Thermally Functionalised Optical Surfaces— 2024 Progress

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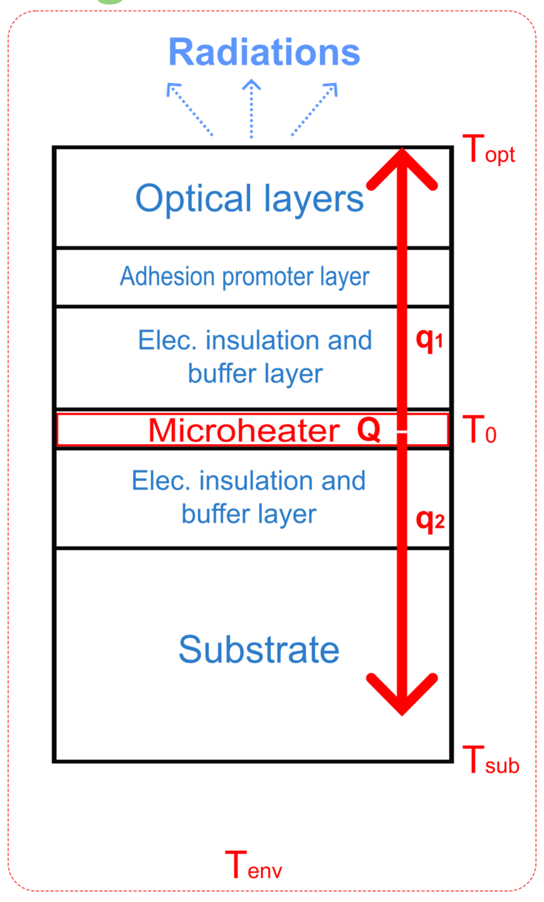
Abstract: In-flight recondensation of outgassing molecular species from a satellite platform or payloads could compromise the performance of onboard optical instruments. In our group, we investigate alternative ways to circumvent this issue through thermally functionalised optical surfaces. Micro-heating 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. Preliminary models of such heating systems are under development and the investigation of manufacturing processes has been initiated.

1. Modelling

1.1 Thermal Steady State Modelling

The primary objective of an initial one-dimensional steady-state model is to assist in selecting suitable materials for the micro-heater and determining the most appropriate manufacturing methods to ensure consistent layer thicknesses.

The model has successfully replicated results from the literature, allowing us to evaluate several material candidates for our surface-integrated system.

