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# nmRC CASE STUDY

## HIGHLY UNIFORM POROUS MAGNETIC MICROSPHERES FOR BIOMEDICAL APPLICATIONS

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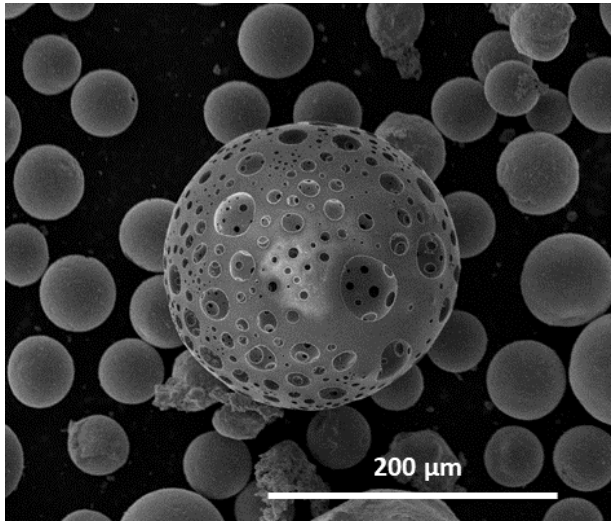
# Porous Magnetic Microspheres for Biomedical Applications

## Mineral Liberation Analysis (MLA) Case Study

# POROUS MAGNETIC MICROSPHERES



- Magnetic nano- and micro-materials have healthcare applications, for example as contrast agents in MRI, magnetically targeted drug-delivery systems, and magnetic-induced hyperthermia treatments.
- Porous microspheres have separate applications in healthcare *e.g.*, drug-delivery systems, tissue regeneration scaffolds etc.
- These materials present functional advantages over dense microspheres *e.g.,* enable payloads to be incorporated on their surfaces or within the pores to enable tailored release kinetics.
- The capacity to develop porous, magnetic materials with high levels of controlled uniformity is highly desirable.




# MORPHOLOGICAL AND COMPOSITIONAL ANALYSIS



- Porous microspheres are composed of external pores on the surface and internal pores in the core (usually interconnected). Therefore, it is important to explore details of such structures.

- Compositional analysis of such porous micro-systems is crucial to understand **mineral distribution** and **chemical concentration**.

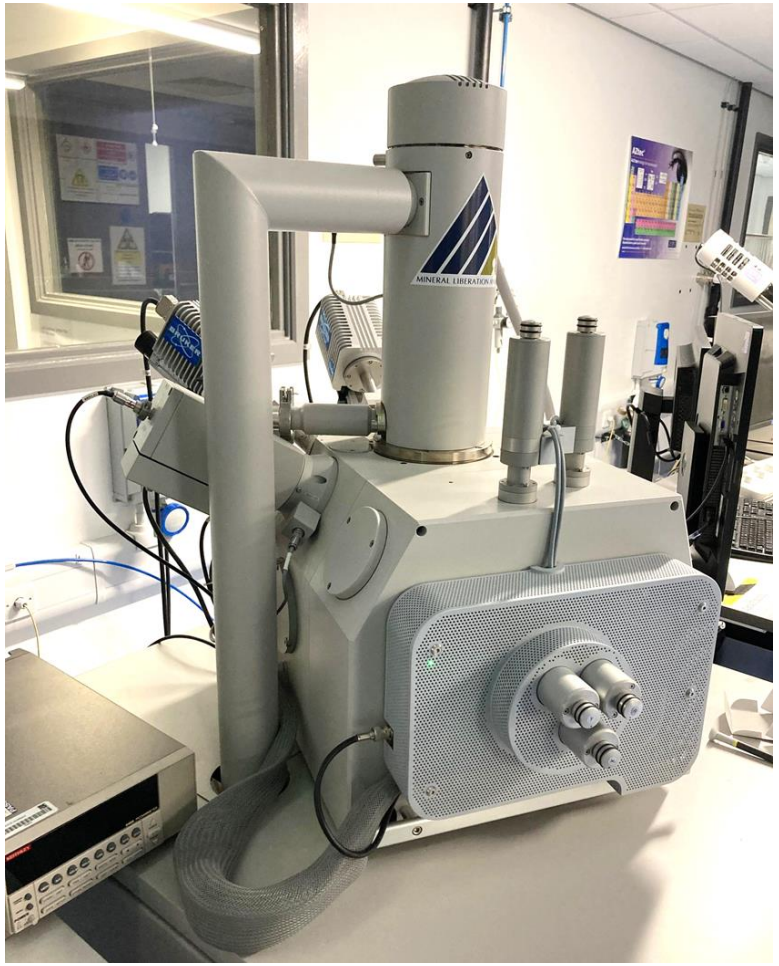
- Important insights into the **chemical reaction pathways** associated with the manufacture of porous microspheres can also be achieved.

