Thermally Functionalised Optical Surfaces— 2025 Progress

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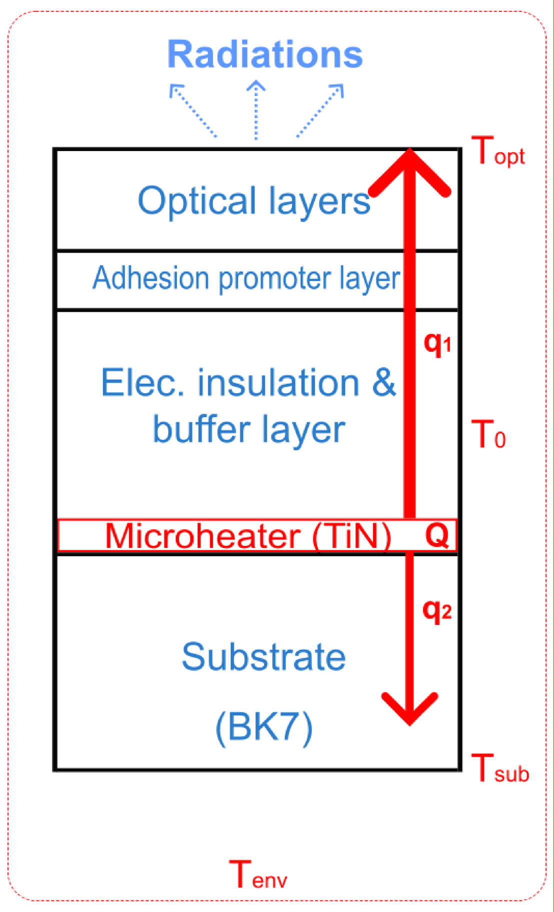
Abstract: In-flight recondensation of outgassing molecular species from a satellite platform or payloads could compromise the performance of onboard optical instruments. In our group, we investigate alternative ways to circumvent this issue through thermally functionalised optical surfaces. Micro-heating systems directly integrated within the surface of optical components offer the potential to increase power efficiency as well as heat transfer homogeneity in degassing molecular contaminations. The manufacturing processes of the heater have been initiated and precise models of such heating systems will be developed soon.

1. Technology Demonstrator

A demonstrator is required to provide a proof of concept. In 2025, our group designed a first demonstrator and initiated the manufacturing process.



1.1 Requirements definitions

The demonstrator should meet 3 primary objectives:

1) Achieve a high surface temperature.

→ For space optics heater application, 80°C is a representative operational condition which should be met.

2) Ensure a homogeneous heating of the optical surface.

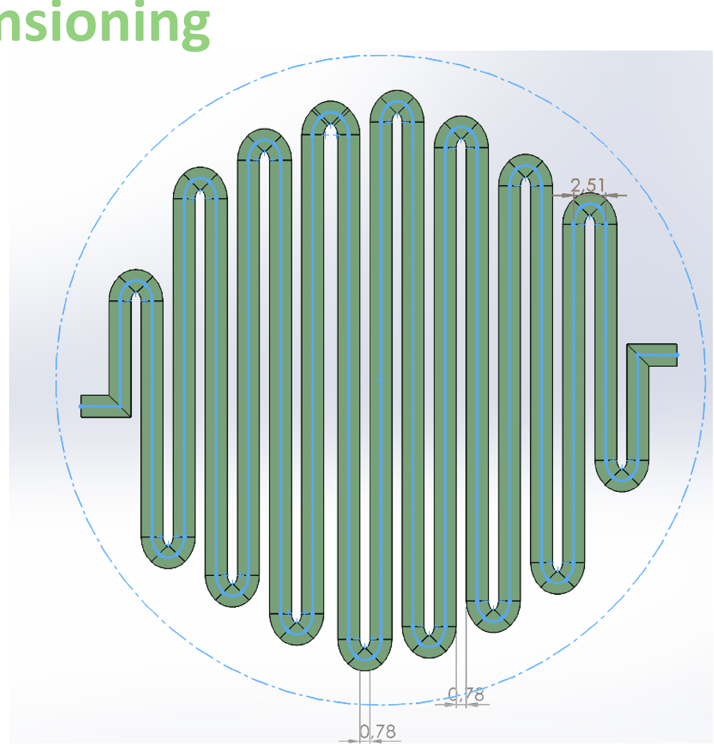
→Temperatures over the effective area should not fall below 80% of the min-max temperatures ratio.

