Grating fabrication in dielectric coatings by TWIN-LIBWE

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Introduction

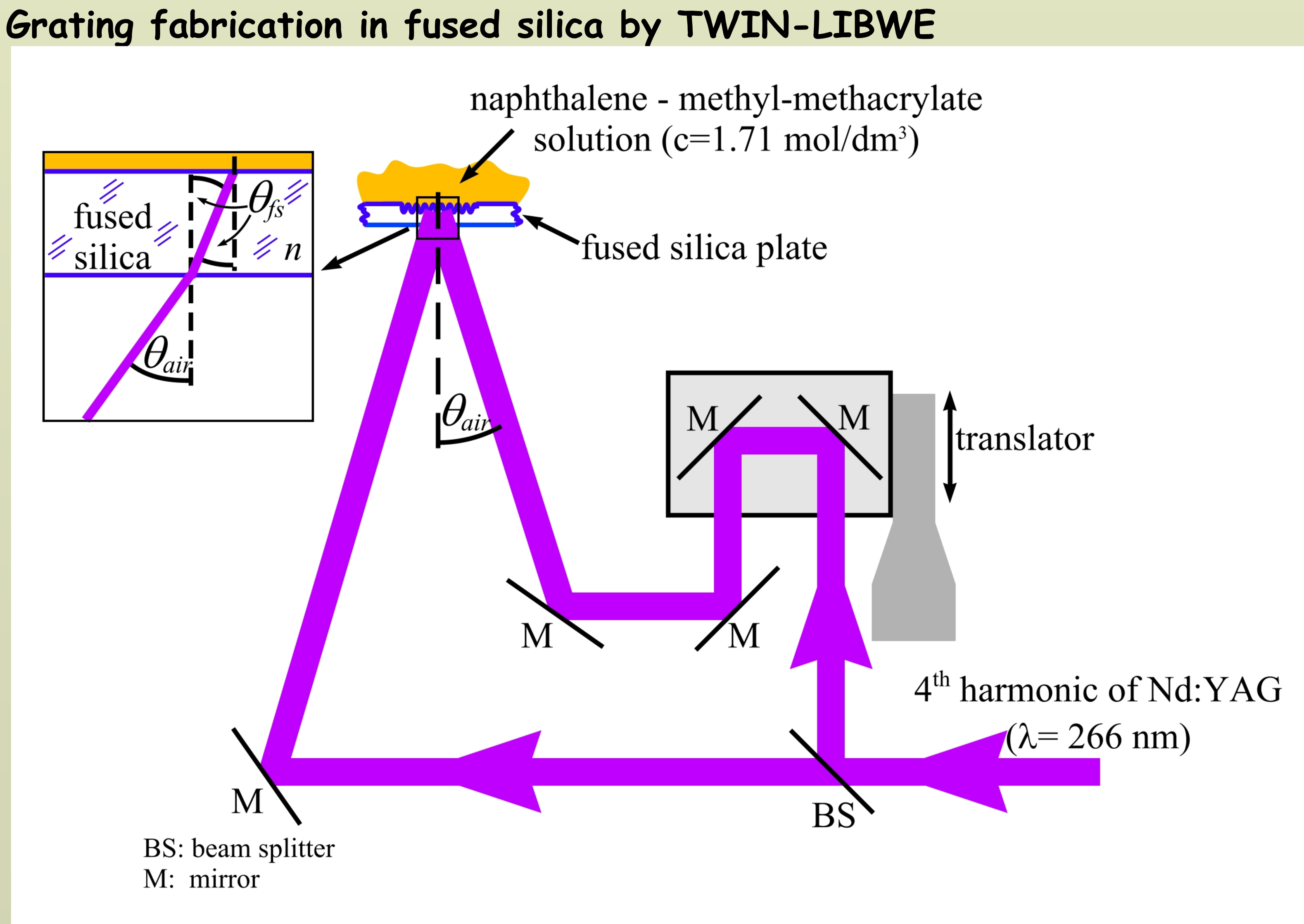
Thin films are widely used in many applications, especially, the transparent films are commonly used as high reflective and antireflex coatings on optical elements. Moreover, several spectroscopic applications need microstructured thin films deposited on bulk dielectric. There were a few attempts to microstructure thin films by laser based methods [1,2].
The **laser-induced backside wet etching (LIBWE)** [3,4] is one of the most promising, flexible and applicable indirect technique. It was recently demonstrated that the **combination of LIBWE with the two-beam interferometric method (TWIN-LIBWE)** is well suited for fabrication of submicrometer period gratings onto the surface of bulk fused silica [5]. Here we report on the fabrication of micrometer period grating structure in SiO_2, Al_2O_3 and Y_2O_3 **thin films** by TWIN-LIBWE.

