UNIVERSITY OF BIRMINGHAM

Emissions and 3D printing - Challenges and Opportunities

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Clean Energy Engineering (CEE) Research Group

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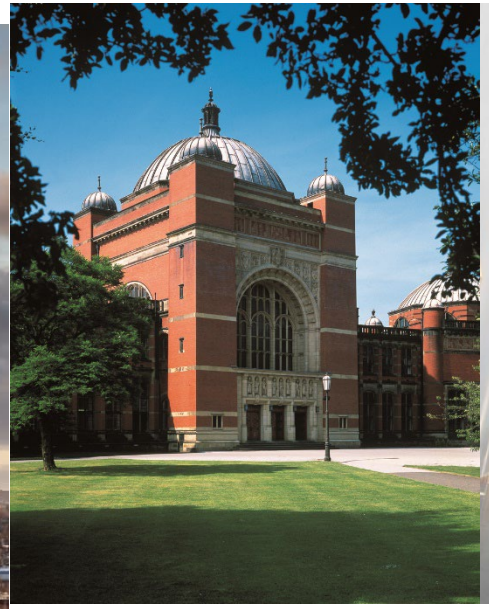
University of Birmingham, UK

Outline

1. The University of Birmingham & CEE Research Group
2. Emissions from Additive Manufacturing
3. Additive Manufacturing for exhaust aftertreatment
4. Remarks

1. The University of Birmingham & CEE RG



5 academic colleges, comprising 26 schools

~40,000 students (including >8,500 international students)

29% Postgraduate and 71% Undergraduate

- **Engineering & Physical Sciences**
- Life & Environmental Sciences
- Social Sciences
- Arts & Law
- Medical & Dental Sciences

School of Engineering
93 Academic Staff, 75 Research Fellows, >2,000 Students.

9-10 Research Groups (RG)
Clean Energy Engineering (CEE)

1. The University of Birmingham & CEE RG

Some of the research areas include:

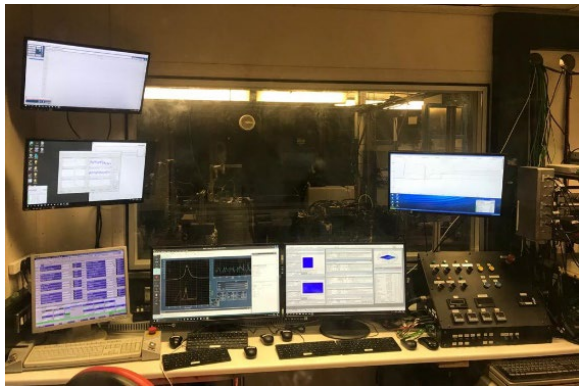
- Zero carbon energy carriers
- Fuels, Lubricants, Combustion & Emissions
- Catalytic Aftertreatment and filtration
- Fuel reforming (H_2) and heat recovery
- AI/ML in fuels synthesis
- Advanced Propulsion Systems
- Environmental Pollutants and Indoor Air Quality
- Waste to Bio-product Technologies
- Additive Manufacturing (3D Printing)
- Textile and Plastics Processing and Recycling
- Tribology (Application in Transportation, Polymer, Textile and Manufacturing Industries)

- 10 Academics
- 6 Research Fellows
- ~30 Doctoral Researchers
- ~16 MSc Projects per year
- ~60 MEng/BEng Projects per year

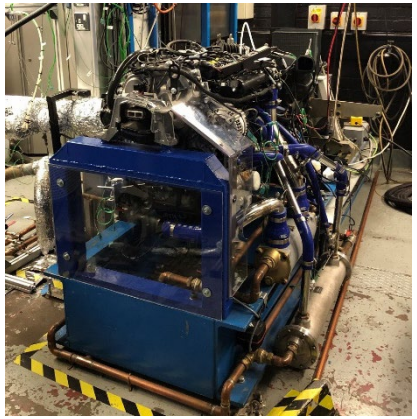
1. The University of Birmingham & CEE RG

1-Cylinder Research Engine

4-Cylinder Diesel Engine



Engine Control Room



3-Cylinder Gasoline Engine

Fourier Transform Infrared (FTIR) Spectrometer

H_2 Electron Ionization Mass Spectrometer

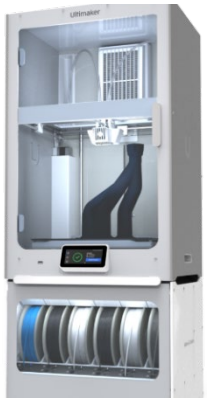
Diffuse Reflectance Infrared Fourier Transform (DRIFT) Spectrometer

Thermo-gravimetric Analyser (TGA) Gas Chromatograph (GC) Mass Spectrometer (MS)

Scanning Mobility Particle Sizer (SMPS)

1. The University of Birmingham & CEE RG

Shredder, Dryer and Filament Maker



3D Printers

Electrospinning

TGA Differential Scanning Calorimeter (DSC)