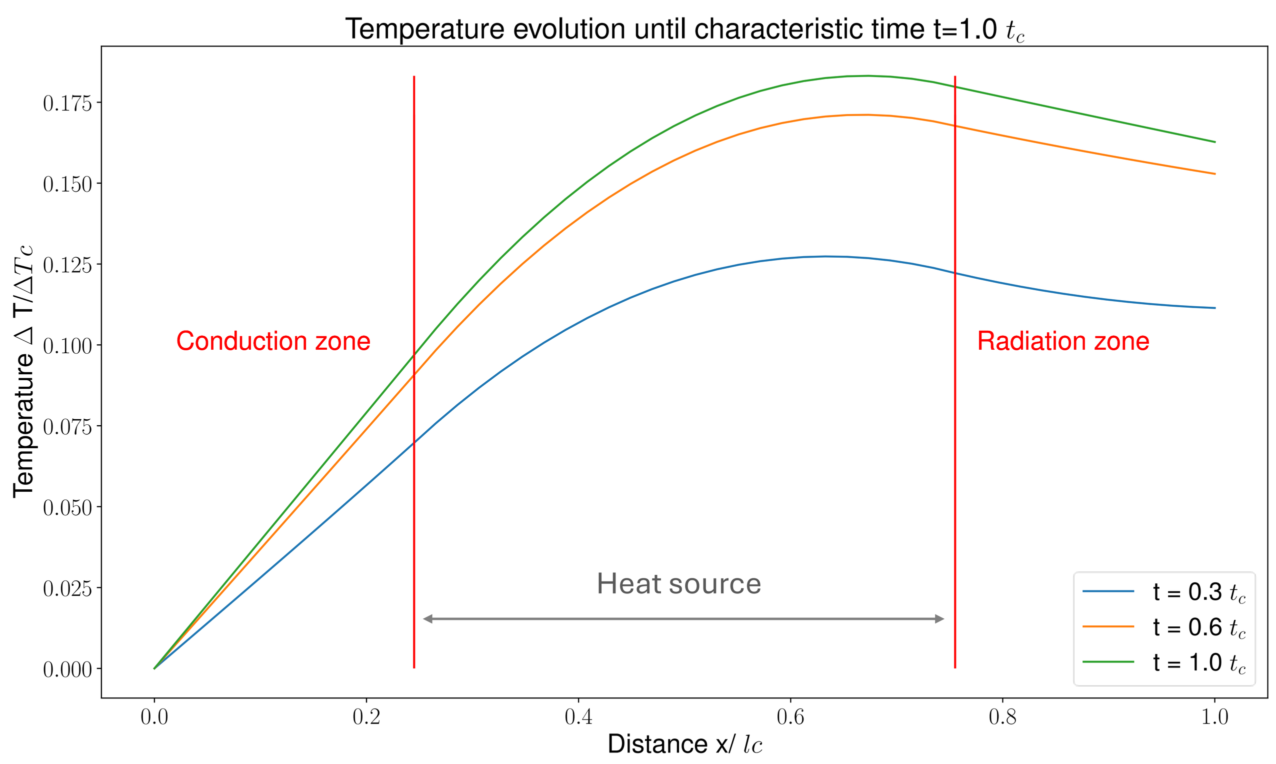


1.2 Non-equilibrium Modelling (1D)

In a second step, a non-equilibrium 1-D model was established for two main purposes:

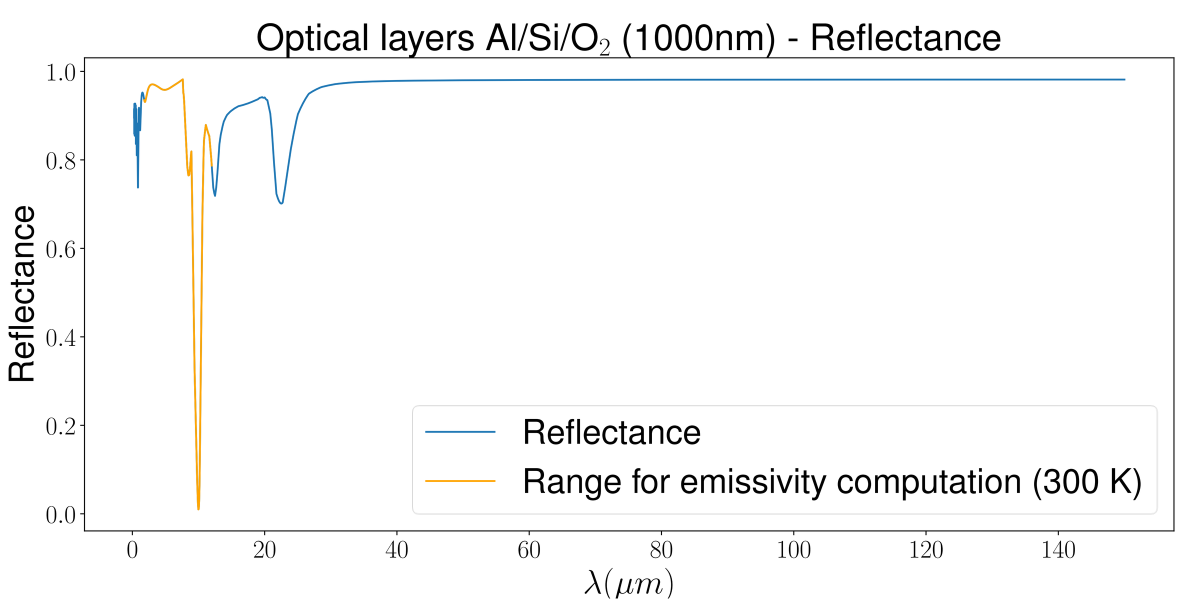
- To develop physical and numerical insights into this regime before employing more elaborate models.
- To estimate the heating time required to reach a steady state.

For operations in space, conduction and radiation are considered:



1.3 (De)contamination : Emissivity analysis

The emissivity of a surface is expected to change in the presence of molecular contaminants. Since this property depends on the surface's reflectance, a spectroscopic investigation can help detect contamination. Given that the system dissipates heat through radiation via optical layers, these detections could be performed at operating temperatures.