The basic technique: LIBWE – laser-induced backside wet etching

In the LIBWE procedure the backside of the transparent target is in contact with a liquid absorber having high absorption coefficient at the wavelength of the applied laser. The target-liquid boundary is irradiated through the transparent dielectric. The material removal can be attributed to thermal- (high temperature target surface), mechanical- (high pressure jet and bubble) and chemical effects (target surface modification, contamination).

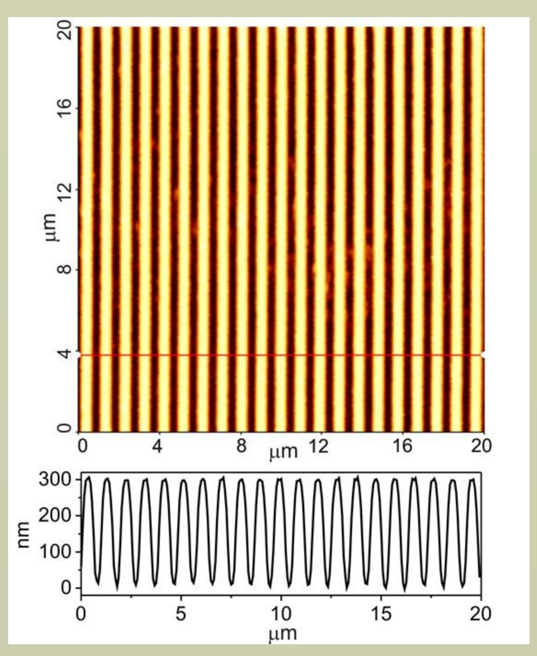
Advantages of LIBWE:
- one step method (contact mask preparation is not necessary)
- fine controllability (etch rate: 0.1-40 nm/pulse)
- high lateral resolution (linewidth: ≈ 50 nm – see below)
- low roughness etched surface (≈ 4 nm)
- low etching threshold fluence (some 100 mJ/cm²)

Grating fabrication in fused silica by TWIN-LIBWE



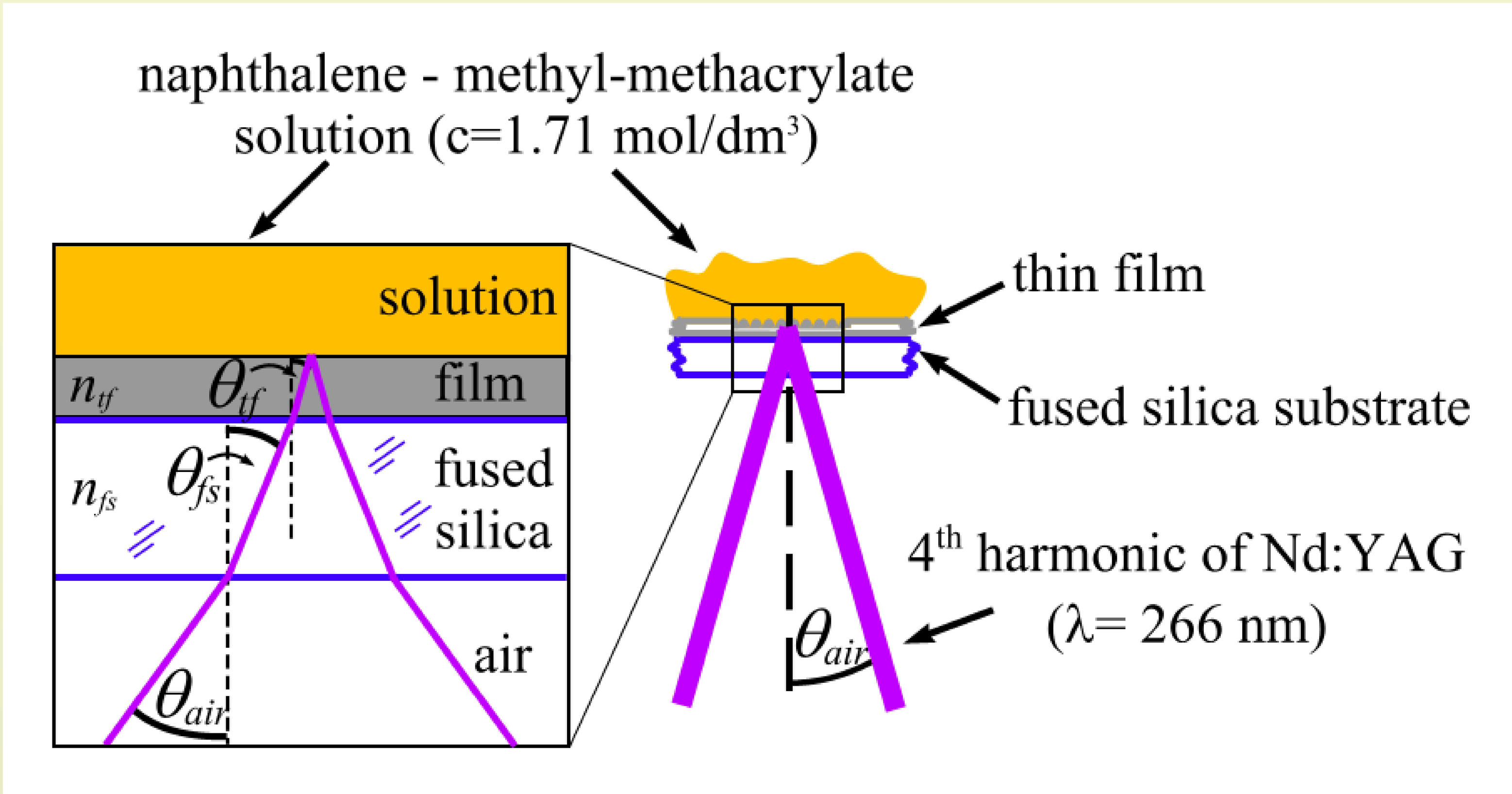
Laser source:
- Q-switched Nd:YAG
- s-polarized pulses
- wavelength: 266 nm (4th harmonic)
- pulse duration: 8 ns
- repetition rate: 10 Hz
- spatially filtered beam in two steps (in green and in UV)
- coherence length: ≈1 cm