3) The decontamination efficiency should be maximal.

1.2 Geometry and dimensioning

The micro-heater integration is the innovative component of this demonstrator.

Its dimensioning was established based on our 1D simulation from previous study, the project requirements, and Electrical Power System (EPS) limitations.



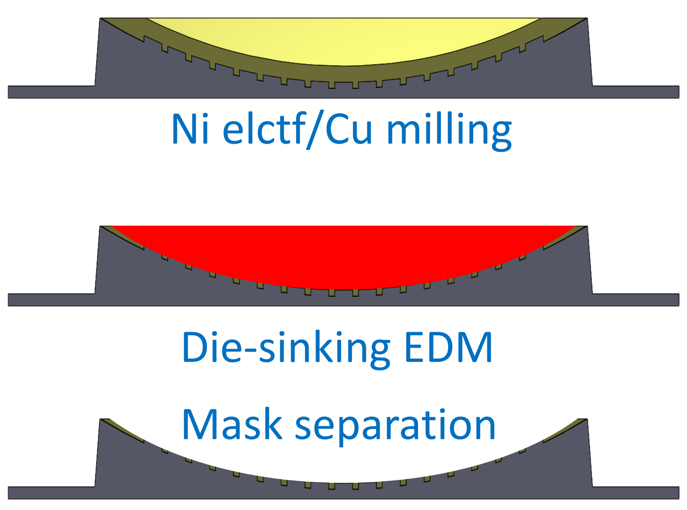
Meander geometry was selected to promote homogeneous heating at the surface.

Material	Track width (mm)	Track height (nm)	Track length (m)	Line spacing (mm)	Total area (cm^2)	Total coverage
TiN	1,74	200	0,58	0,78	20,27	50%

1.3 Contact mask and micro-heater manufacturing

In collaboration with Sirris, two contact masks are currently under development using "Die-Sinking Electrical Discharge Machining techniques".

These masks will be positioned on the substrate prior to the deposition of the TiN layer. The deposition will be performed using "Ion Beam Sputtering" (IBS) process, consistent with the method employed previously for thin-film preparation.



Contact mask manufacturing steps

Contact mask prototype

2. Experiments: Thin films characterisation

The experimental work focuses on characterising the electrical resistivity of micro-heater material (TiN) with various Ti-N stoichiometries, with the aim of achieving the heat density required for the system. The current study spans from sample preparation to characterisation.

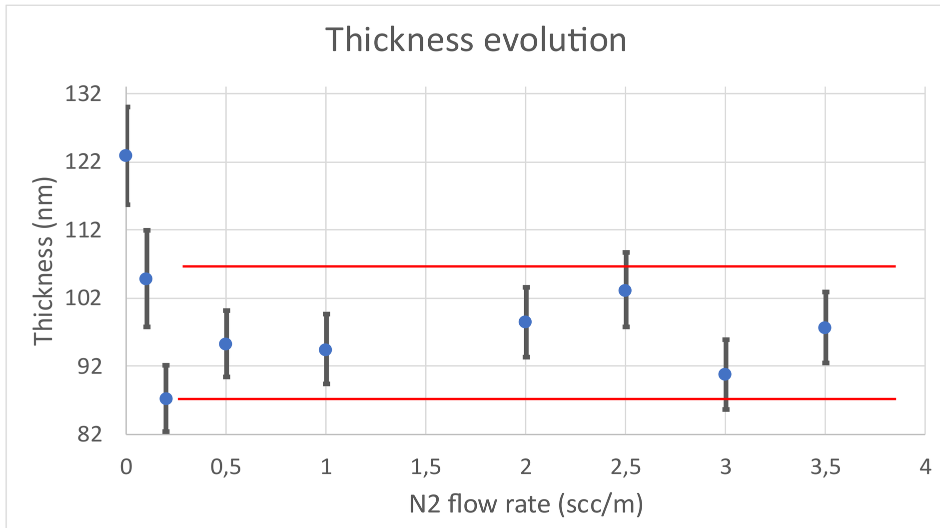
2.1 Film thickness and electrical resistivity measurements

