Nanoparticle release mechanisms during laser ablation of ceramic tiles

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Introduction

Laser ablation can be described as the interaction of intense optical fields with matter, in which atoms are selectively driven off by thermal or non-thermal mechanisms [*C. Phipps, 2007*]. Laser ablation has a high potential to unintentionally generate nanoparticles, due to the high energy print of the specific process [*A.S. Fonseca et al. 2015*]. The objective of this work is to understand the factors that are influencing nanoparticle emissions during laser ablation, which can be material related (tile characteristics e.g. composition, roughness, porosity) and process related (parameters such as laser wavelength, power, frequency), with a focus on occupational exposure mitigation.

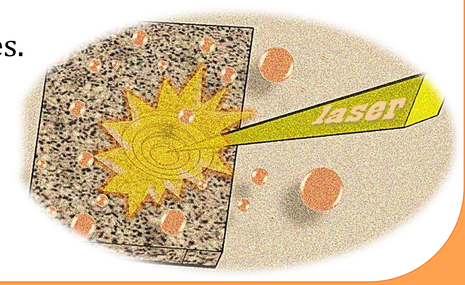
Experimental Methodology

The laser ablation experiments and the aerosol nanoparticle measurements took place in the Materials Science Institute of Aragón (ICMA) at University of Zaragoza, for an overall duration of 1 week. Different ceramic tiles were used as the target materials: Unglazed Grey Porcelain (UGP), Unglazed Porous Alumina (UPA), Unglazed Porous White Earthware (UPWE) and Glazed Porous Earthware (GPE). Two separate Settings, each one hosting a different laser setup, were monitored:

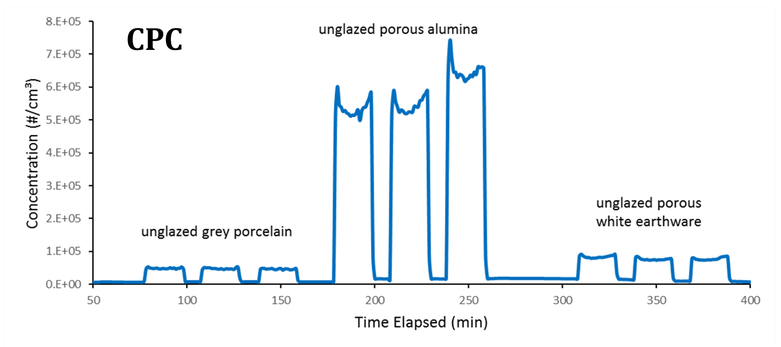
1. A laboratory setting equipped with a near-IR laser (1064 nm) with which the tiles UGP, UPA, UPWE were processed.
2. A pilot-plant setting (CeramGlass), in which a mid-IR (10.6 μm) laser was utilized to process the UPWE, UGP and the GPE tiles.

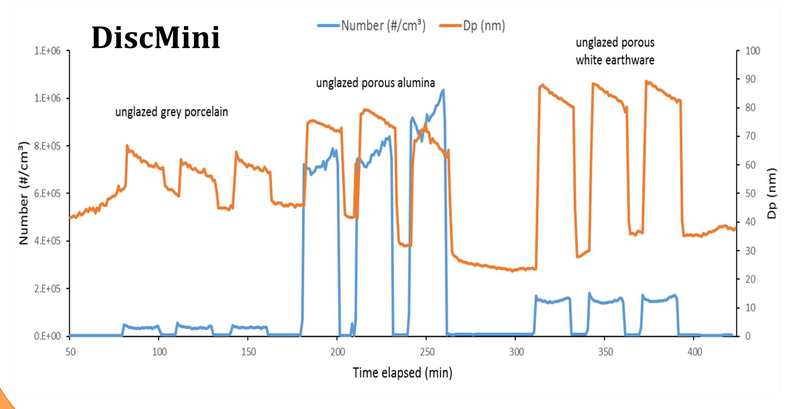
One experimental cycle comprising 3 repetitions for each combination of process parameters and target tile, following the pattern bellow:

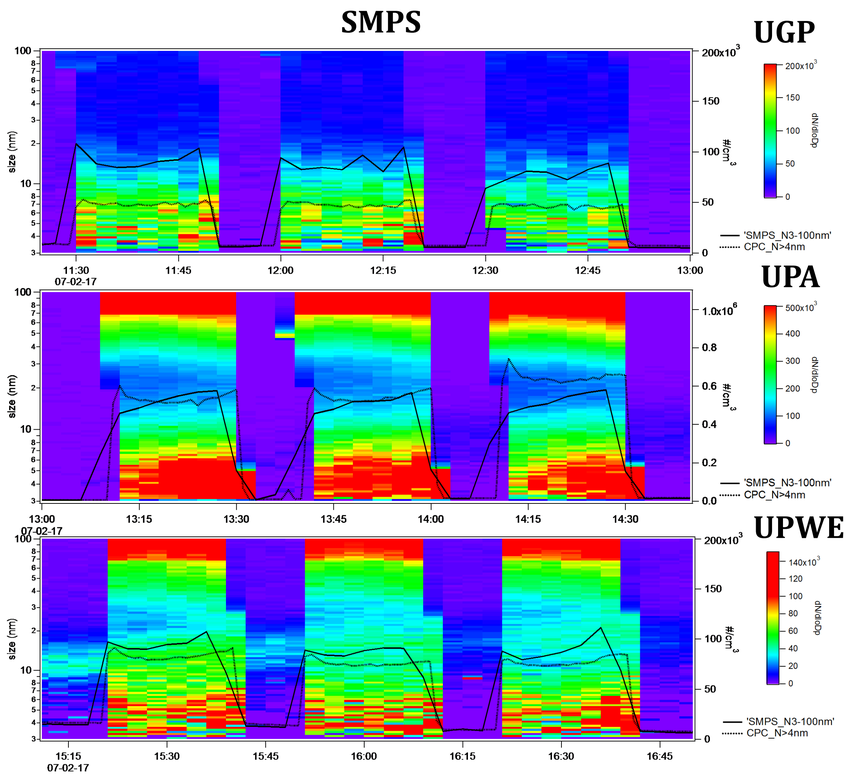
Repetition#1 : 20 min → Break/settle down time : 10 min → Repetition#2 : 20 min → Break/settle down time : 10 min → Repetition#3 : 20 min → Settle down time: 20 min

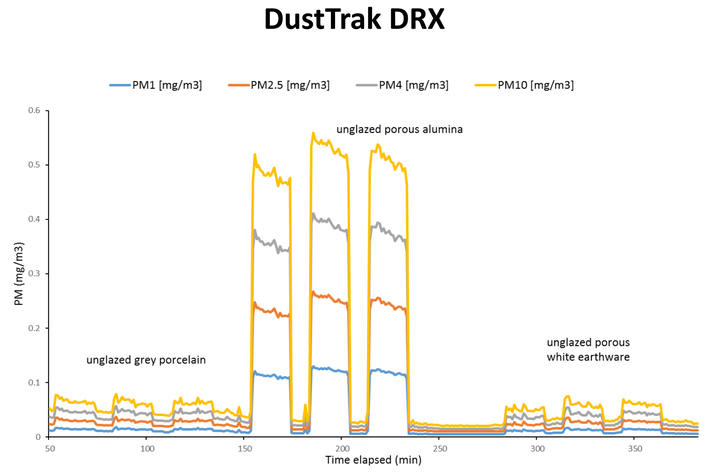


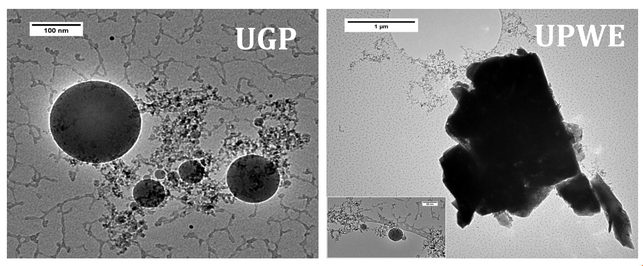
Near-IR Laser (Low energy settings)