FT-IR Alpha II

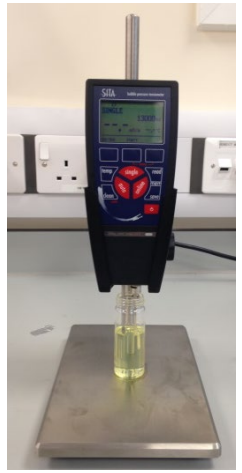
TE 77 High-Frequency Friction Machine

HFRR – Friction and Wear test system

UMT TriboLab

Force-Board – Tactile friction measurements

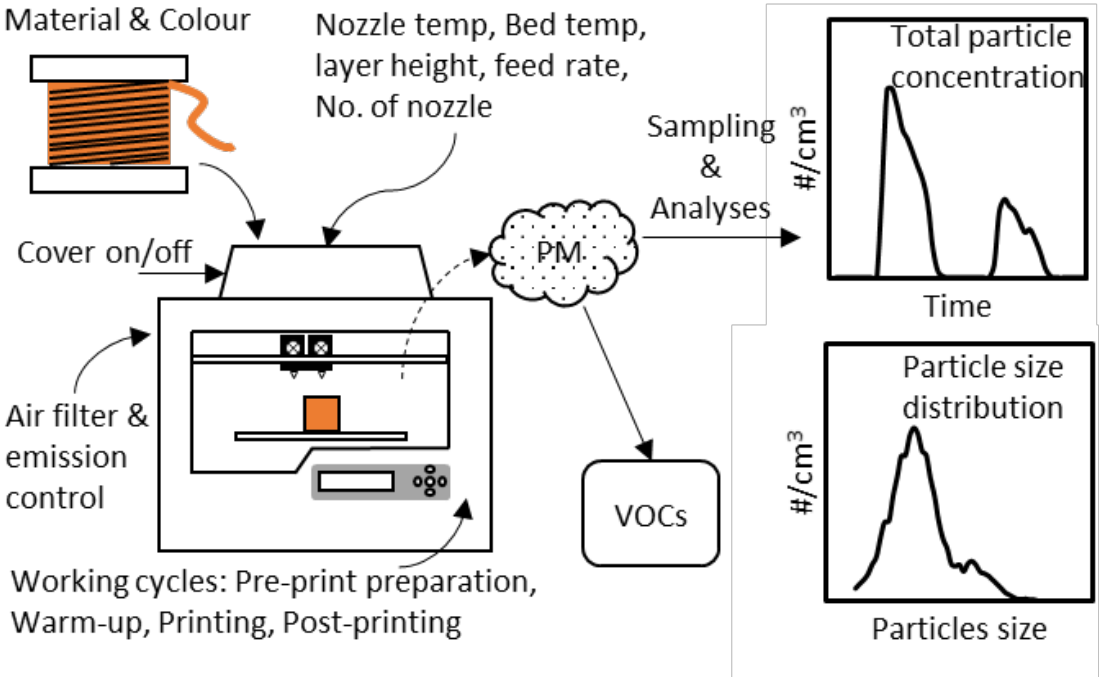
Ultra Shear Viscometer

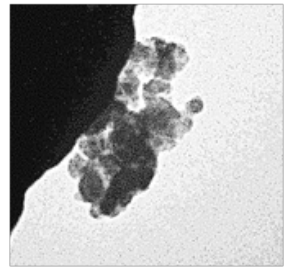


Surface Tension Equipment

2. Emissions from Additive manufacturing

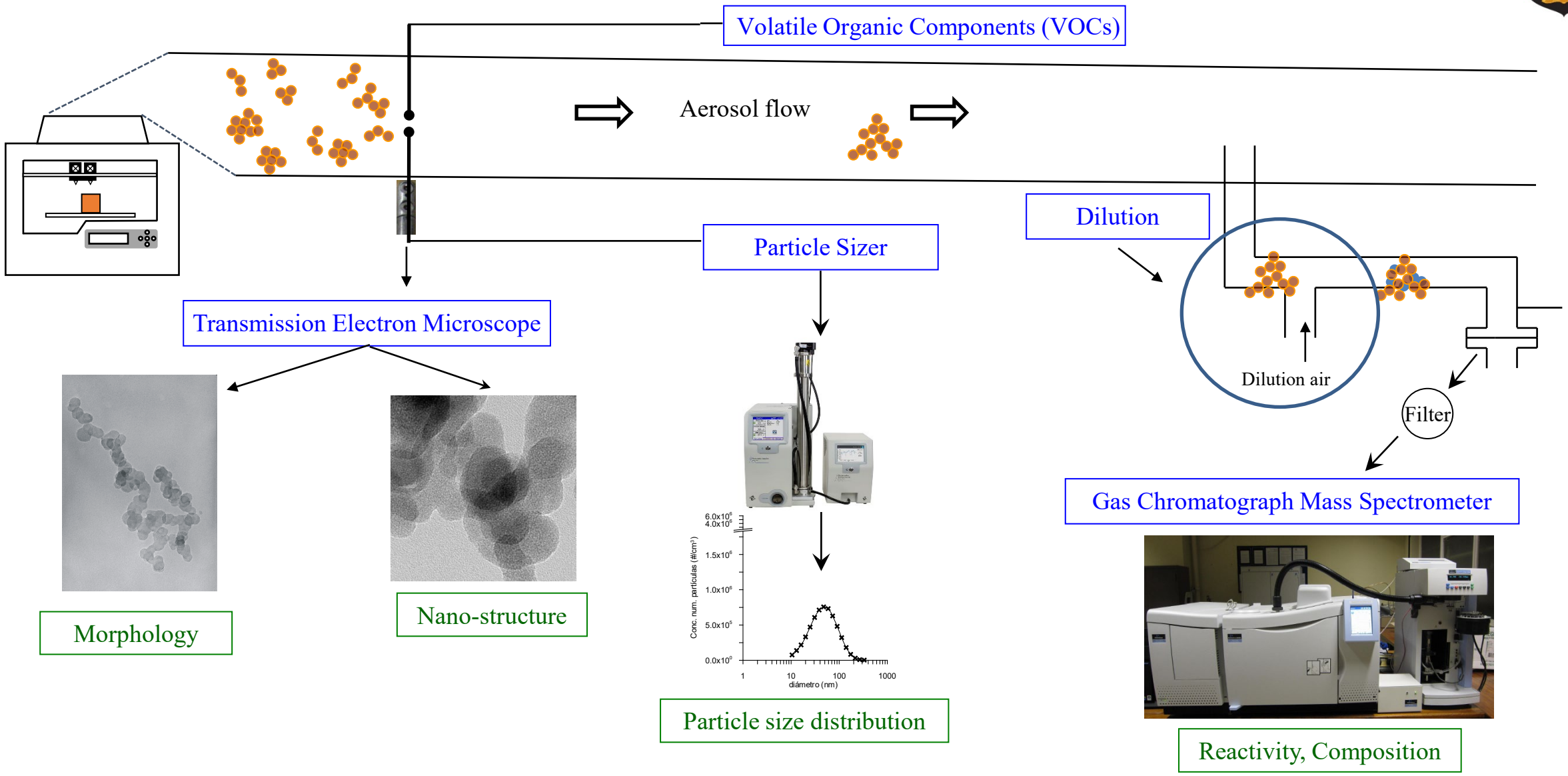
- Adoption of 3D printing thanks to time efficiency, cost, enabling digitalization
- Widespread use of Fused Deposition Modelling (FDM) 3D printers in educational, medical and manufacturing institutions as well as own households
- FDM printers employ a heated nozzle to melt solid thermoplastic filament to form a solid 3D object ➔ During the extruding, the plastic filament is heated, thus particle emissions, volatile and semi-volatile components are released





