Property variations of Laser components under vacuum conditions

M. Jupé, T. Groß, H. Mädebach, K. Starke, D. Ristau, Laser Zentrum Hannover e.V., Hannover, Germany
Thin Film Technology Department

**Characterization**
Development of test procedures, service for analysis devices

**Coatings**
Production of optical coatings following customer specifications

**Process development**
Optimization of coating processes, online-process monitoring
Process Development

**Thermal Processes**
E-beam and boat evaporation
Consulting and Implementation for industrial production
Coatings for deep-UV and vacuum-UV applications

**Ion Assisted Deposition (IAD)**
Characterization and optimization of ion sources
Process monitoring and controlling
Rapid manufacturing, MIR-spectral range

**Ion Beam Sputtering (IBS)**
Low optical losses, dense layer system
High power edge filters, Rugate filters
Precision IBS coating technology
Coatings

Production of custom-requested coatings

Spectral range 130nm to 5µm
Small batch sizes, special requirements
- optical performance, low losses
- damage threshold, stability
- complex spectral requirements

Special substrates and materials
- complex geometries
- laser and nonlinear crystals
- fiber and laser diode facets
- special coating materials
Optics Characterization

**Damage threshold ISO 11254**
157 nm, 193 nm
780 nm (ultra-short pulses), 1064 nm
single and multiple-pulse testing

**Absorptance ISO 11551**
355nm, 532 nm, 1064 nm, 10.6 µm

**Total scattering ISO 13696**
157 nm, 193 nm, 633 nm, 1064 nm

**Spectrophotometry ISO 15368**
120 – 240 nm, 190 – 3200 nm, 2.5 – 25 µm

**Precise Reflectometry ISO 13697**
532nm, 1064 nm, 10.6 µm

Development of standard characterization procedures (DIN, CEN und ISO)
What changes?

Spectral behavior

- Spectral curves of a HR1064 coated in a conventional electron beam process \([(HL)_{19}H - Ta_2O_5/SiO_2]\). The spectrum significantly shifts to shorter wavelength under vacuum conditions.

Damage threshold
(measurement according ISO11254)

- Damage threshold decreases strongly in vacuum!!!
Changing of the spectral behavior

- Method: spectral photometrical measurement in the coating plant (BBM).

- Method: spectral photometrical measurement of thermal shift in with a special heating set-up.

Comparison of the measurements

Content of water in layer
Where is the water located in the layer?

- Focus on the physical absorption
  (The chemical binding of hydroxide molecules on the silica is also possible.)

Porous microstructure
- Including of water in the structure
- Changing of the refractive index
- Absorption in the infrared
- Obviously, changes of the laser light resistance

Demanded of layers with a higher density of the microstructure

1. IBS
2. IAD
Coating processes

IBS- Coating plant
• Low loss optics (laser gyro mirror)
• Crystal coatings
• High power (Rugate)
• Shift free, water free
• But: High stress

IAD- Coating plant
• Water free optics for the MIR-application
• Shift free
• Optionally stress free
• But: Contamination??? → Test of different Ion sources (APS, Lion, Denton CC105)
**Results of shift measurements**

Vacuum shift of a HR1064 conventional

- The samples have shown different behaviors during evacuation and venting.
- The vacuum shift of IBS-samples is negligible. For IAD –samples the vacuum shift depends on the Ion dose.
- Time of relaxation is in the range of 1 to 5 hours.
- The relative accuracy of the measurement is $1E^{-3}$. 

Vacuum shift of AR-coatings

Hysteresis of the AR-optics

Vacuum shift overview
Thermal Shift Measurement

- Thermal shift reveals the content of water. The results correspond with the spectral measurements in the IR.
- Problem of thermal shift measurement is the annealing of the samples.
**Damage of samples under vacuum conditions**

AR- coating manufactured in an e⁻-beam process

In air the LIDT is stable at 20 J/cm². In vacuum the LIDT decreases dramatically.

AR- coating manufactured in an IBS process

The damage threshold is relatively low, but environment conditions do not have an influence on the LIDT.
**IBS-Coating**

The increasing LIDT can be achieved using alternative coating materials. Vacuum test are planned.

**IAD:**

The damage threshold is in the range of e^{-} beam coatings. Vacuum test are planned.
Summary

- Vacuum and thermal shift measurement have shown spectral shifts.
- Coatings of different processes were tested.
- Coating properties change under vacuum conditions.
Acknowledgements

• The European Space Agency (ESA) supported the work under the contract number: 19176/05/NL/AR. Special Thanks to Denny Wernham and Yngve Lien for the valuable discussions.