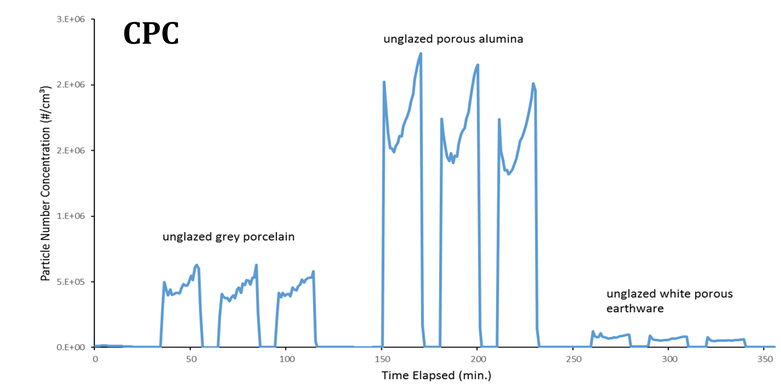


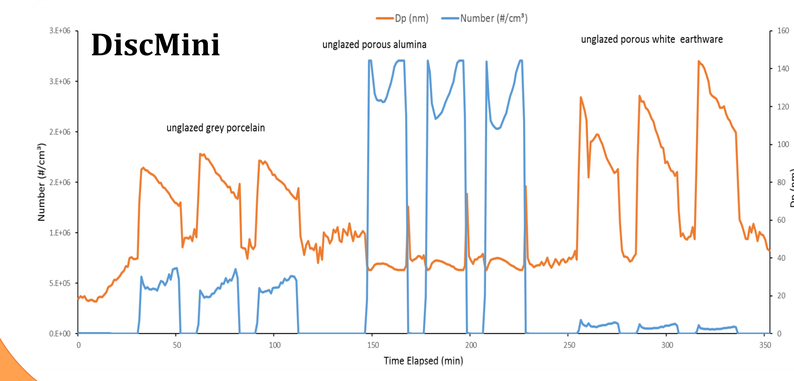


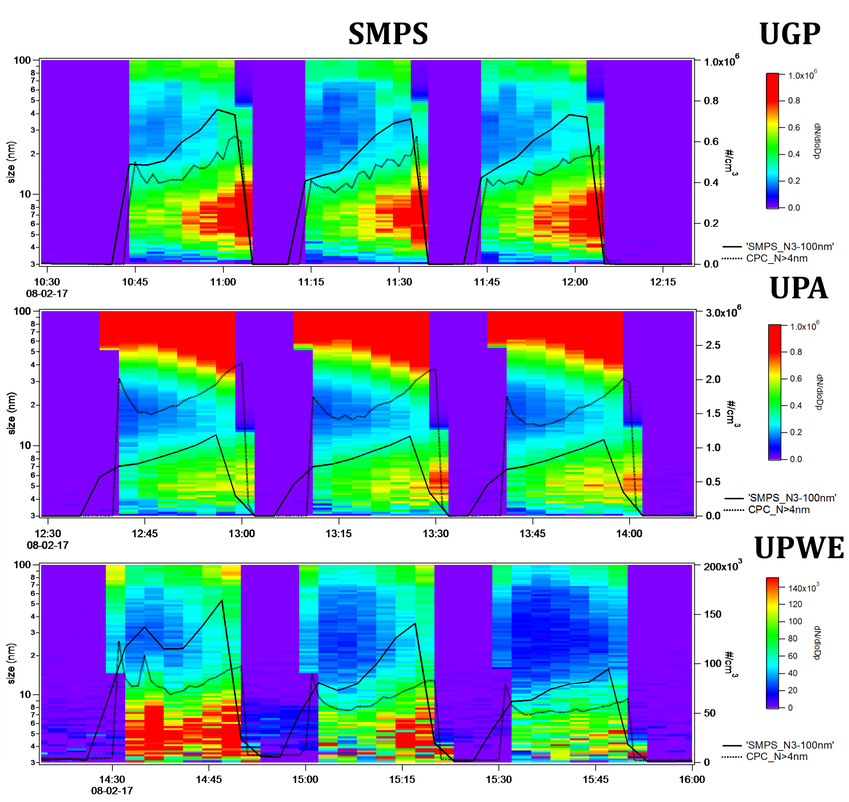


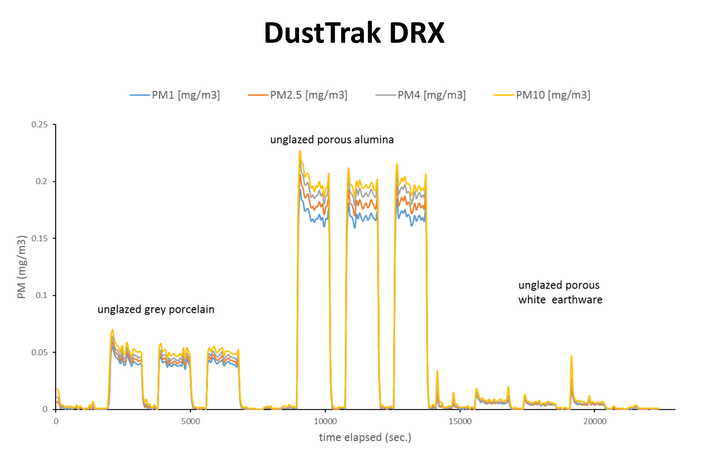


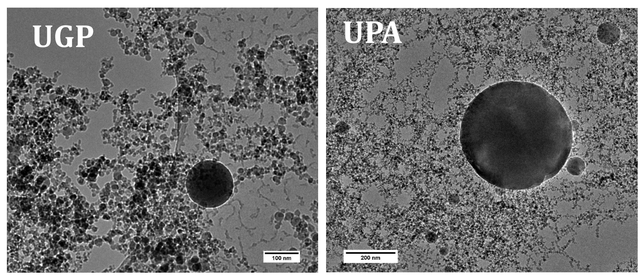
Near-IR Laser (High energy settings)











Conclusions

- **Low energy settings:** In the case of the UGP the main emission mechanism is nucleation, for the UPWE mostly primary particles are released, while for the UPA both mechanism are contributing.
- **High energy settings:** Increased emissions in terms of number concentration in comparison with low energy settings. In the case of the UPA mostly primary particles were emitted, while for the UPWE the dominant mechanism has shifted to nucleation.
- The process parameters have a strong effect on the NP release (number concentration). The bias of the emission mechanisms is effected by the characteristics of the respective ceramic tile as well as the process parameters .

Acknowledgements

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