Particle morphology

2. Emissions from Additive manufacturing



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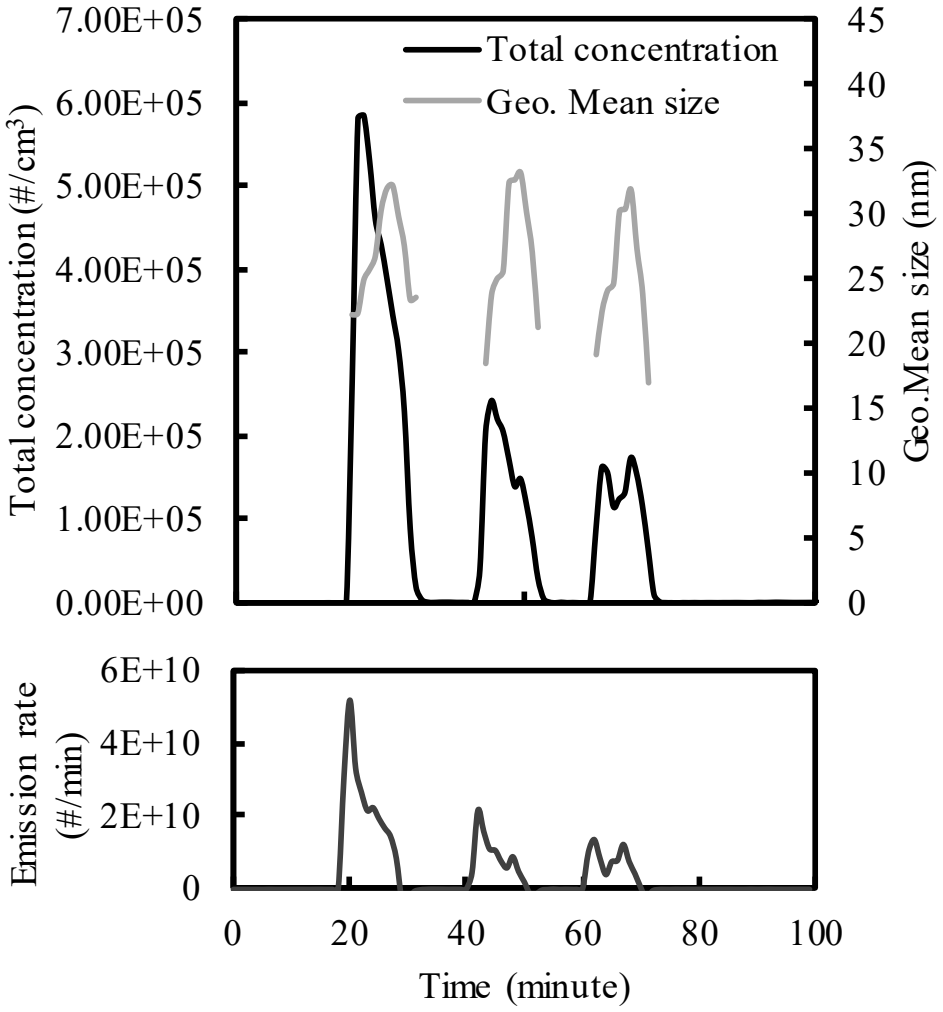
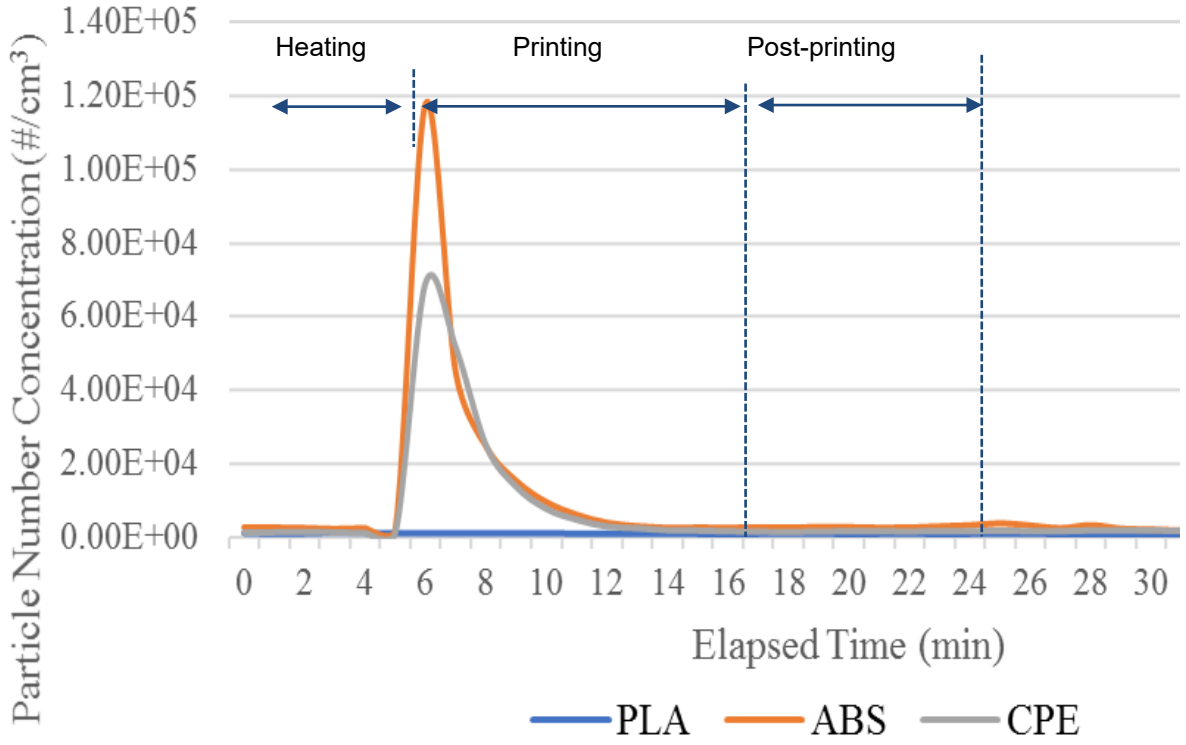
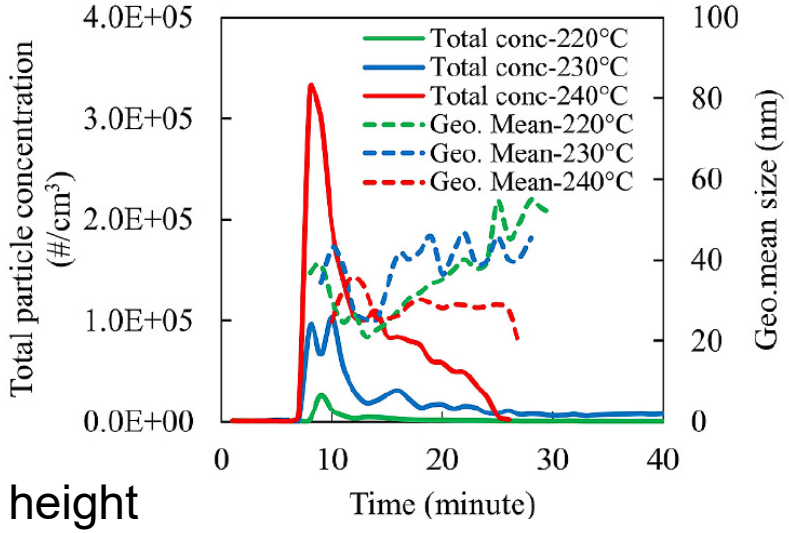


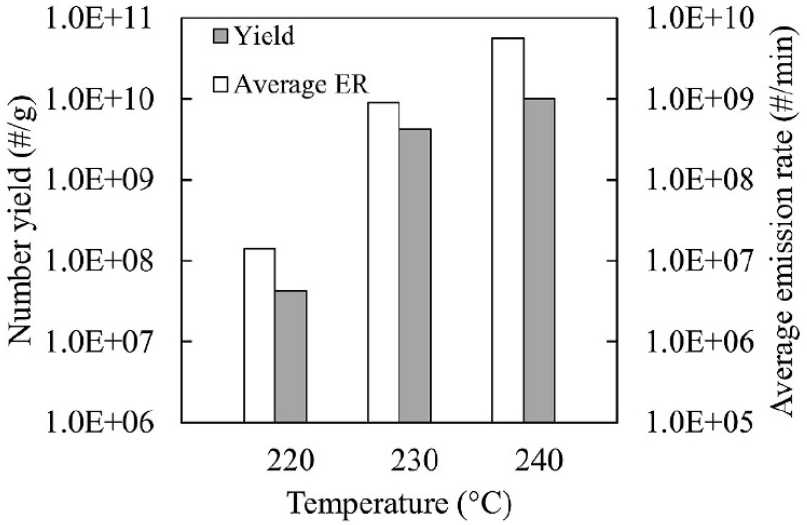


***Source**: S. Sittichompoo, S. Kanagalingam, L.E.J. Thomas-Seale, A. Tsolakis, J.M. Herreros. Characterization of particle emission from thermoplastic additive manufacturing. Atmospheric Environment, 239 (15) 117765, 2020.*

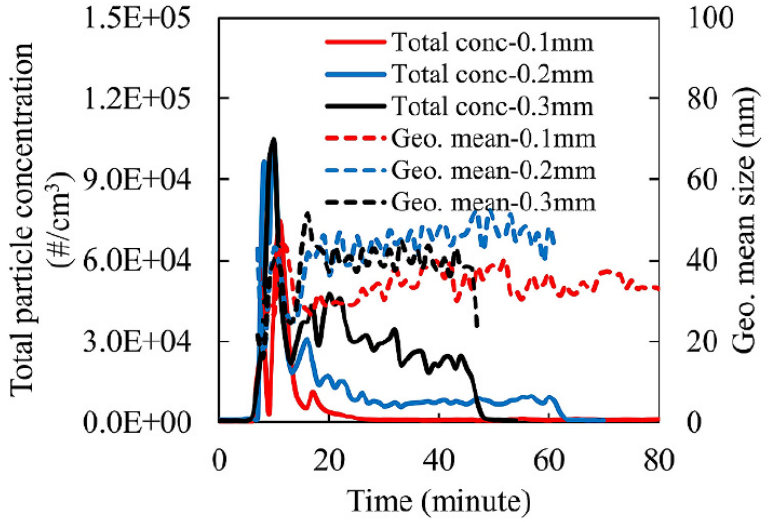
2. Emissions from Additive manufacturing