- **To investigate homogeneity and internal porosity we need a technique capable of both mineral quantification and high-resolution imaging from a large population of microspheres.**

# MINERAL LIBERATION ANALYSIS (MLA)



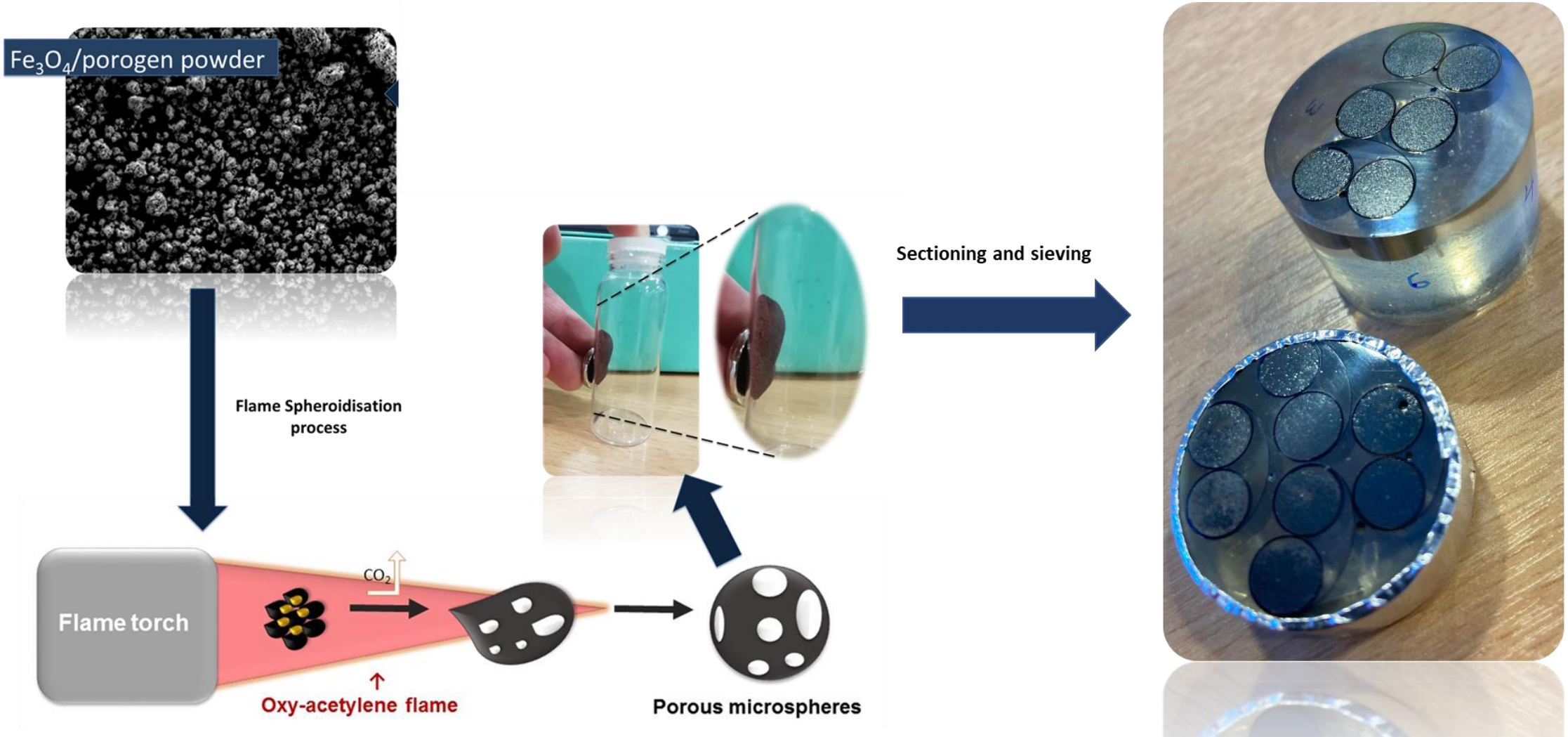
- The MLA system integrates a combination of back-scattered electron (BSE) imaging and energy dispersive x-ray spectroscopy (EDS) analysis.
- Via software automation this allows visualisation and elemental analysis of a large number of particles for a statistically significant data set.
- Outputs include calculated assay, elemental distribution, particle size distribution, modal mineralogy, mineral association, mineral locking etc.
- Process can take up to 14 polished mounts at a time, or samples up to 150mm$^2$ with automated analysis of each sample in turn.
- Resolution reported at 3.5nm @ 30kV