BULK FUSED SILICA



Surface characterization:
- **AFM** - modulation depth measurements
- **Profilometer** - etch depth measurements

THIN FILM GROOVING by TWIN-LIBWE (θ=7.57°; p=1010 nm)

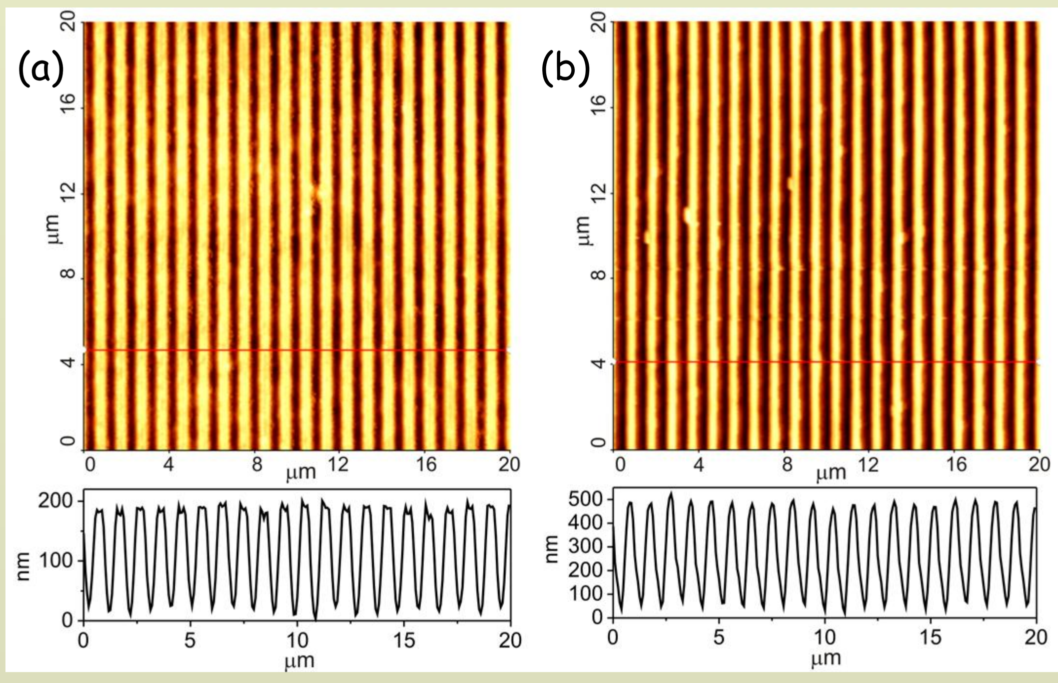


$$p = \frac{\lambda_{tf}}{2\sin(\theta_{tf})} = \frac{\lambda_{fs}}{2\sin(\theta_{fs})} = \frac{\lambda_{air}}{2\sin(\theta_{air})}$$