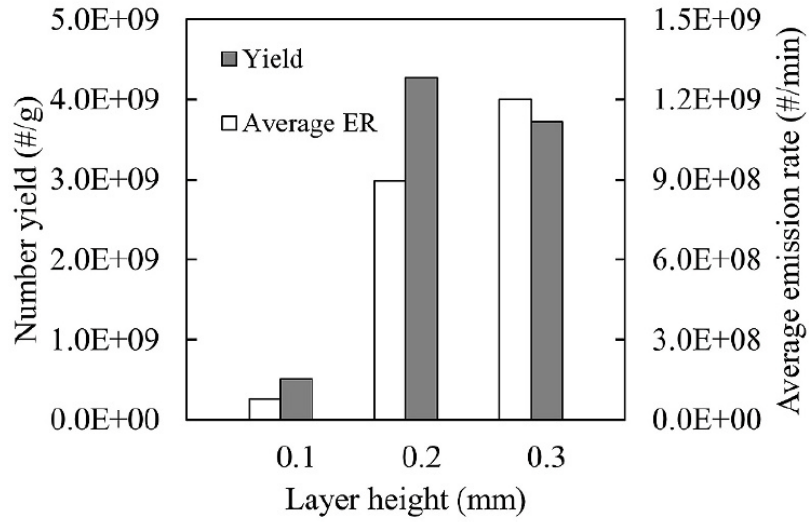
Printing temperature





Layer height





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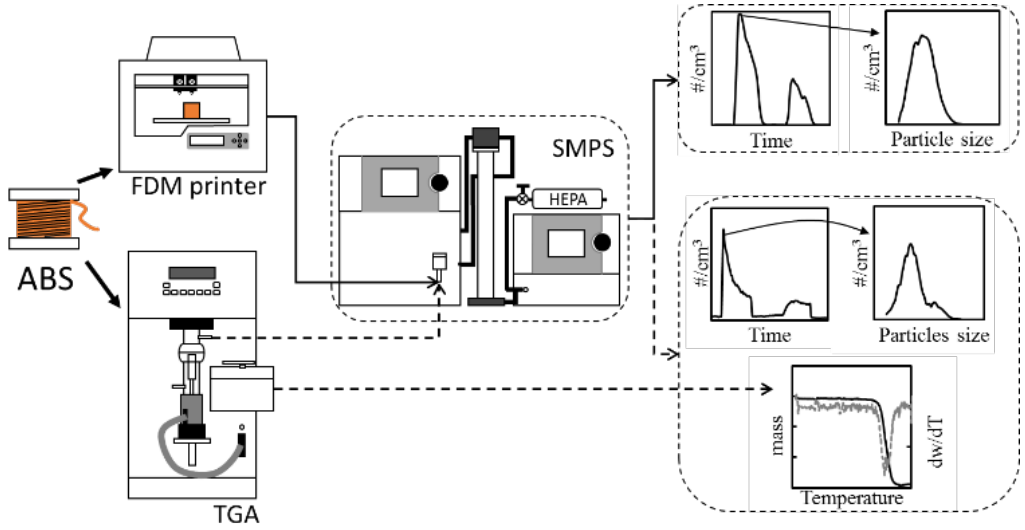