***FEI Quanta 600 with Mineral Liberation Analyser (MLA) available at the Nanoscale and Microscale Research Centre (nmRC), University of Nottingham***

# MANUFACTURE AND SAMPLE PREPARATION



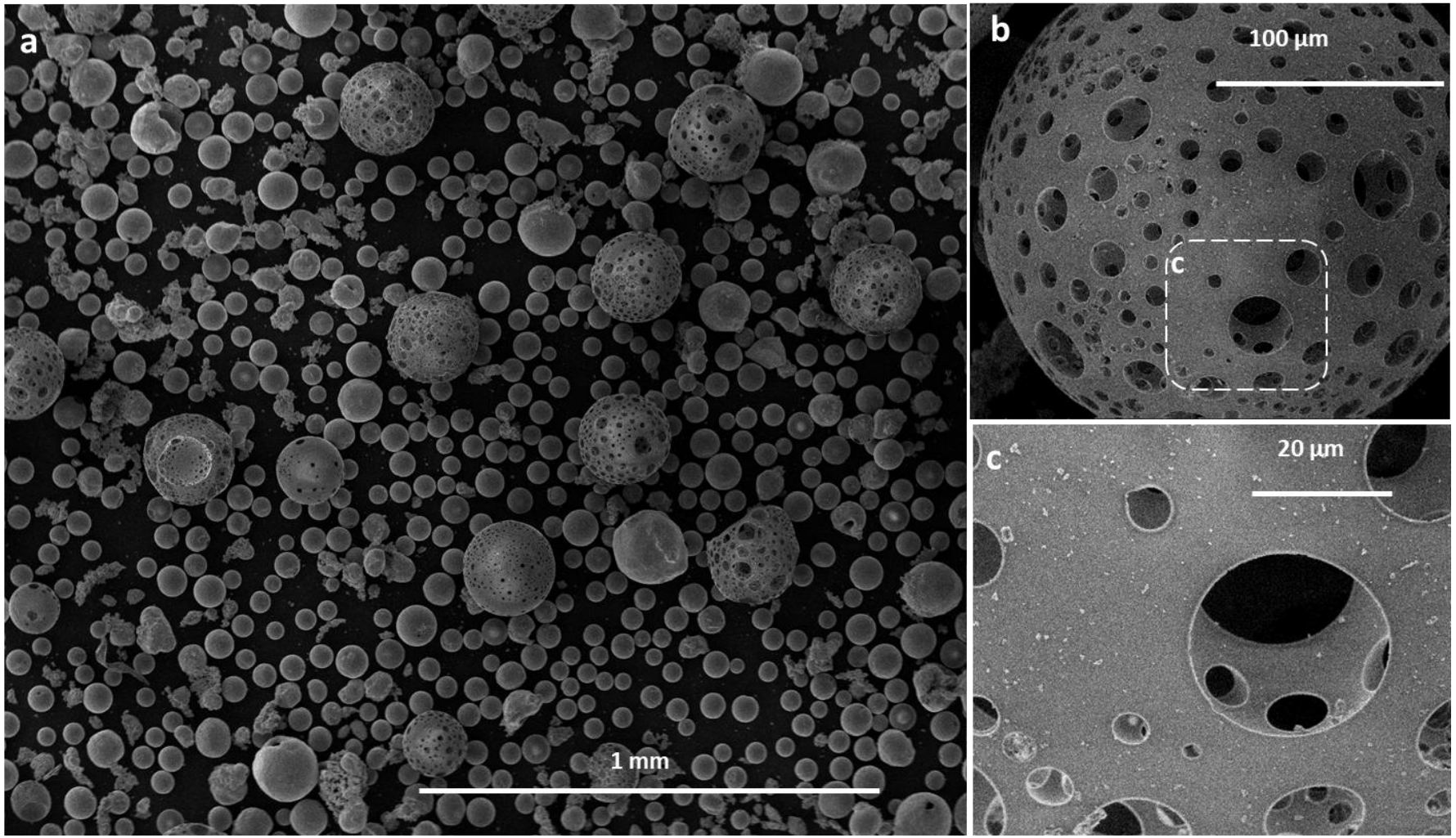



**Schematic diagram for porous and dense microsphere manufacturing via a rapid flame spheroidisation method, and