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# POWERING SPACE EXPLORATION: Np-237 TARGET MANUFACTURING

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## Method

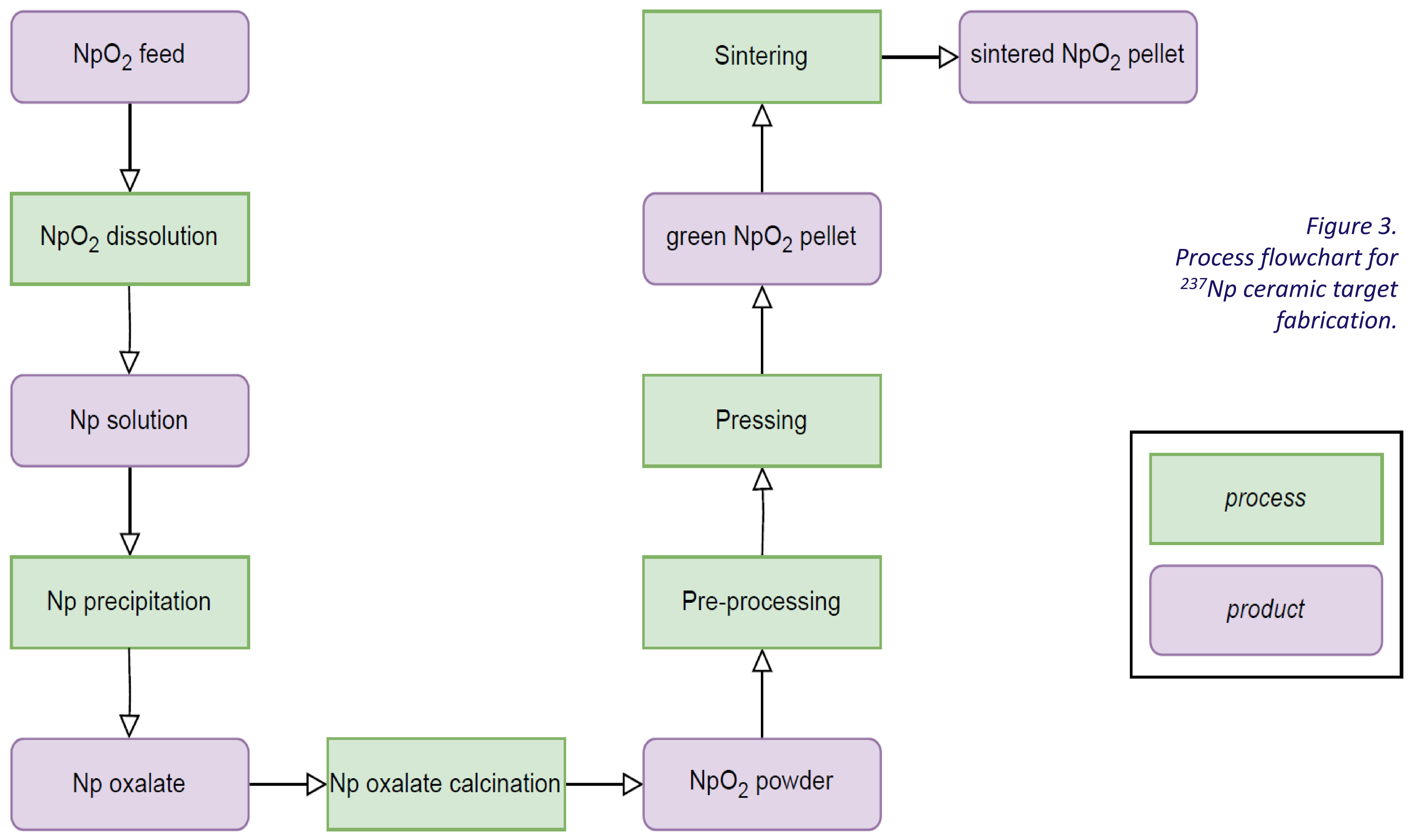



*Figure 3. Process flowchart for ²³⁷Np ceramic target fabrication.*

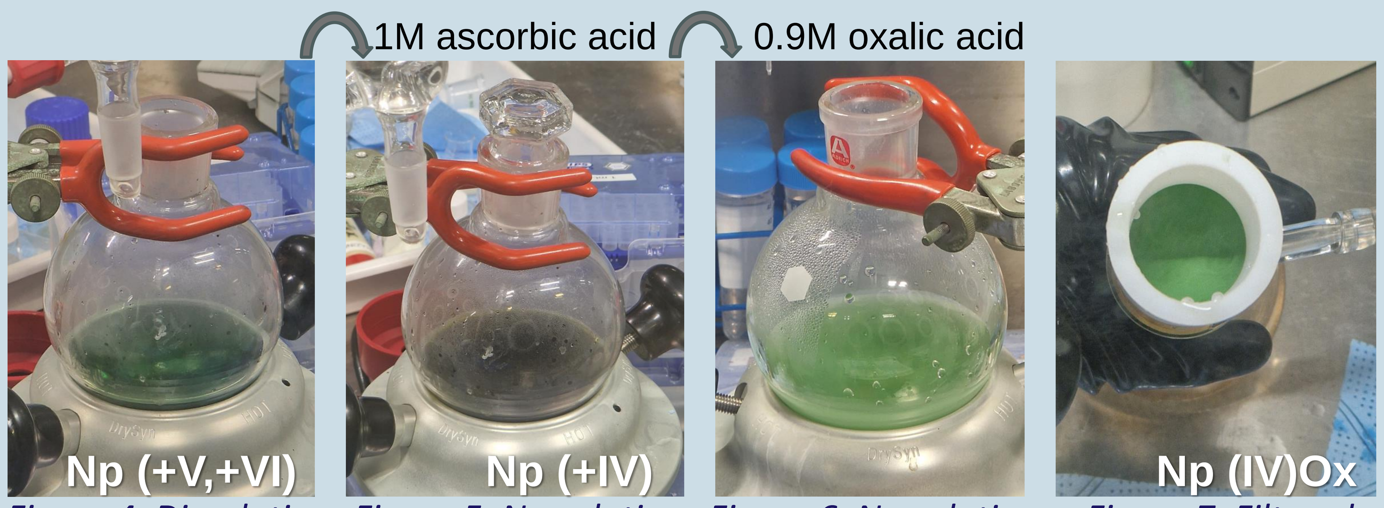



*Figure 4. Dissolution product of Np source.* *Figure 5. Np solution after ascorbic acid addition.* *Figure 6. Np solution after oxalic acid addition.* *Figure 7. Filtered hydrated Np oxalate.*

Np can be converted to solid phase via oxalic precipitation. It requires a full conversion of Np to the +IV oxidation state. Ascorbic acid is used for the reduction from Np(+V, +VI) to +IV. Np(IV) oxalate forms a non-soluble precipitate in aqueous solutions.

## Introduction

$$^{237}\mathrm{Np}(n,\gamma)\ ^{238}\mathrm{Np} \xrightarrow{\beta^-} {}^{238}\mathrm{Pu}$$

### Europe strives for 238-Pu

For exploration of the outer parts of our planetary system, solar panels combined with batteries are no longer a standalone energy source option. NASA's deep-space exploration probes and planetary rovers rely on radioisotope heating units (RHU) and thermoelectric generators (RTG) powered by Plutonium-238 ($^{238}$Pu). $^{238}$Pu is the preferred isotope since it is an alpha emitter with an almost total absence of penetrating gamma radiation. It has a convenient half-life of 86.4 years combining high specific power density with steady power supply for decades.

$^{238}$Pu is produced through high-flux neutron irradiation of $^{237}$Np.

