EUV mirror layers that are highly reflective, with both low stray light and low internal stresses.

OUR SOLUTION

With magnetron-sputter deposition (MSD), the IWS has a technique at its disposal that has been proven in industry and used for the exploration of EUV reflective layers for several years. The coating properties are defined by the vacuum conditions, as well as, above all, the kinetic energy of the particles impinging on the substrate. Thus, reduced coating roughness can be achieved by, for example, an increase in the mean kinetic energy of the particles that form the layer. However, this activation must be exactly measured to avoid any intermixture of the materials at the interfaces, as well as an amplification of the compressive stresses that typically occur.

To obtain precise information about the distribution of kinetic energy as a function of the coating parameters, an EQP 500 plasma monitor was positioned at the point of coating (Fig. 2). This device makes it possible to quantify the energy distributions of both the charged and neutral particles.

Energy distributions, such as those typical for magnetron plasmas, are verified with standard processes, in which coating roughness values of < 0.1 nm rms cannot be achieved. For surfaces that are inclined by more than 30 °, roughness clearly increases and internal stresses change. For this reason, an activation of the coating process was introduced, in which the energy distribution is shifted to levels of higher energies.



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However, when making use of activation processes to obtain the desired smoothing, there is the risk that the coatings will mix thoroughly at their interfaces. By balancing the various above mentioned objective criteria, we found a parameter set involving discharging power, sputter gas pressure and ion activation, for which the coating properties could be substantially improved.

RESULTS

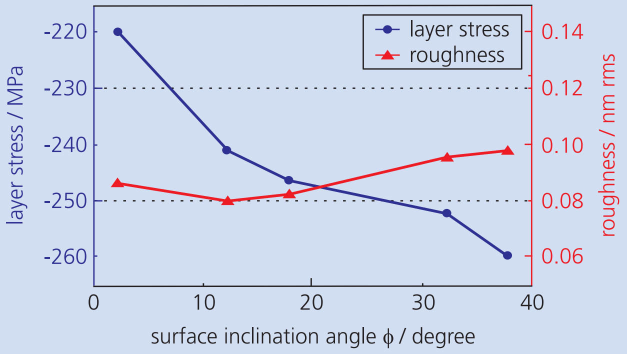
The increased kinetic energies of the particles impinging on the substrate at first resulted in the desired smooth surfaces: roughness surveyed by means of a scanning force microscope ranged now from 0.06 to 0.10 nm rmp. The lower roughness limits were achieved for planar substrate surfaces. Roughness values lay at approximately 0.10 nm rmp for surfaces with concave curvature, with 40 ° angles of slope against the incoming particle flow.

Reduced roughness at first resulted in a reduction of the light diffusely reflected by the mirror. In optical imaging units, this effect improved the signal-to-background ratio, that is to higher image contrast.

Plasma activation at first caused stronger intermixture at the interfaces, which we could reduce. The specular reflection of the mirrors could also be increased. The reflection coefficients > 70.5 percent (λ = 13.5 nm, α = 5 °) were reproducibly evidenced both by the National Metrology Institute (Physikalisch Technischen Bundesanstalt (PTB)) and the Berkeley National Lab (BNL) in independent investigations. The previous record value is R = 70.7 percent.

An unintentional increase in the compressive stresses of the layers can be a negative concomitant effect of the plasma activation. This expectation was confirmed in the first investigations: compressive stresses from -200 MPa to -250 MPa, typical in standard coatings, were clearly exceeded and lay in the range from -300 MPa to -650 MPa. Intentional customization of the activation both in terms of intensity and duration avoided a more pronounced formation of properties without reducing the desired smoothing effect. With this configuration, coatings with internal stresses from -220 MPa to -260 MPa and of < 0.1 nm rms roughness can be fabricated. These values are feasible on large substrates of 300 mm diameter and on substrates with strong curvature, with local surface inclinations of up to 40 ° (Fig. 3).

Roughness and internal stresses on substrate surfaces of concave curvature as a function of surface slope.



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1 *EUV mirror (photography)*

2 *Setup for energy quantification by means of the EQP 500 plasma monitor*

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