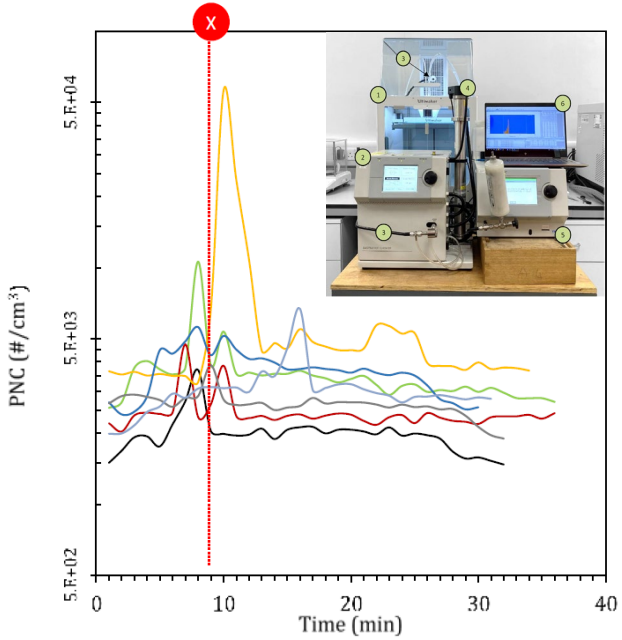

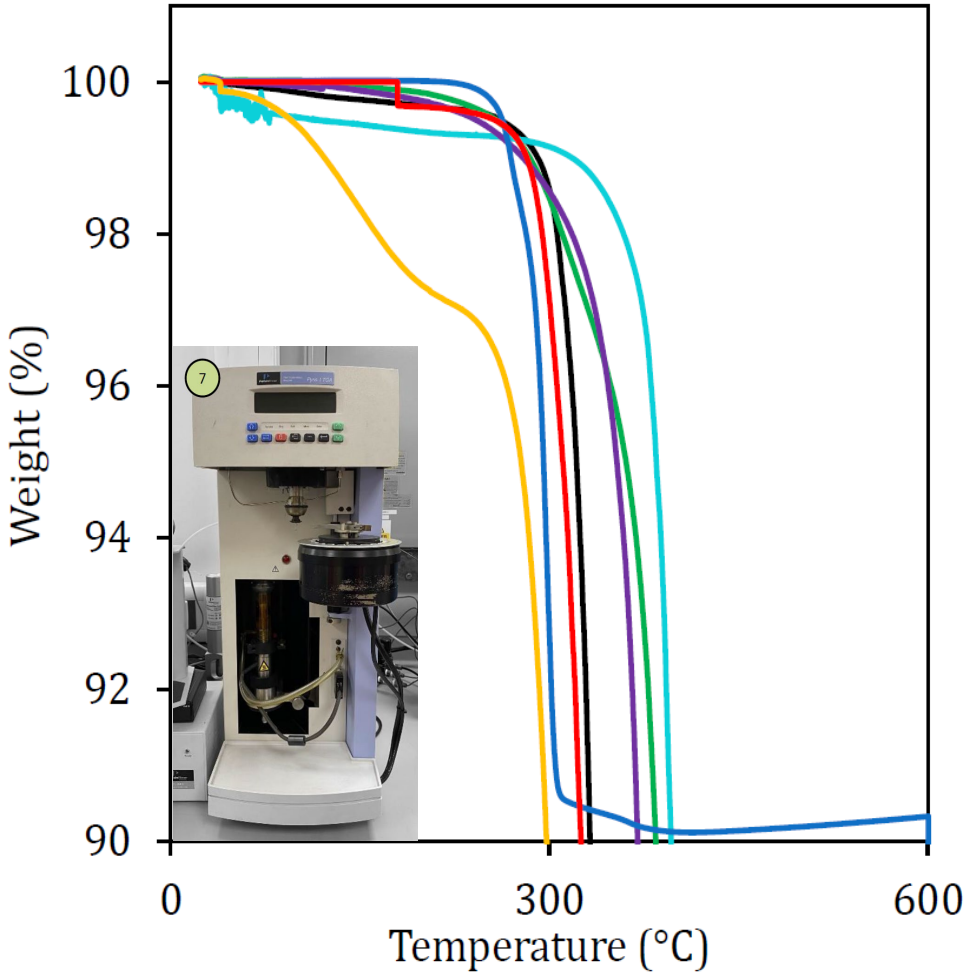

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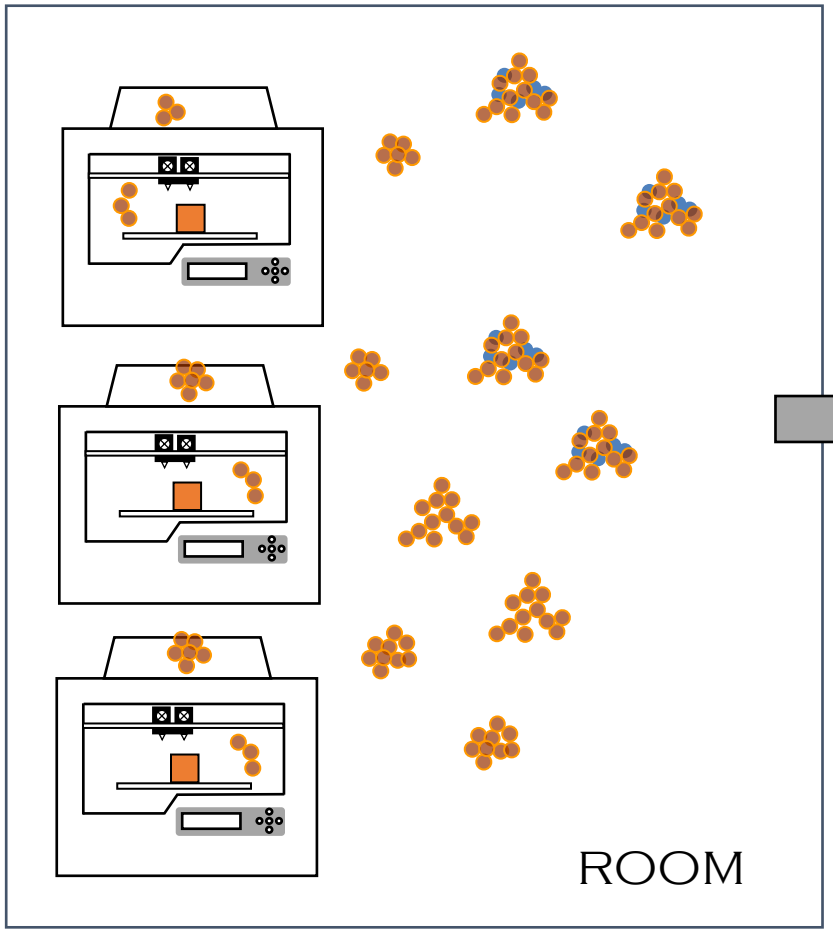
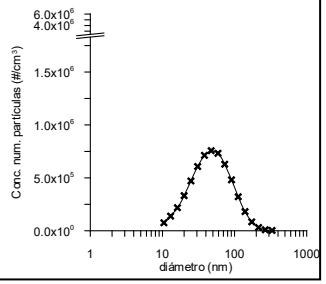
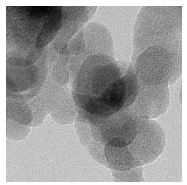


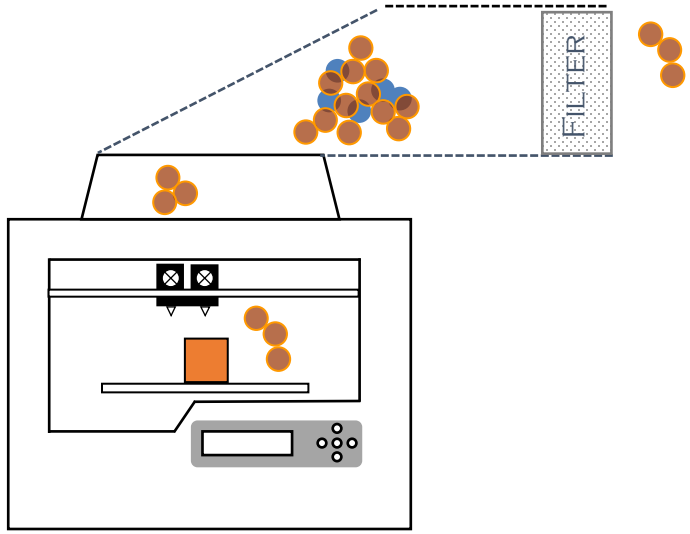
Volatile Organic components
Particle composition