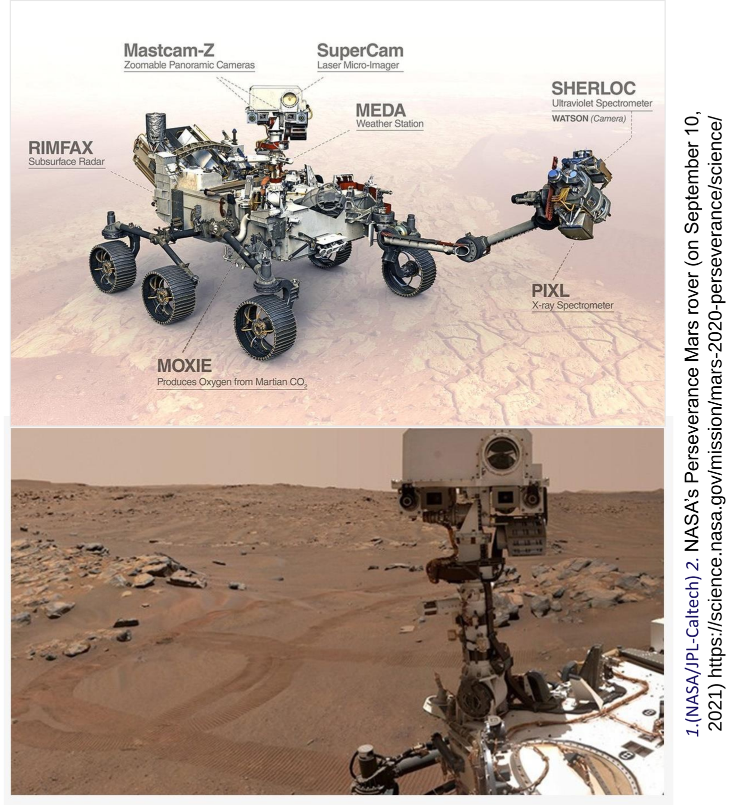



*Figure 1. Perseverance Mars rover's scheme and "selfie".*

1.(NASA/JPL-Caltech) 2. NASA's Perseverance Mars rover (on September 10, 2021) https://science.nasa.gov/mission/mars-2020-perseverance/science/

Given the advantages of $^{238}$Pu, there is a renewed interest to re-open a European $^{238}$Pu production chain for its deep space exploration missions.

## Objectives

Optimus Pro project contributes to outlining a way of producing $^{238}$Pu in Europe. It will demonstrate fabrication of $^{237}$Np targets at laboratory scale.

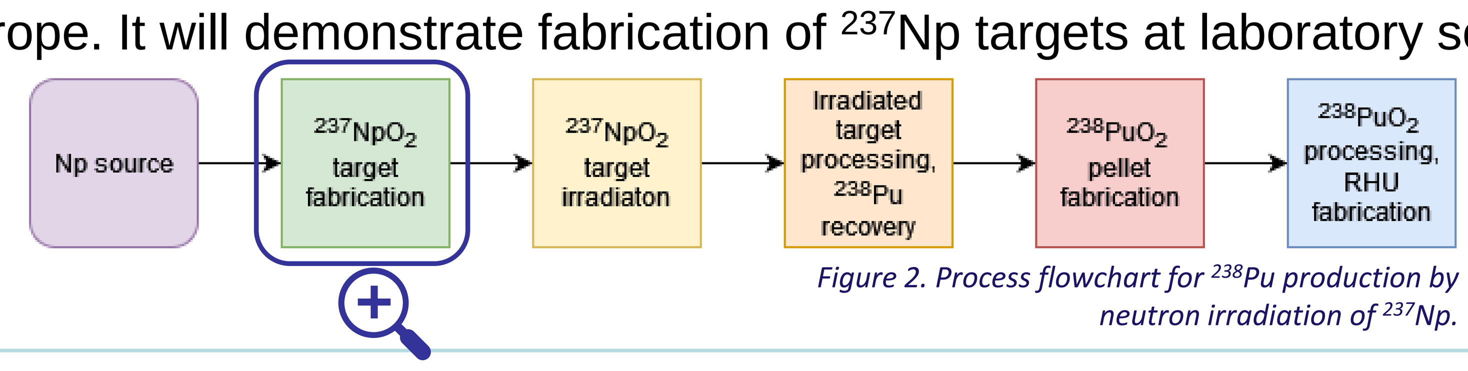



*Figure 2. Process flowchart for ²³⁸Pu production by neutron irradiation of ²³⁷Np.*

*Figure 8. Diffractogram of hydrated Np(IV) oxalate sample at room temperature on zero-background holder.*

