New Generation of Immersed Gratings for High Resolution Spectroscopy in the Near and Short IR

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Spaceborne remote sensing of the chemical composition of the earth atmosphere is an important monitoring tool for scientists studying the influence of gases on the climatic changes and the weather. The requirements of diffraction gratings used in such spaceborne spectrometers are permanently increasing in complexity. Using conventional diffraction gratings would result in larger gratings, and consequently in bulkier instruments. Immersed gratings and especially immersed gratings in transmission are technical solutions to achieve higher performance and more compact instrument configurations simultaneously. Within two ESA projects the important technology building blocks for the successful realization of fused silica (NIR) and Si (SWIR) immersed gratings in reflection and transmission are being developed and demonstrated.

The realization of immersed gratings started with an analytical study to optimize performance and fabrication tolerances of the grating using RCWA (Rigorous Coupled Wave Analysis), FDTD (Finite Difference Time Domain) and raytracing methods. Parameters such as groove shape, period, duty cycle, depth, and incidence angle were screened in respect to diffraction efficiency, polarization sensitivity, dispersion resolution and manufacturability. In the end, gratings with rectangular grooves of high aspect ratios were chosen, because they yield the best performances (efficiency >90%, polarization sensitivity <2%, dispersion 0.2°/nm), and they enable optical contact to a planar surface thanks to their flat top.

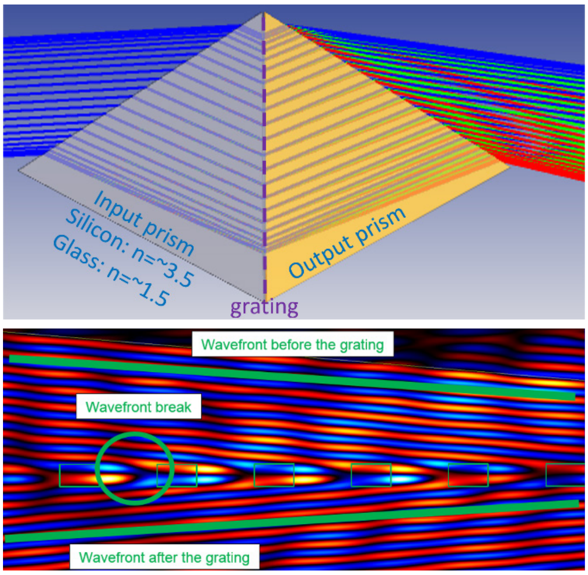

Figure 1: Proposed and simulated immersed grating in transmission using raytracing (top) and FDTD (bottom).

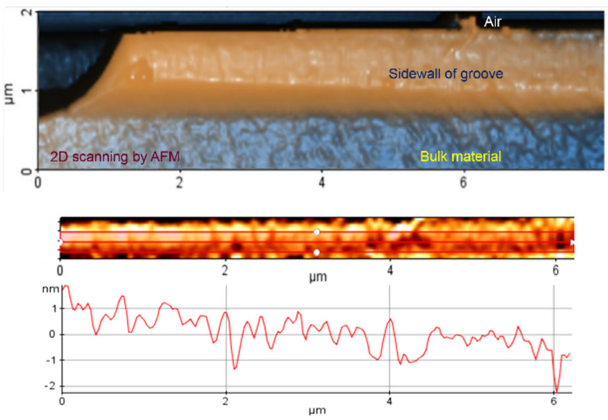

Figure 2: Fabricated grating with ultra-smooth sidewalls.

In a next step, technology developments for the chosen binary gratings with high aspect ratio were carried out. To obtain the required depth, while reaching very low straylight values, special efforts targeted ultra-smooth grating sidewalls. Thereby, special efforts were devoted to the development of an advanced new two-step reactive dry etching process, as well as an additional smoothening step of the holographically structured photoresist.

Silicon, as well as fused silica glass gratings were then bonded to silicon and fused silica surfaces, respectively. This step was performed by our partner WZW, who introduced special polishing and cleaning procedures to achieve surfaces with low roughness and cleanliness required for successful contacting.

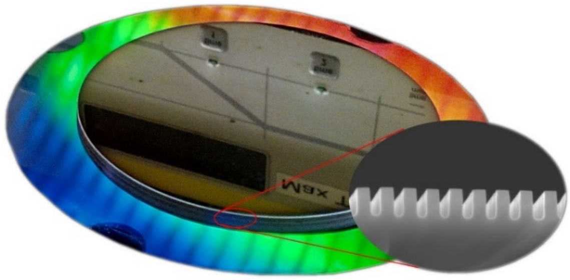

Figure 3: Bonded Si-grating to plane Si-substrate.

Lastly, the final immersed gratings are tested and characterized using metrology, modelling and interpretation of the optical measurements. First measurements carried out by our partner Micos on the fabricated gratings showed straylight (BTDF, bidirectional transmittance distribution function) below the measurement sensitivity.

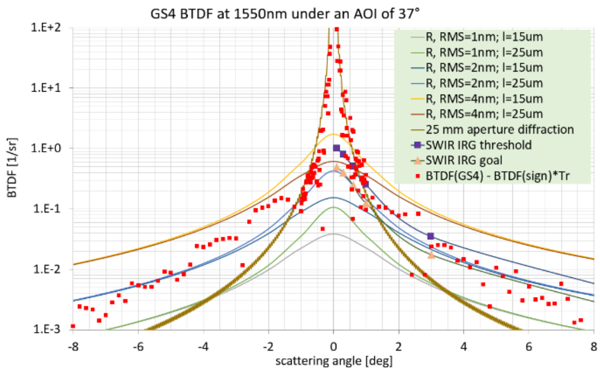

Figure 4: Grating BTDF below measurement sensitivity.

These technology developments will enable the realization of new generation SWIR & NIR immersed gratings with unprecedented performances.