Particle size concentration



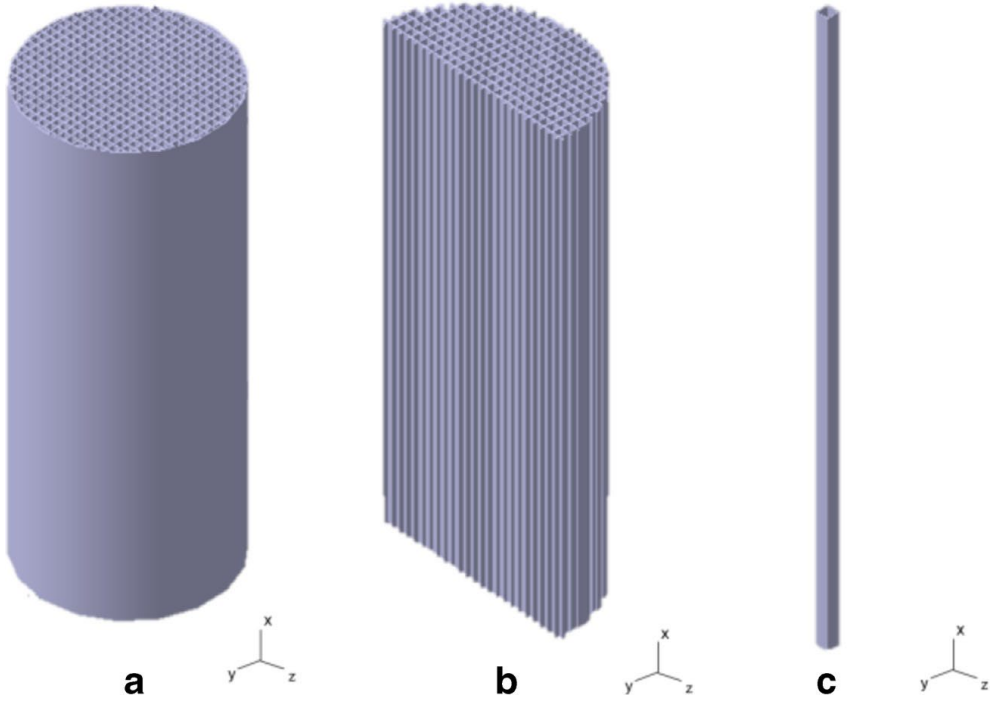
Particle morphology & nanostructure

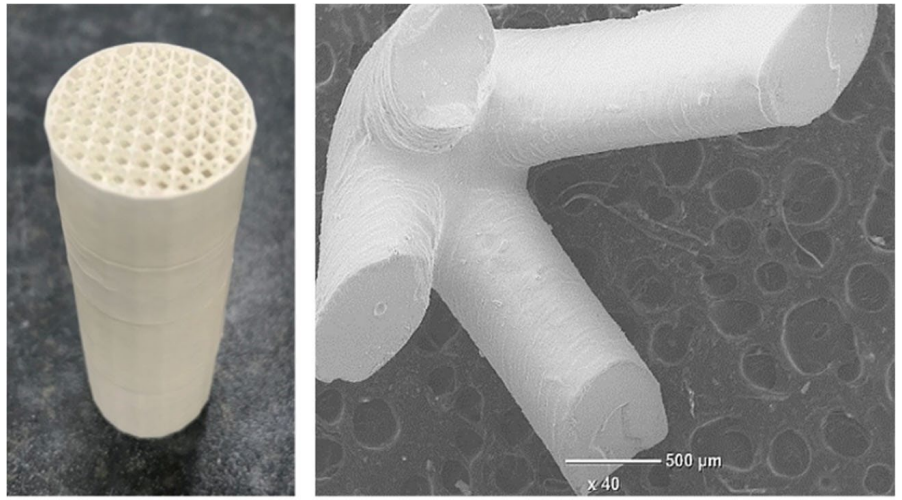


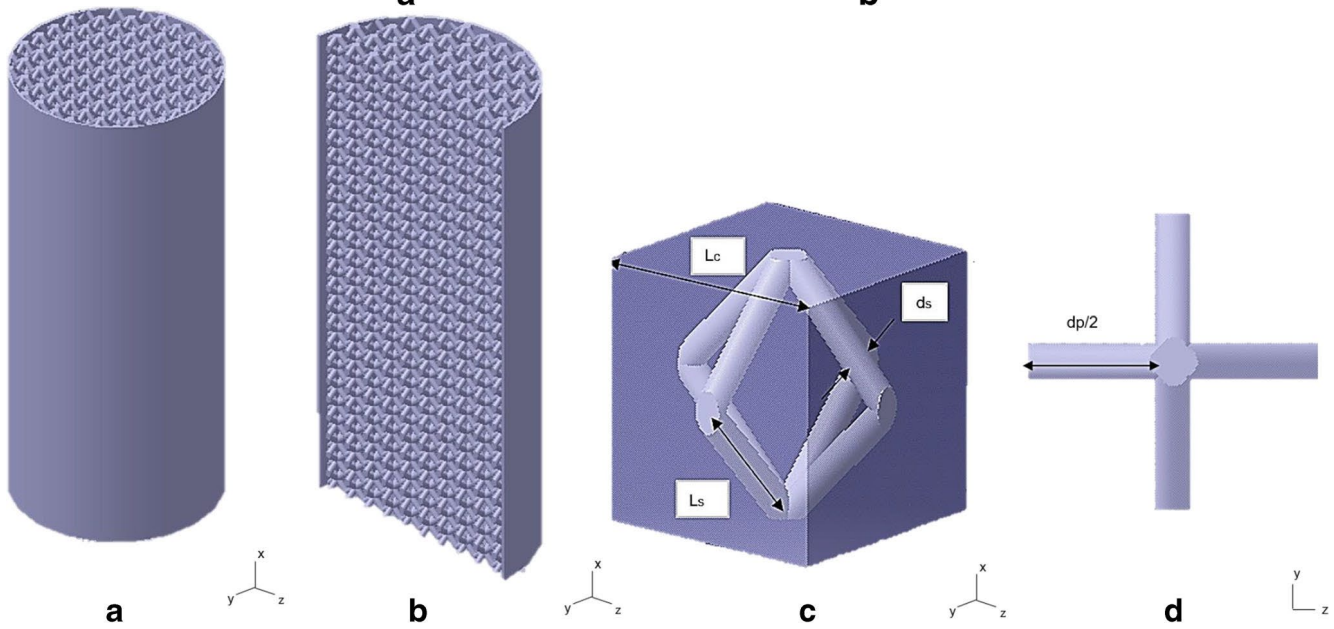


3. Additive Manufacturing for exhaust aftertreatment

Digital Light Processing (DLP) technology was effectively utilised to manufacture lattice structures







***Source**: N. Kovacev, S. Li, S. Zeraati-Rezaei, H. Hemida, A. Tsolakis, K. Essa. Effects of the internal structures of monolith ceramic substrates on thermal and hydraulic properties: additive manufacturing, numerical modelling and experimental testing. The International Journal of Advanced Manufacturing Technology, 112, 1115–32, 2021.*

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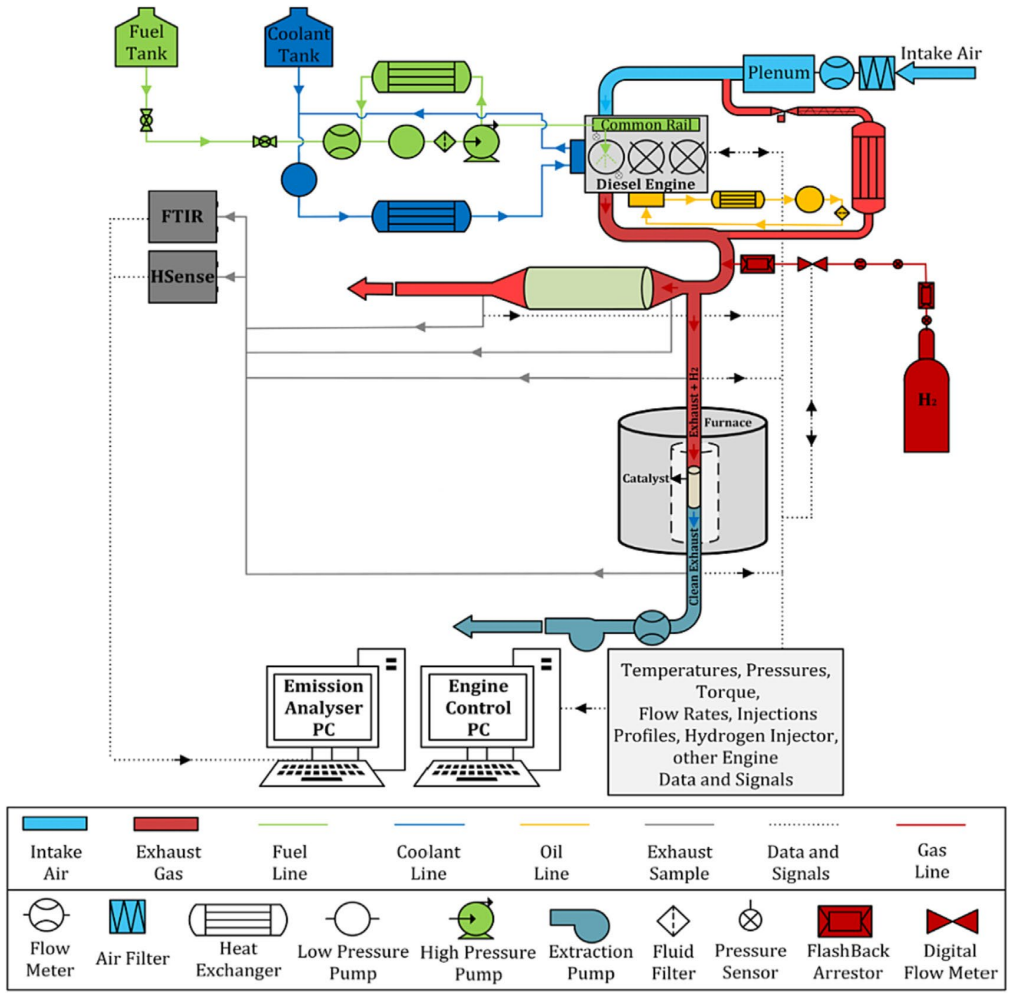

