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Experimental and numerical study of the thermal radiative properties of Al/air flames

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Aluminum microparticles have been proposed as green energy vectors, given their high combustion enthalpy and the availability of clean recycling routes for the oxide products. Unfortunately, most studies in the field have dealt with either nanometric or very large Al particles, each with their own disadvantages. Combustion of Al spheres in the 1-10 μm range has been suggested as a compromise solution, but the properties of these systems are poorly known. This contribution presents an experimental setup and an optical model to study the radiative properties of these flames [1].

The studied flame is formed by independent Al particles burning in vapor phase, from which liquid Al_2O_3 nanoparticles are formed by condensation. In contrast to the gas phase, the emission by the condensed products does not have an exact solution. A direct electromagnetic simulation of this system is computationally expensive, so a homogenization procedure has been used, where the particulate nature of the alumina cloud is modeled using the Maxwell-Garnett approximation. The emissivity of each burning particle can be solved exactly using the core-shell Lorenz-Mie solution, allowing for different temperatures in each layer. We found that the complex refractive index of liquid alumina had to be modified with a term corresponding to pre-gap optical absorption (the Urbach tail) to correctly reproduce the results in the visible range. This simplified model constitutes a starting point for more in-depth studies of heat transfer and pyrometric temperature measurements in Al/air flames.

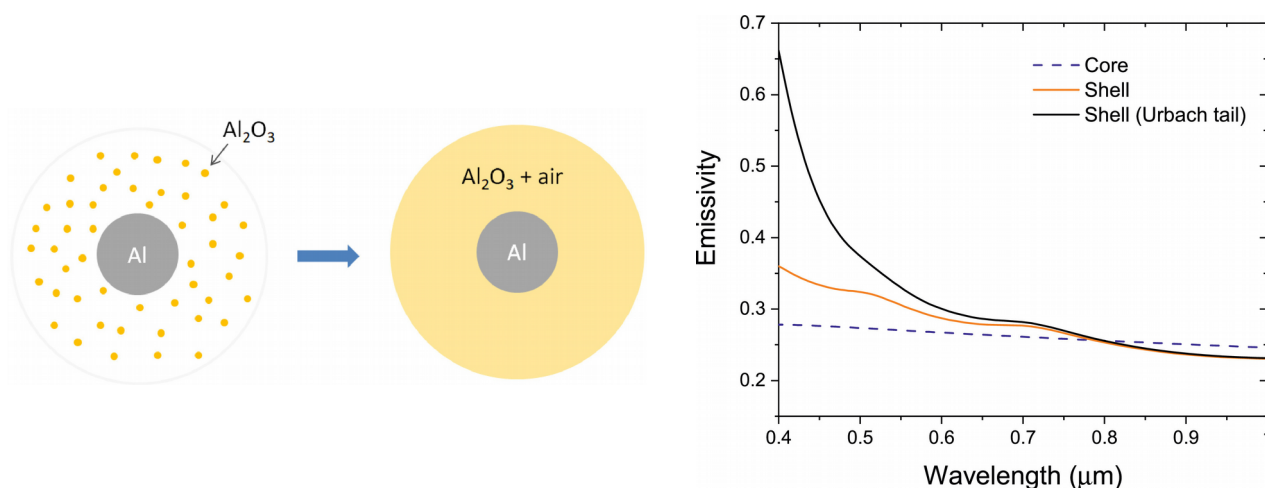


Fig. 1. Left: Geometry of the burning process and homogenization approach. Right: Calculated emissivities for the Al core at 2790 K and $\text{Al}_2\text{O}_3/\text{air}$ shell at 3200 K. The effect of accounting for the Urbach tail in the calculation is shown.

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Significant references

1. I. González de Arrieta, C. Blanchard, P. Laboureux, C. Chauveau, C. Genevois, O. Rozenbaum, and F. Halter, *Int. J. Heat Mass Transfer*, vol. 203 (2023), 123815.