sample preparation prior MLA analysis**

# SCANNING ELECTRON MICROSCOPY



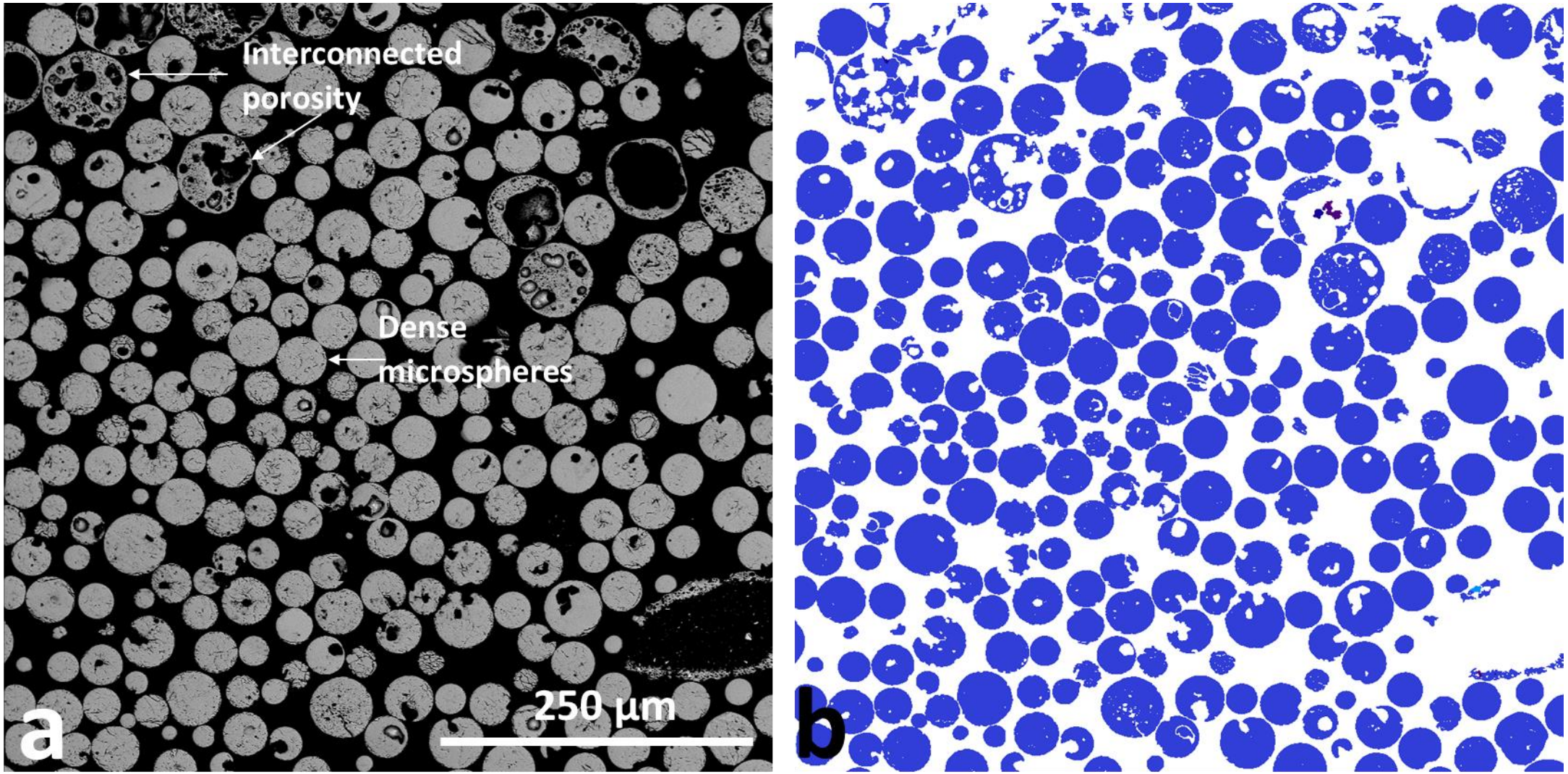
- Secondary electron images reveal **(a)** small, dense and large, porous microspheres; **(b)** localised morphology and topology of porous microspheres; **(c)** microsphere interconnected porosity (boxed in region **(b)**)