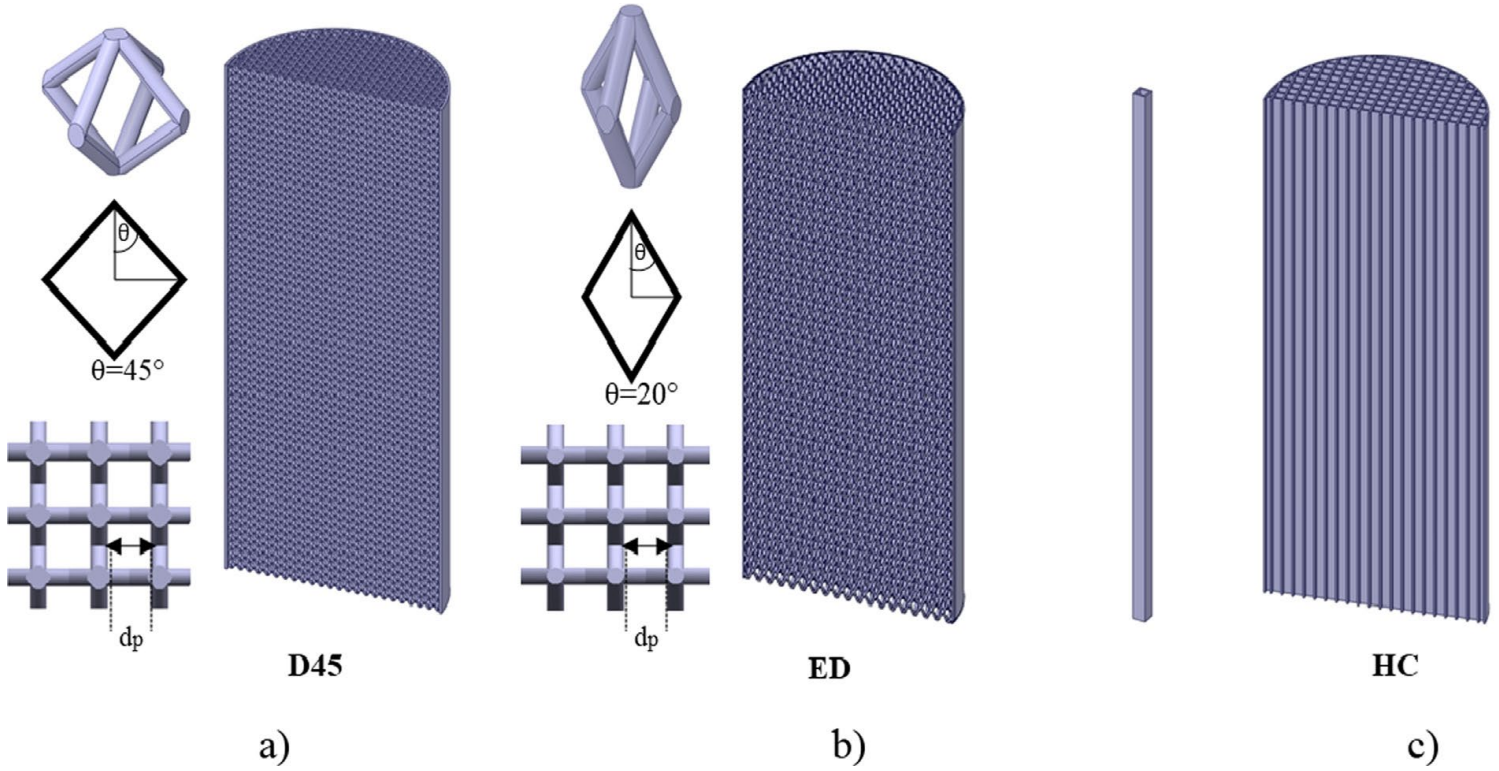

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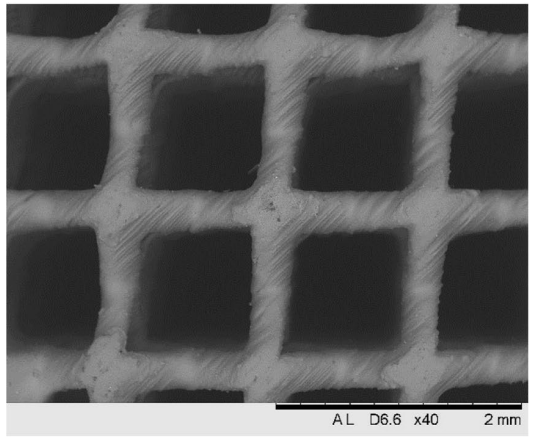

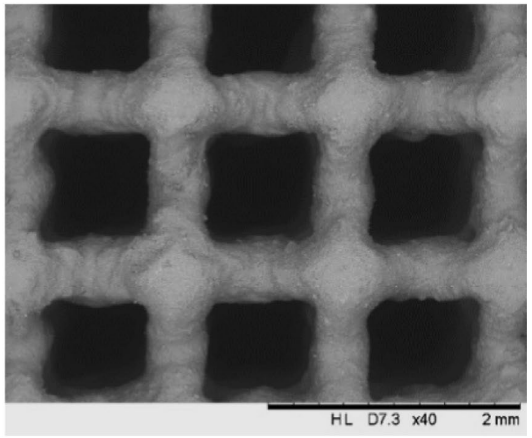

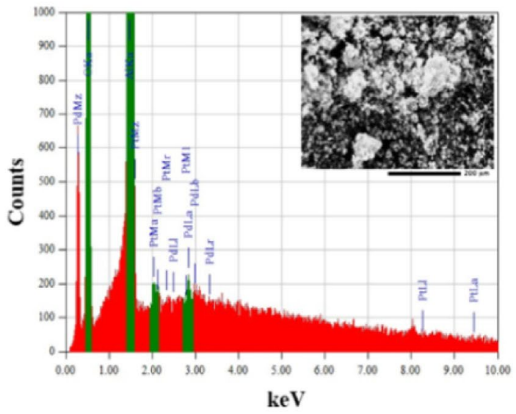

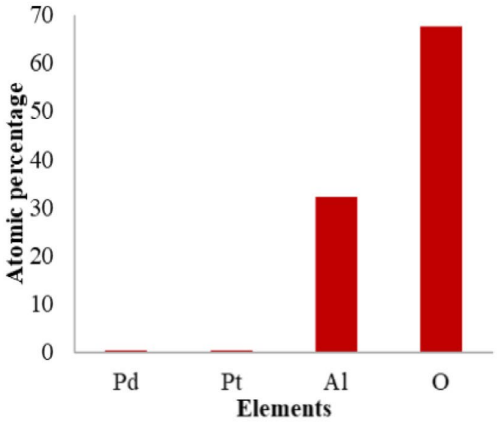

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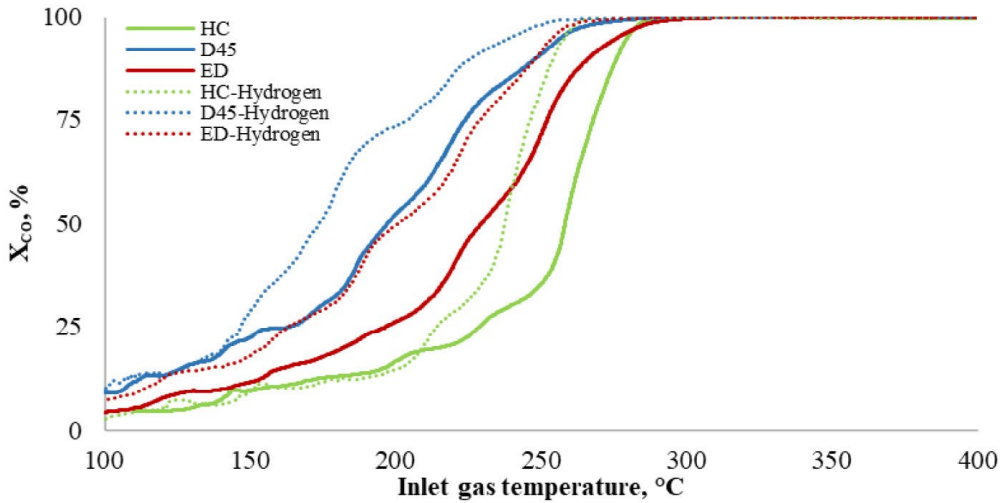