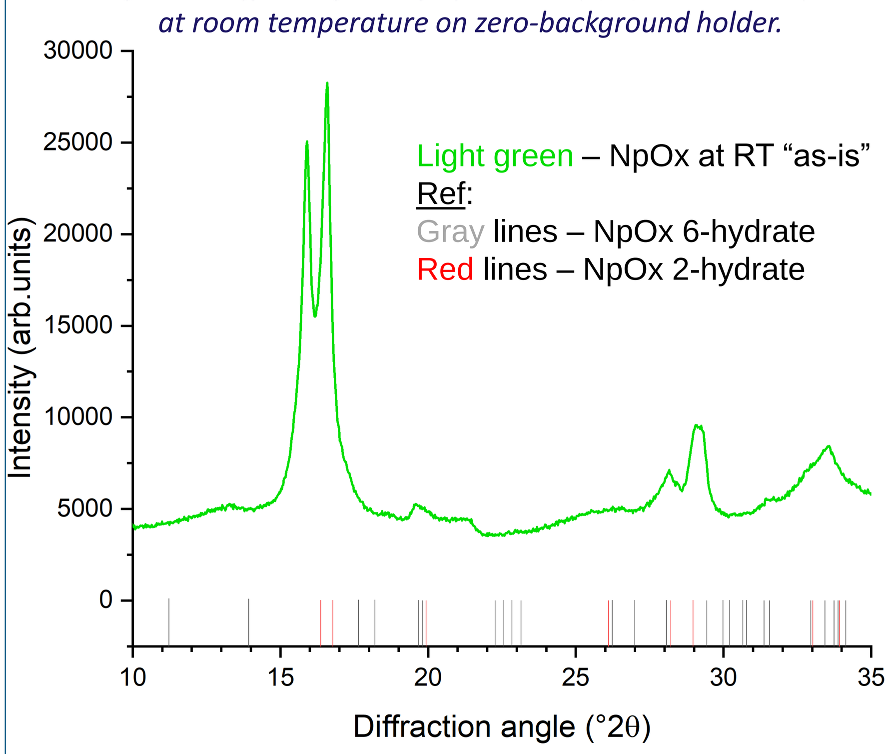
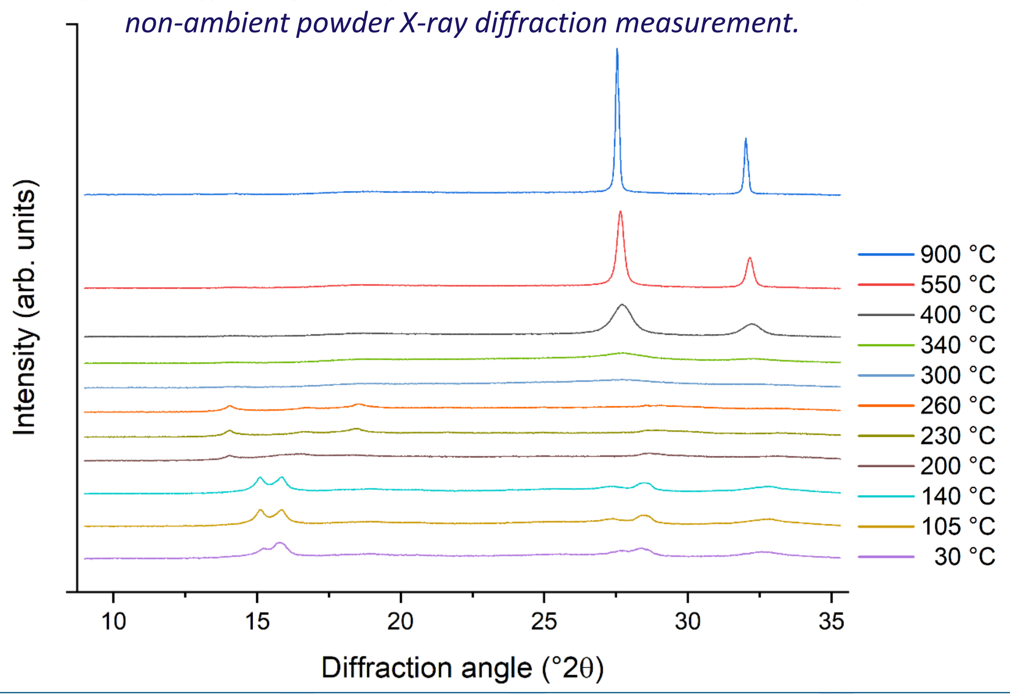



*Figure 9. Diffractograms of hydrated Np(IV) oxalate in course of non-ambient powder X-ray diffraction measurement.*




Oxalates upon heating in air undergo degradation to oxide, Powder X-ray diffraction and thermogravimetry were used to determine the conversion conditions.

| Measured weight fraction | Calculated weight fraction of $NpO_2$ to $Np(C_2O_4)_2 \cdot nH_2O$, where | | | | | | |
|---|---|---|---|---|---|---|---|
| | $n = 6$ | $n = 5$ | $n = 4$ | $n = 3$ | $n = 2$ | $n = 1$ | $n = 0$ |
| 51.5 % | **51.6%** | 53.5% | 55.5% | 57.6% | 59.9% | 62.4% | 65.1% |

*Table 1 - Weight fraction (%) of the TG product ($NpO_2$) with respect to the initial compound; measured and calculated values assuming various oxalate hydrates.*