# MINERAL LIBERATION ANALYSIS

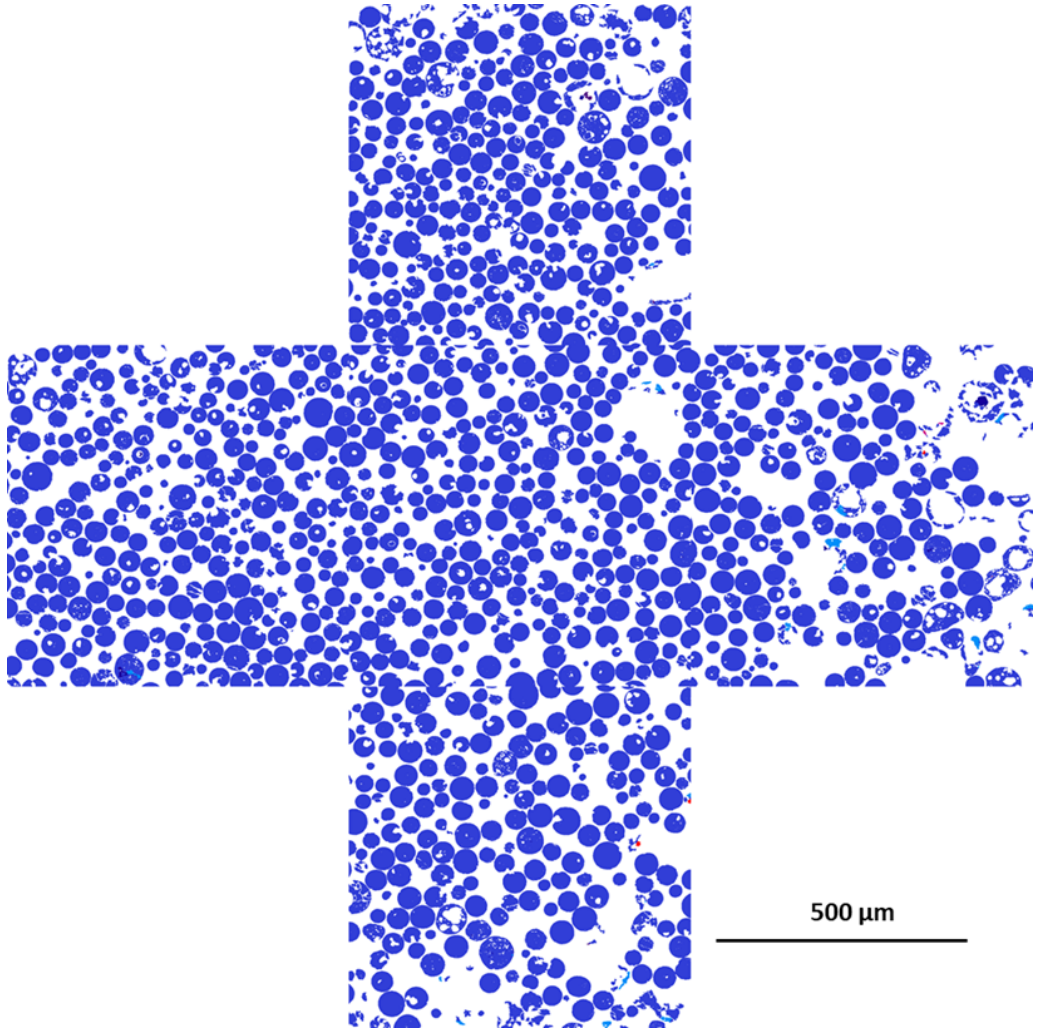


**(a)** BSE image and **(b)** MLA compositional analysis of microspheres, following sieving and sectioning, illustrating microsphere porosity and revealing high levels of homogeneity



# MLA MAPPING






Modal Mineralogy - S3 XBSE

| Name | Pixels | Particles | Area % | Weight % |
|---|---|---|---|---|
| Magnetite | 318 | 5 | 0.01 % | 0.01 % |
| Magnetite with Ca | 138 | 2 | 0.01 % | 0.01 % |
| 1 CaFeO | 325 | 3 | 0.01 % | 0.01 % |
| 2 CaFeO | 1866 | 24 | 0.07 % | 0.08 % |
| Ca2Fe2O5 (srebr... | 2503262 | 1501 | 99.40 % | 99.74 % |
| 4 CaFeO | 5481 | 25 | 0.22 % | 0.14 % |
| Calcite | 0 | 0 | 0.00 % | 0.00 % |

- A total of **1501 particles** (**99.74 wt%** of the sample) were classified as $Ca_2Fe_2O_5$ (srebrodolskite).

- EDS data from the MLA showed the elemental composition as follows:

  **Ca – 19.1%, Fe – 57%, O – 23.9%.**

**Full MLA compositional analysis of FS-processed microspheres, following sieving and sectioning, demonstrating very high levels of $Ca_2Fe_2O_5$**

# SUMMARY



- Mineral Liberation Analysis (MLA) [JKTech/FEI] allows automated large area analysis of polished specimens to identify and quantify mineral composition and distribution.
- Electron microscopy reveals morphologies and porosity of flame-spheroidised porous microspheres.

- MLA technique details:
  - **Mineral mapping** – used to reveal compositional uniformity of microspheres
  - **Large number of particles** – used to obtain a statistically significant set of data

- This study demonstrates the role MLA can play in understanding the morphological homogeneity and mineral distribution of microparticles, critical when validating new formulations / manufacturing methods.

# REFERENCES / ACKNOWLEDGEMENTS



**For more details on the work showcased in this case study see the following publications:**

J. Molinar Díaz, S. A. Samad, E. Steer, N. Neate, H. Constantin, M. T. Islam, P. D. Brown and I. Ahmed, "Flame spheroidisation of dense and porous Ca2Fe2O5 microspheres", Materials Advances, 2020, DOI: 10.1039/D0MA00564A

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# ADDITIONAL INFORMATION



- We hope the information provided in this case study is of interest.
- If you wish to get in touch with us to discuss any of the information provided, raise a query/concern or provide feedback then please use any of the methods listed below:

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