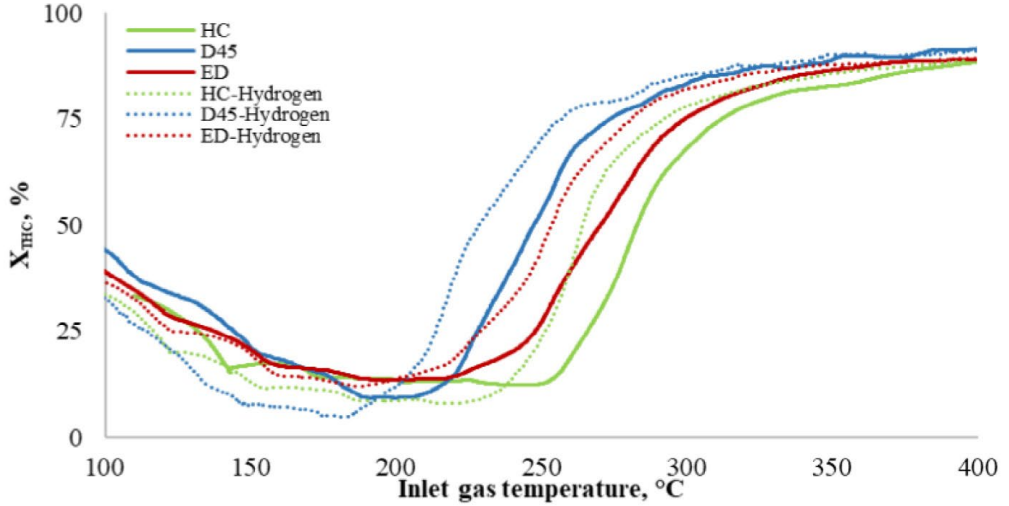

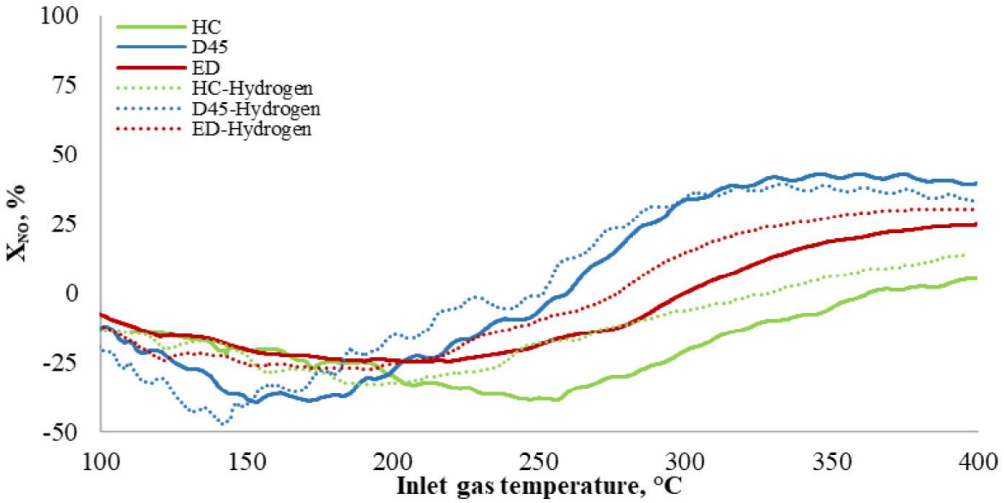

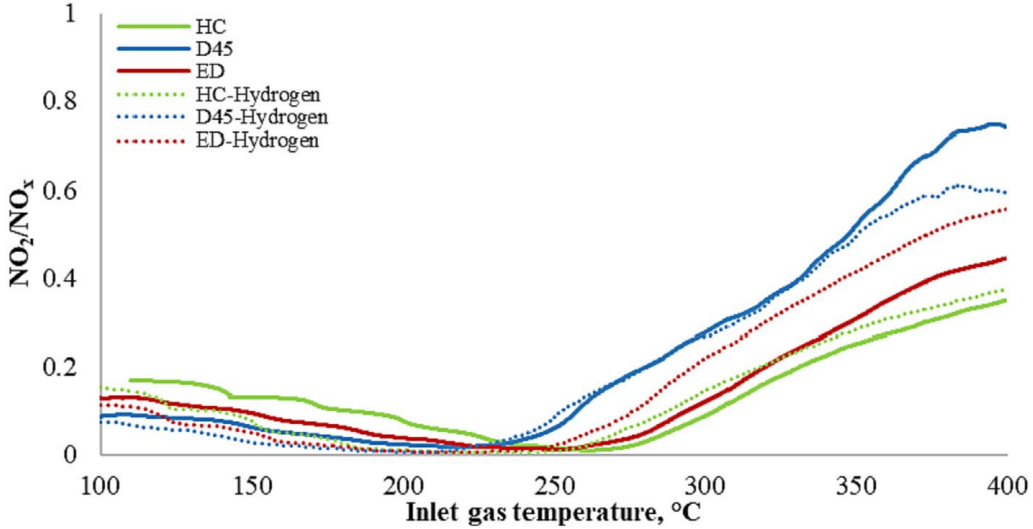

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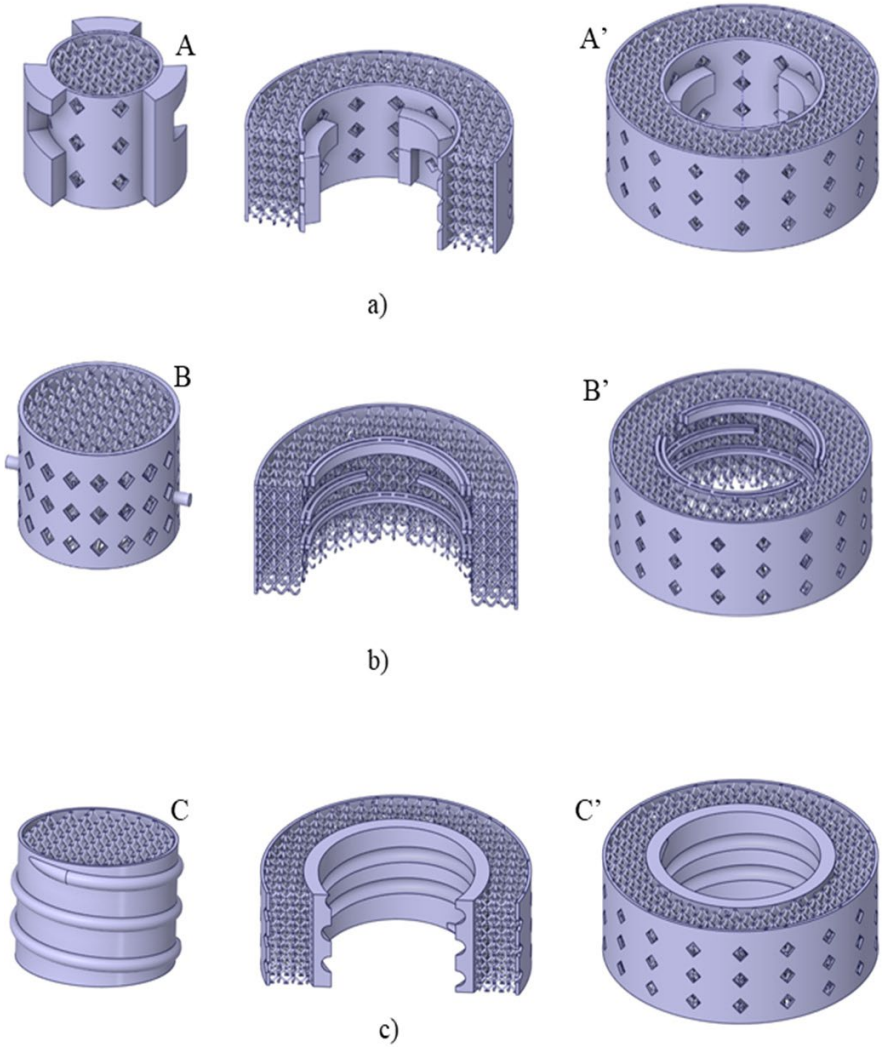

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4. Remarks

- Methods for the measurement of emissions from Additive Manufacturing should be developed and standardised at formation and exposure levels
- Methods to relate 3D printing materials and their properties to 3D printing emissions are under development
- Impact of 3D printing parameters and materials should be investigated under realistic environments
- Disruptive technologies incorporating Additive Manufacturing in the design of novel compact integrated catalytic emission filtration and abatement solutions would be advantageous

Acknowledgments

- EPSRC EP/P03117X/1. FACE - Novel Integrated Fuel Reformer-Aftertreatment System for Clean and Efficient Road Vehicles

- Horizon Europe Marie Sklodowska Curie Innovation Action underwritten by UKRI. Bio-Eco-Trans4.0. - Production & utilization of environmentally friendly Bio-Eco-products towards Transport4.0

- Clean Energy Engineering staff, researchers, PhD students and technical officers

UNIVERSITY OF BIRMINGHAM

Thank you!

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