6-10 JULY 2026
NANOSMAT
RHODES ▪ GREECE

17th International Conference of Surfaces, Coatings
and Nanostructured Material | **NANOSMAT2026**
RHODES-GREECE | 6-10 JULY 2026
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ABSTRACT:

Metallic Periodic Open Cellular Structures as Innovative Selective Catalytic Reduction Systems for Sustainable Heavy-Duty Gas Engines: A Case Study

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The future of mobility lies in the development of innovative solutions that ensure its environmental sustainability. While electrification represents a viable pathway for light-duty vehicles, heavy-duty applications require complementary technological approaches capable of ensuring a neutral CO_2 balance and ultra-low pollutant emissions. In this scenario, the present talk focuses on the development and validation of innovative after-treatment systems for biomethane fuelled heavy-duty power units, targeting zero equivalent emissions. A research activity combining fundamental studies, advanced modelling and experimental validation at multiple scales will be illustrated. A central pillar of the study is the adoption of additively manufactured metallic Periodic Open Cellular Structures (POCS) as alternative catalytic substrates to conventional honeycomb monoliths for NOx abatement in SCR systems. At the fundamental level, a model Cu-CHA SCR catalyst was investigated at laboratory scale in both monolith and POCS configurations. A heterogeneous 1D+1D reactor model, including intrinsic kinetics and geometry-dependent mass transfer correlations, was developed and successfully validated against experimental data. At engine scale, a heavy-duty spark-ignition unit was characterized and integrated with both conventional honeycomb monolith and POCS-based SCR prototypes. The analysis was further extended to engine and vehicle scale through a validated 1D simulation framework (Gasdyn), coupled with CFD-derived correlations and vehicle simulations (VECTO) [1]. The combined experimental and modelling activities validated the technical feasibility of metallic POCS as high-performance SCR systems for heavy-duty applications, achieving NOx conversion comparable to conventional solutions while maintaining low pressure drop [2]. The results contribute to the long-term objective of zero-impact mobility and provide transferable methodologies for the design and optimization of catalytic systems, with potential applications to low- or zero-carbon fuels (e.g., hydrogen) and to other fields such as industrial catalysis.

[1] G. Montenegro, G., Marinoni, A., Della Torre, et al., SAE Technical Paper 2024-37-0009, (2024).
[2] F.S. Franchi, N. Usberti, I. Nova, A. Della Torre, G. Montenegro, C. Guido et al., EUROPACAT 2025.