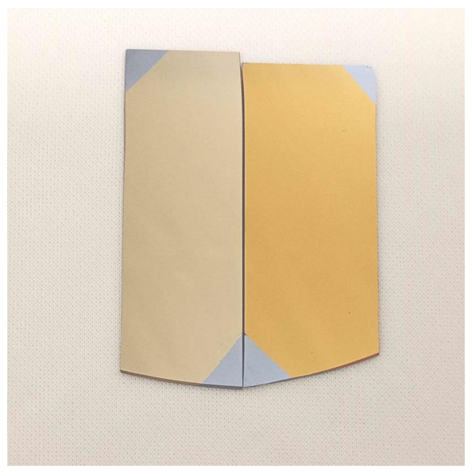
A numerical method is currently being investigated to identify contamination signatures in reflectance measurements, providing an indication of when the optical layers would require decontamination.

2. Experiments: Methods and results

The experimental work focuses so far on characterising the electrical resistivity of micro-heater material candidates, with the aim of achieving the required heat density for the system. The current study spans from sample preparation to characterisation.

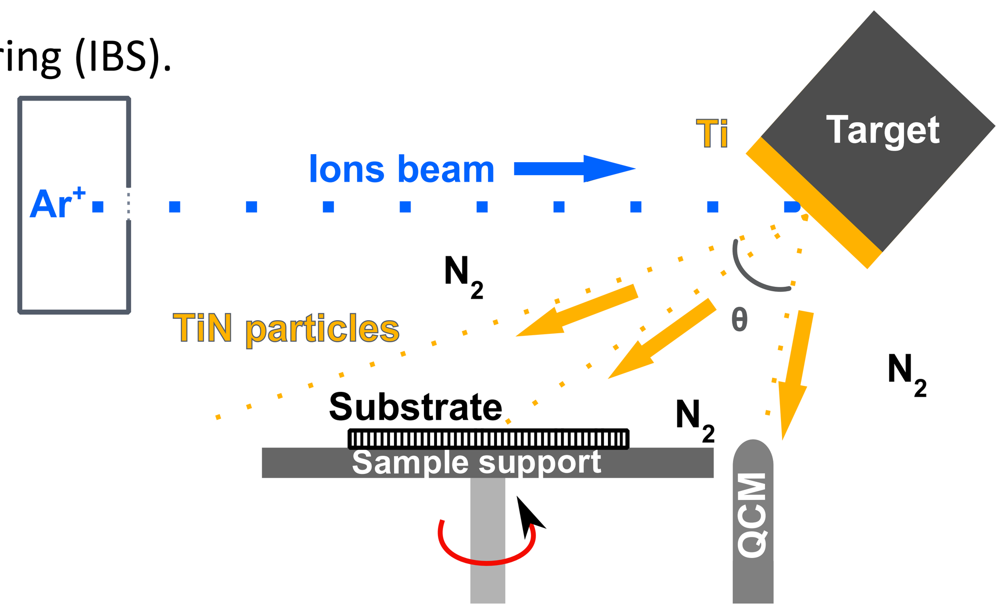
2.1 Samples preparation: Thin film deposition

TiN thin film were deposited by Ion Beam Sputtering (IBS).



TiN thin films

Thickness: 22nm (left) and 46nm (right)



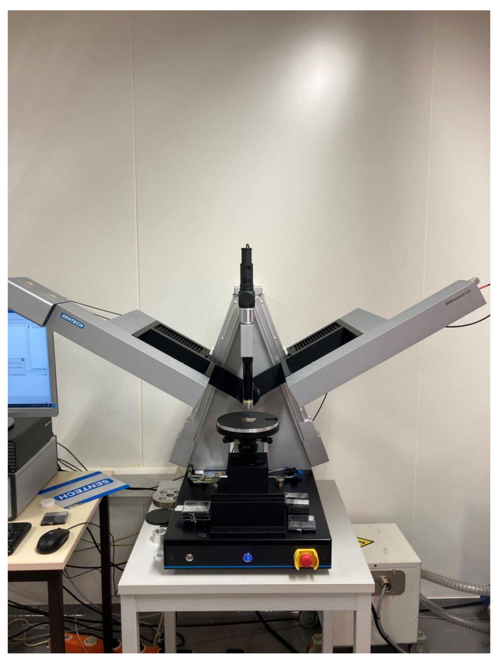
IBS Principle

Several (21) thin films of various thicknesses have been prepared mainly with the following parameters:

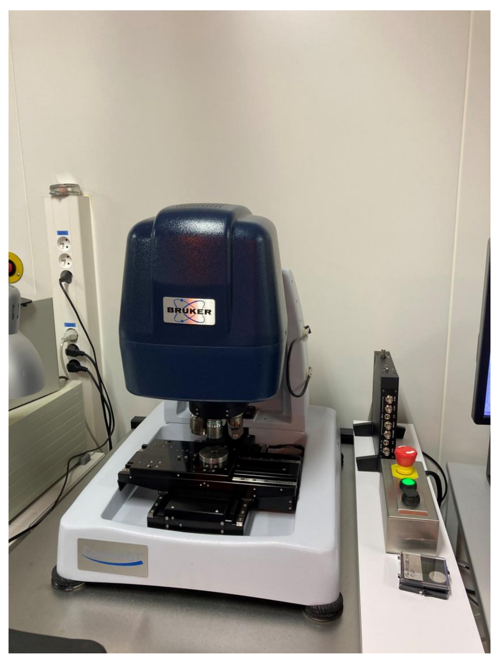
N_2 flux	Ar flux	Thicknesses	Deposition rate	Ion beam energy
2scc/m	4scc/m	[19, 170] nm	[0.5,0.8] nm/min	940 eV

2.2 Thickness and electrical resistivity measurements

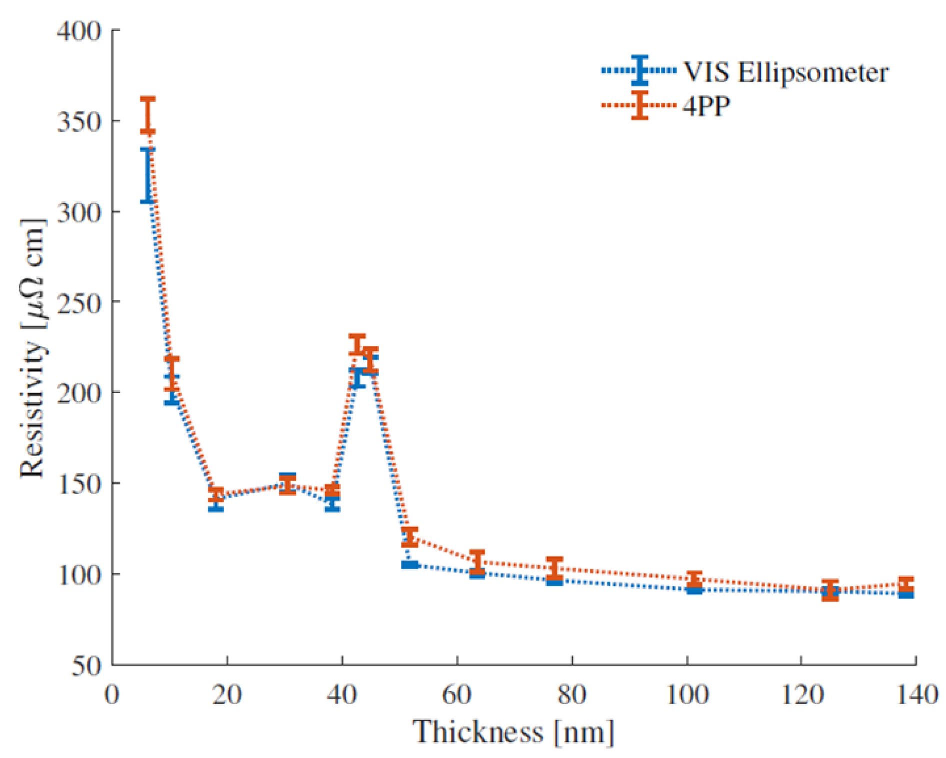
Electrical resistivity is a key parameter in ensuring optimal heat production from the micro-heater. The achievable resistivity depends on the deposition conditions and layer thickness.



UV-VIS-NIR Ellipsometer



Interference microscope



- Thicknesses were measured by ellipsometry and/or interference microscopy.
- Electrical resistivity were independently determined by ellipsometry and "4 Points Probe" (4PP) and both methods yielded consistent results.

2.3 Deposition process and resistivity optimisation

Thin films deposition test under various conditions are currently underway to find an optimal resistivity for the material.

3. Conclusion

- Steady-state simulations have enabled us to estimate the scale of each layer component, and the current results do not challenge the feasibility of the project.
- Non-equilibrium modelling is ongoing, providing insights into the numerical and physical subtleties of these simulations before proceeding with more complex approaches, such as finite element modelling.
- A method for determining emissivity is currently being studied to detect molecular contamination signatures. However, the impact of these signatures on emissivity still needs to be assessed to validate the method.
- TiN is one of the candidate materials for the micro-heater. Optical and electrical analyses have been conducted, but other Ti-N stoichiometries still need to be tested.

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