CORNING
Discovering Beyond Imagination

SPIE
Conference 2002

Laser Resistance of Fused Silica for Microlithography: Experiments and Models

By Dr. Johannes Moll

Laser Damage in Fused Silica: Impact in Microlithography

- Absorption increase over lifetime: loss of throughput, lens heating (reduced imaging quality)
- Increased wavefront aberration over lifetime: reduced imaging quality

Laser-Induced Changes in Fused Silica

- Absorption changes: due to color center formation
- Compaction and Expansion: changes in material density, leading to changes of index of refraction and stress-induced birefringence
- Photorefractive effect: increase of index of refraction in the material due to the formation of SiH and SiOH

Model for ArF Induced Absorption in Fused Silica

$$\begin{aligned}
h\nu &\rightarrow X \\
X &\rightarrow \text{ground state} \\
X + H_2 &\rightarrow \text{ground state} \\
X + P &\rightarrow P^* \\
P^* &\rightarrow E' \\
E' + H_2 &\rightarrow SiH + H\bullet \\
SiH + h\nu &\rightarrow E' + H\bullet \\
E' + H\bullet &\rightarrow SiH
\end{aligned}$$

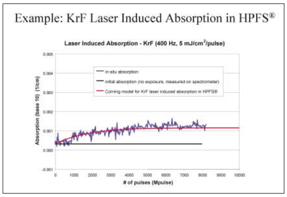
Summary

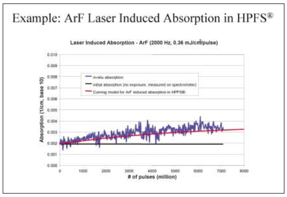
- Marathon testing of HPFS® samples is performed to verify material performance close to actual use conditions
- Measurements demonstrate testing of wavefront distortion at typical test wavelength (633nm) is not sufficient; testing is required at the wavelength of use
- Corning has developed models for laser induced absorption and wavefront distortion in HPFS® to allow lens designers to assess error budgets

Acknowledgments

I would like to thank Dr. Paul Dewa from Corning-Tropel for doing the 193 nm interferometry. Also, I am very grateful to Dr. Charlene Smith and Dr. Michael Linder for valuable discussions on the subject, and William Wilson for technical support.

2000 Hz ArF Laser Damage System at Corning


Example: KrF Laser Induced Absorption in HPFS®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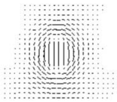
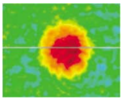
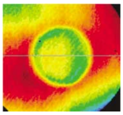
Model for ArF induced wavefront distortion

- Measured wavefront distortion = combined effect of density changes (compaction and expansion) and a photorefractive effect
- Compaction, expansion, and photorefractive effect each depend in different ways on exposure fluence and material parameters
- The relative magnitude of the photorefractive effect (compared to the wavefront distortion due to density changes) is larger at 193 nm than at 633 nm

Example - Expanding HPFS® Sample


Vector plot of birefringence in the damage spot. The vectors indicate the slow axis of birefringence. The tangential pattern around the edge of the damage spot indicates that the sample density has decreased inside the exposure region


Interferogram of the damage spot, measured using a 633 nm laser. The wavefront inside the damage spot is advanced, i.e., the optical path at 633 nm has decreased


Interferogram of the damage spot, measured using a 193 nm laser. The wavefront inside the damage spot is retarded, i.e., the optical path at 193 nm has increased due to the larger contribution from the photorefractive effect at 193 nm

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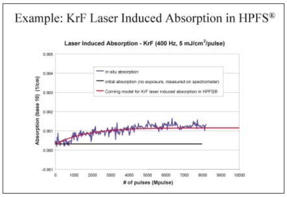
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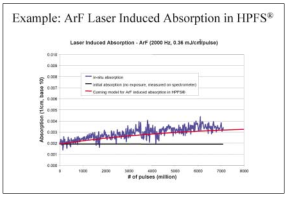
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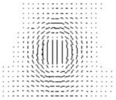

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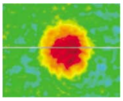

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