Studies on laser heating and laser ablation of ITER-like surfaces

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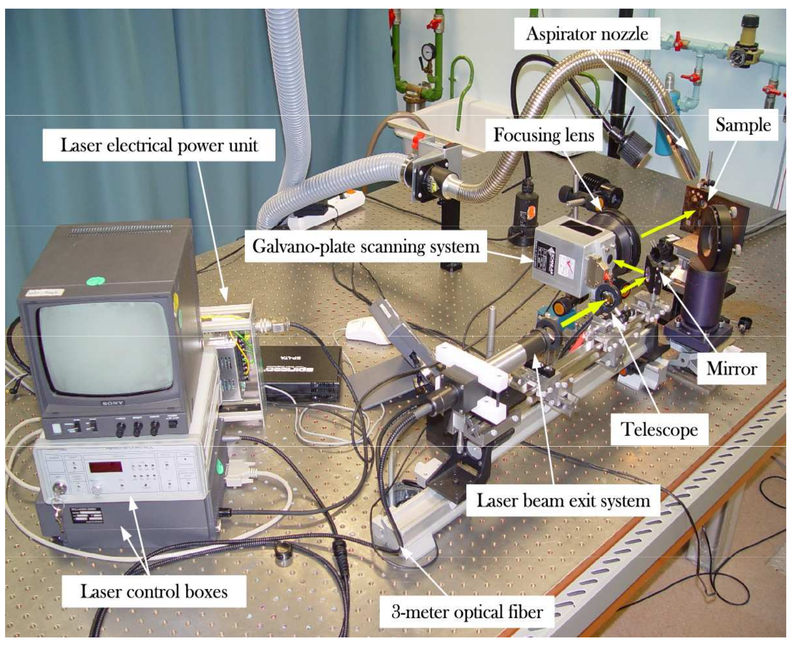
Introduction

During the operation of modern fusion devices, tritium, which is the essential element of fusion reaction, becomes trapped on the surface of Plasma Facing Components (PFC). For safety reason the overall quantity of tritium is limited for each component. Periodical cleaning of all PFC is necessary to avoid exceeding the permitted values of the tritium quantity [1]. Laser heating and laser ablation of deposited layers with high tritium content is seen as a promising technique for PFC detritiation [2].

In this work, laser ablation and laser heating of ITER-like samples that resemble the PFC surfaces of future ITER installation are investigated. The samples consist of stainless steel or tungsten substrate with deposited layer composed of tungsten, aluminium or diamond-like carbon (DLC) with hydrogen and deuterium content. The laser heating calculations were performed with the model developed in our laboratory [3].

Experimental setup

Laser ablation setup

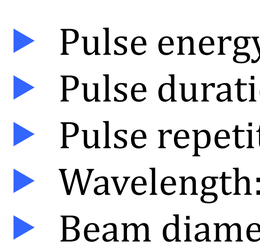


- Pulse energy : 0.2-1.0 mJ
- Pulse duration: 120 ns
- Pulse repetition rate: 20 kHz
- Wavelength: λ=1.064 µm
- Beam diameter: 100 µm on *1/e* level

Laser heating measurement setup

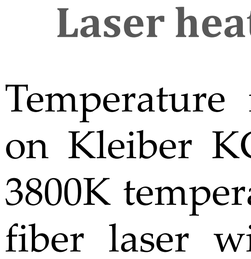
Temperature measurement setup is based on Kleiber KGA 740-LO pyrometer (500K-3800K temperature range) and IPG YLR-100 fiber laser with adjustable repetition rate and pulse duration (1 - 100 ms) .

Samples



Layer: **Al + C**
Layer thickness: 1 µm

Substrate: **C (carbon)**

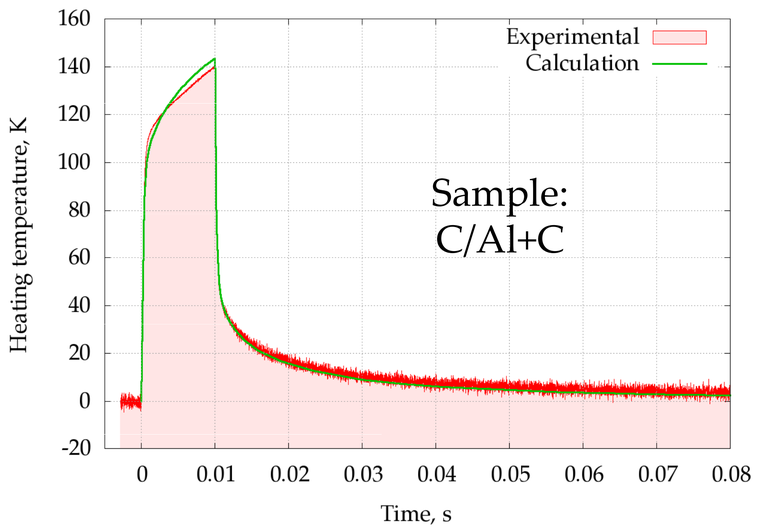


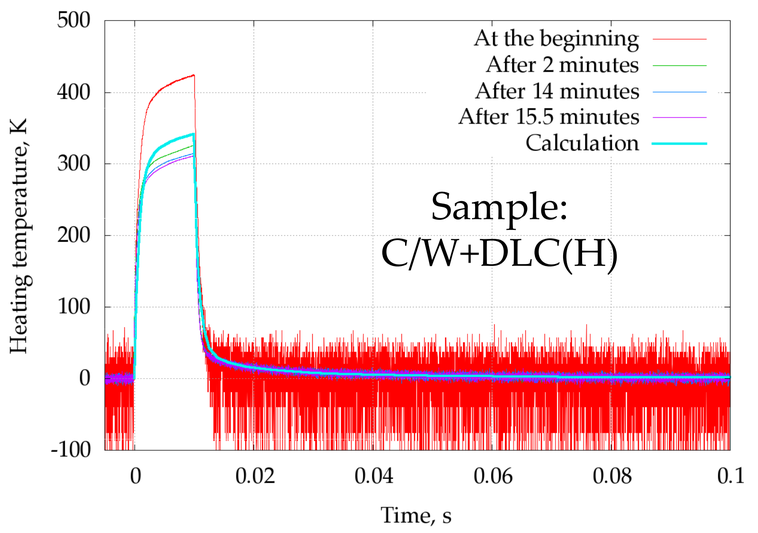
Layer: **W (tungsten) + DLC (diamond-like carbon)** with **hydrogen** content
Layer thickness: 1.5-2 µm
Substrate: **C (carbon)**