Results

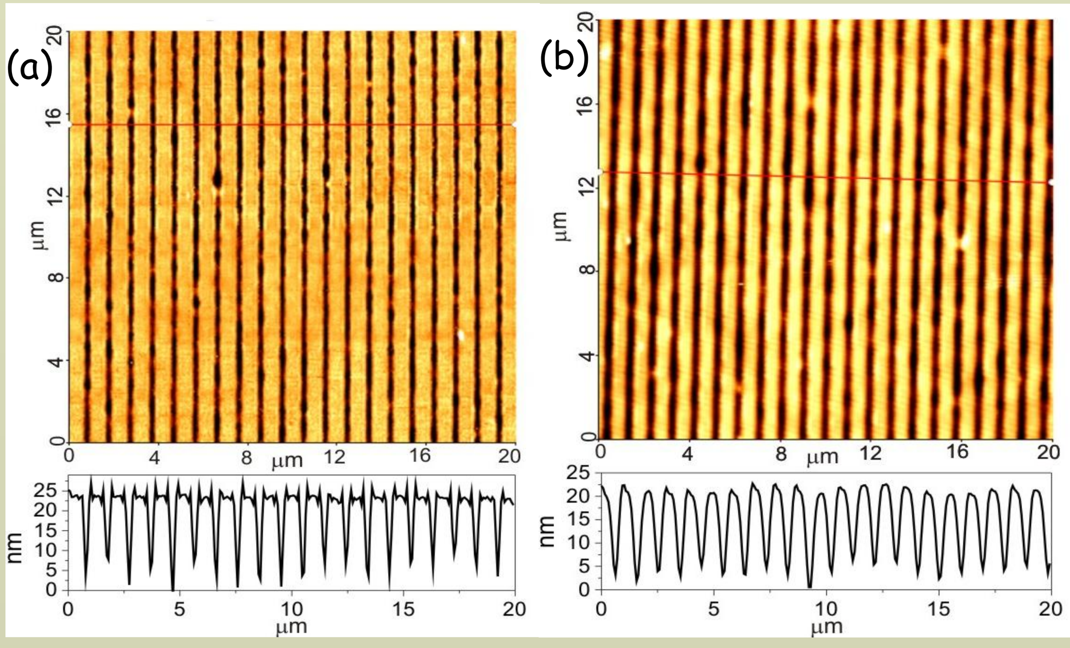
SiO_2
(a) film thickness: 200 nm,
F=321 mJ/cm², 75 pulses
Modulation depth: 170 nm
Etch depth: -30 nm

(b) film thickness 800 nm,
F=500 mJ/cm², 100 pulses
Modulation depth: 400 nm
Etch depth: 220 nm

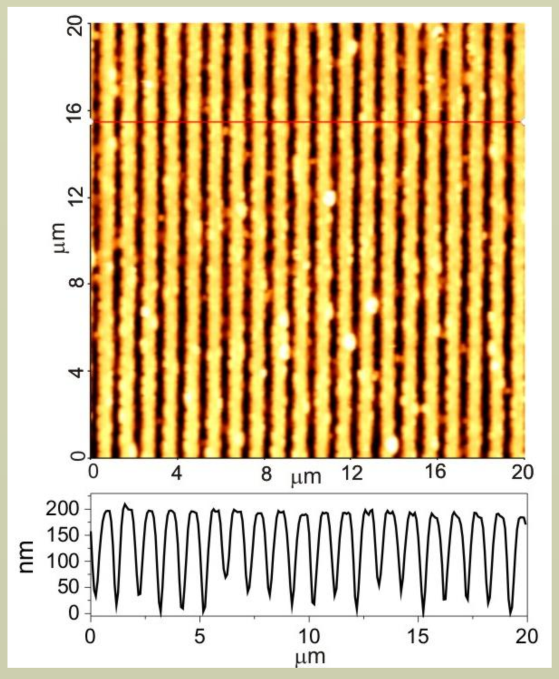


Al_2O_3
(a) film thickness: 205 nm,
F=250 mJ/cm², 3 pulses
Modulation depth: 17-20 nm
Etch depth: 0 nm

(b) film thickness 890 nm,
F=250 mJ/cm², 10 pulses
Modulation depth: 15-18 nm
Etch depth: 0 nm



Y_2O_3
film thickness: 200 nm,
F=250 mJ/cm², 8 pulses
Modulation depth: 180-200 nm
Etch depth: 5 nm



- absorption of films
- different thermal properties

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- quality loss
- cracks, peel off

Summary

We have fabricated micrometer resolution periodic structures in transparent dielectric films deposited onto fused silica substrates by TWIN-LIBWE method. The quality of the etched SiO_2, Al_2O_3 and Y_2O_3 films is excellent, however the modulation depth of sapphire and ittrium-oxide films are appeared to be less scalable than bulk/film SiO_2. The use of TWIN-LIBWE may open a new promising route for microfabrication of dielectric thin films required by sensoric and spectroscopic applications.

Acknowledgments

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