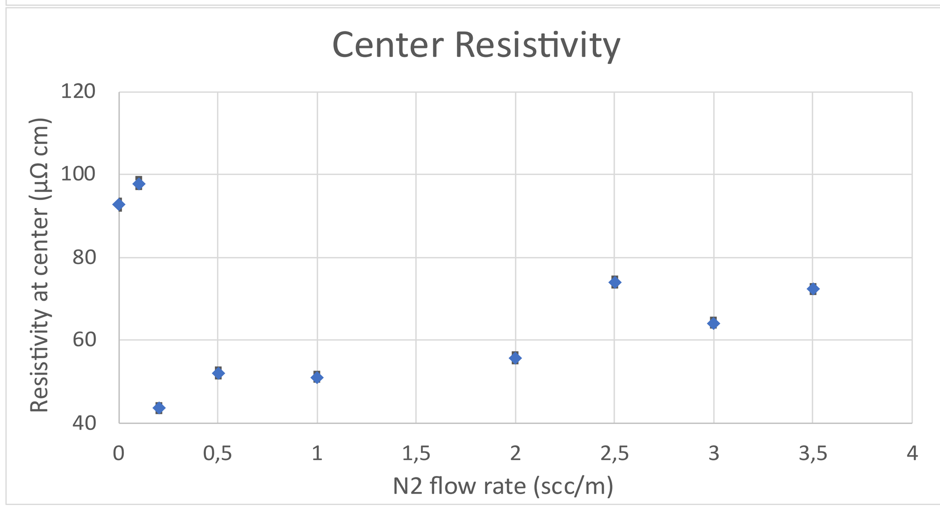
Electrical resistivity is a key parameter in ensuring optimal heat production from the micro-heater. The achievable resistivity depends on the deposition conditions and layer thickness.

During 2025 , 9 different Ti-N stoichiometries were tested to estimate the influence of Nitrogen content on the TiN material properties.

- Film thicknesses were measured using ellipsometry and interferences microscopy.
- Electrical resistivity was determined by "4 Points Probe" (4PP).

The thickness ranged from 87 to 125 nm while electrical resistivity ranged from 44 to 98 $\mu\Omega \cdot cm$.