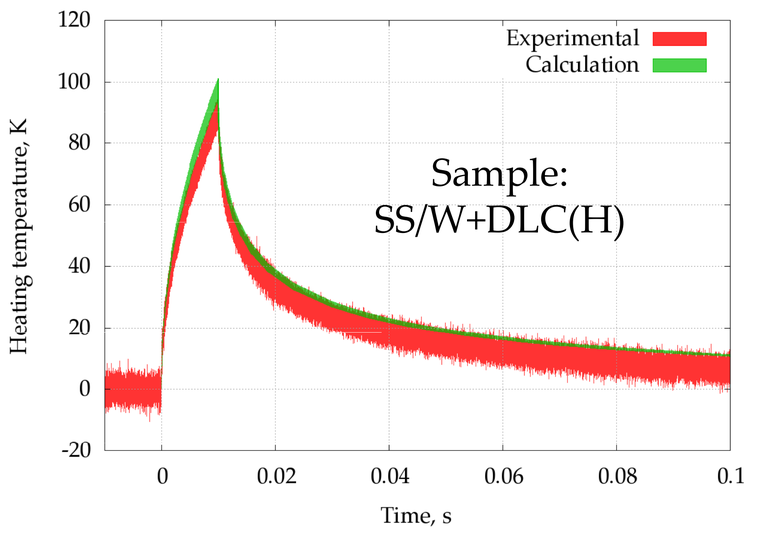
Layer: **W (tungsten) + DLC (diamond-like carbon)** with **hydrogen** content
Layer thickness: 1.5-2 µm
Substrate: **SS (stainless steel)**

Laser heating

Layer and substrate thermophysical parameters (thermal conductivity, specific heat capacity) applied in the calculations were determined from active lock-in pyrometer measurements [4]. The thermal conductivity of the substrate was obtained by fitting calculation results to the experimental temperatures.





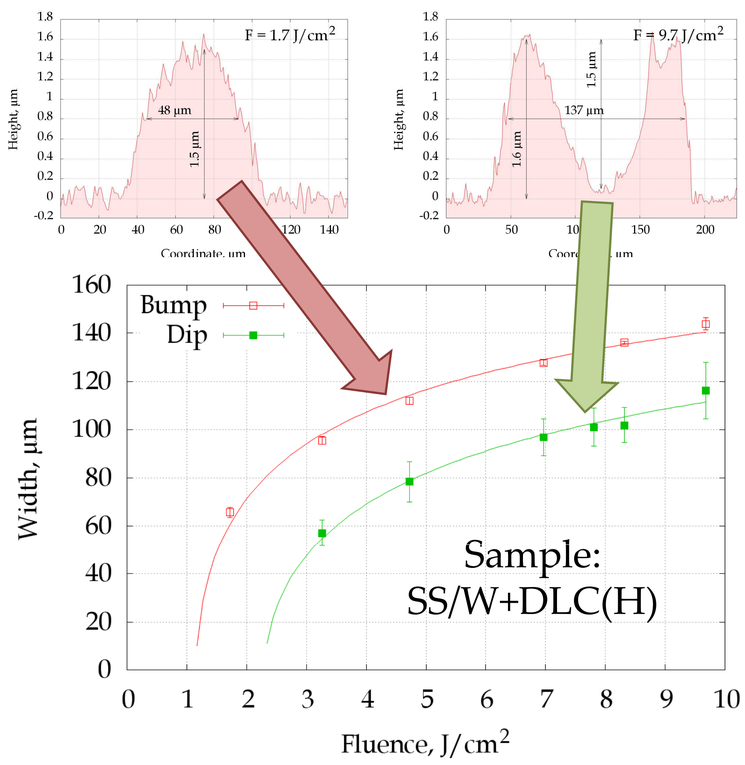


Heating temperature (measured and calculated) for different samples.

Knowing the layer parameters, we can calculate laser heating of the sample.

Laser ablation and cleaning

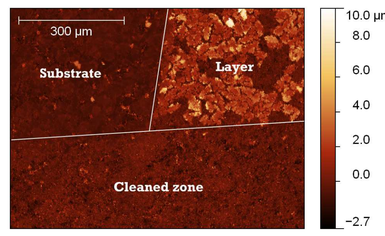
Laser ablation thresholds



- F_{th} = 1.16 ± 0.10 J/cm² for bump formation
- F_{th} = 2.3 ± 0.4 J/cm² for dip formation

Laser cleaning performances

- SS/W+DLC(H):
  0.003 m²/hour per W
- C/Al+C:
  0.05 m²/hour per W



Conclusions

✓ Laser heating of ITER-like samples was measured and compared with the results of calculation.
✓ A good agreement was obtained between the measured and calculated temperatures.
✓ The damage threshold and the ablation threshold were found for diamond-like carbon layer.
✓ The cleaning performances were found for two types of layers.
✓ Further investigations will take place with new ITER-like samples (different layers on tungsten substrate).

Acknowledgements

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