Modeling of Protection Schemes for EUVL Masks under Low Pressure Conditions

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Motivation
Particle contamination control is crucial for protecting Extreme Ultraviolet Lithography (EUVL) masks. Due to the small structure sizes, particles with diameters down to 30 nm can deteriorate the mask performance. Therefore schemes are required to protect the mask from particle deposition. To protect the masks, they are maintained upside down to avoid gravitational settling of particles onto the mask. Further a plate is used to cover the mask in order to minimize the risk volume and maybe an electric gradient established between mask and cover plate to make use of thermophoresis and electrophoresis. We present a model to quantify the effectiveness of these protection schemes.

Protection Schemes

- Using argon instead of air reduces the stopping distance by 0.3% - 12%
- At 2 mTorr, the stopping distances are significantly longer and particles travel significantly further at low velocities
- For low speed (e.g. diffusion driven) particles, electronophoresis has very high protective potential, however its effectiveness is very uncertain, because particles cannot get intentionally charged and might have wrong polarity
- For high speed particles, drag force is dominant

Conclusions
- An analytical model was developed to predict particle behavior in EUVL equipment at low pressure
- Model was experimentally verified and showed good agreement (see companion poster)
- Electrophoresis has very high protective potential, however its effectiveness is very uncertain, because particles cannot get intentionally charged and might have wrong polarity
- Model was experimentally verified and showed good agreement (see companion poster)

Figure 1: Evolution of concepts for protecting the mask from particle contamination: (a) mask inside container, (b) with cover plate to reduce the volume from where particles can reach the mask, (c) critical surface facing down to avoid gravitational settling of particles onto the mask, thermal and electrical gradient between mask and cover plate to facilitate thermophoresis and electrophoresis, (d) with particle trap around the mask to deposit particles entering from the side before they reach the mask [1]. Particles might be generated in the gap (e.g. due to condensation) or penetrate through the side opening.

Figure 2: Model assumptions. Particle within the gap traveling at an initial velocity \( v_i \) forces that counteract the motion are: gravity \( F_g \), drag force \( F_d \), electroophoresis \( F_e \), and thermophoresis \( F_t \) [2]. Particle contamination within unprotected volume is very likely.

References

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