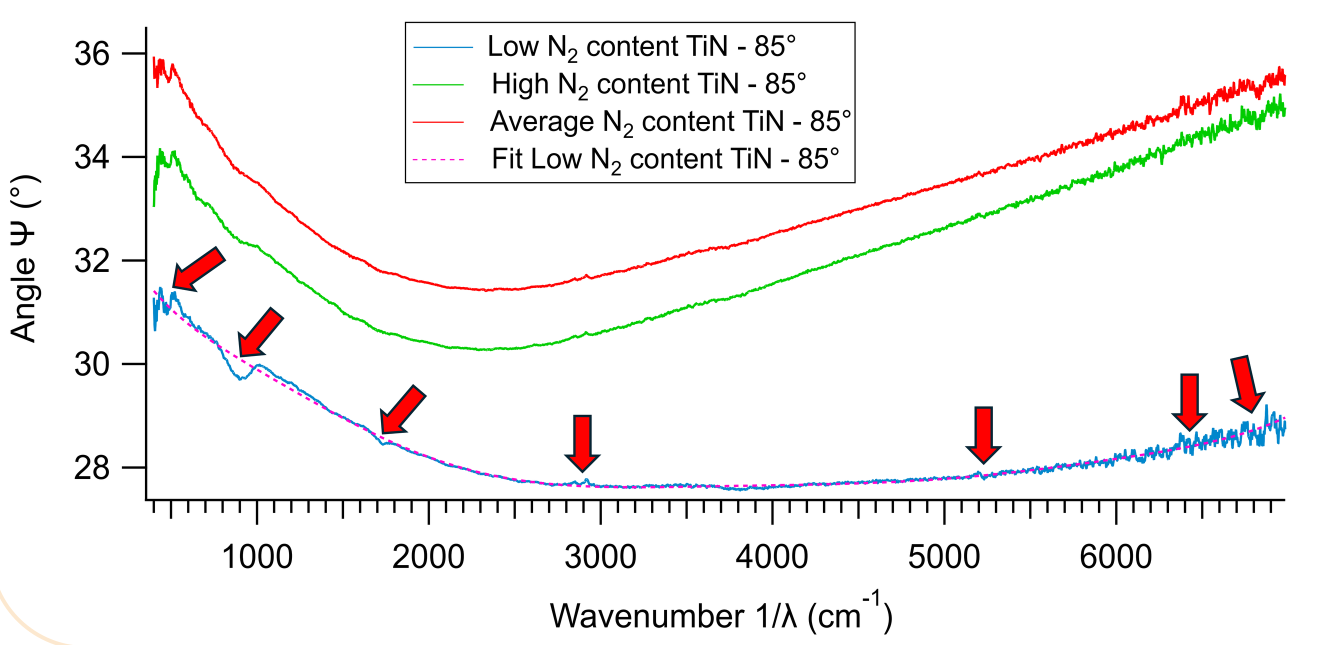


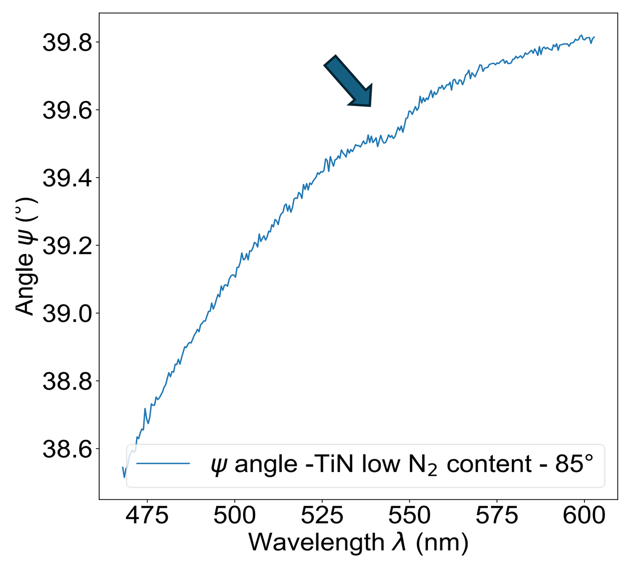
2.2 Contamination witnesses and characterisation strategy

To evaluate decontamination performance, contamination witnesses are required. Characterisation of contamination protocol will be tested using TiN witnesses due to its chemical stability, accessibility, and lower cost in comparison with alternative candidates such as gold.

Preliminary non-destructive tests were conducted on TiN samples using two ellipsometers (spectral ranges from 190nm to 25µm) to validate its suitability as contamination witness.

These measurements revealed unexpected structures at high wavenumbers (low wavelength) whose origin is not yet fully attributed. The current hypothesis is that these features may result from fundamental molecular resonances at lower wavenumber and/or overtones. Their identification is currently ongoing.





Up: Spectral line at 543nm (=18 416 cm-1) with 15nm bandwidth
Left: IR Spectra of 3 TiN samples differing by their stoechiometries

3. Conclusion

- This year, the focus was on the demonstrator design and conception. The system requirements have been defined, the micro-heater dimensioning and geometry were established, and contact mask prototypes have been initiated.
- Material characterisations were conducted both for the micro-heater and the contamination witnesses. The latter characterisation unveiled unexpected structures in ellipsometry measurements that are currently under investigation.

4. Perspectives

- Micro-heater preparation and encapsulation (electrical insulation) constitute the next steps to be undertaken in the following months.
- Contamination characterisations will be initiated shortly and will be analysed using the emissivity analysis methodology developed during a previous study.
- Spectral lines should be identified and attributed to a physical phenomenon and/or a chemical origin.

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