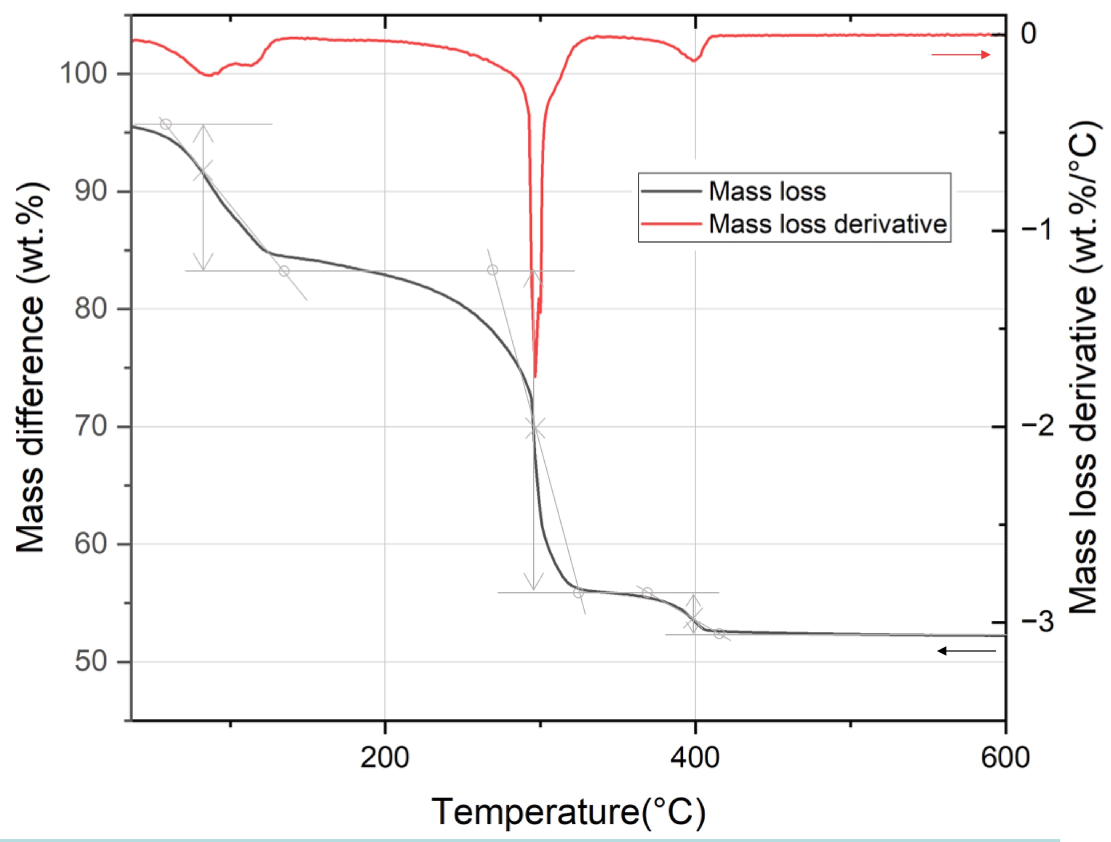
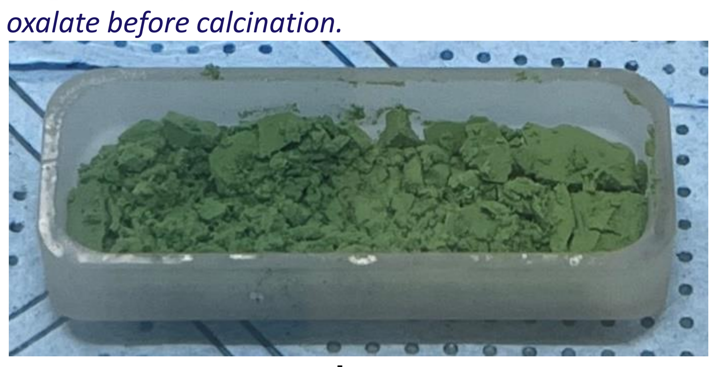



*Figure 10. Thermogravimetric curve of hydrated Np(IV) oxalate sample.*

### $^{237}$Np Oxalate production and characterisation

*Figure 11. Hydrated Np oxalate before calcination.*



550 °C

### $^{237}$Np Oxide characterisation and processing

*Figure 12. Hydrated Np oxalate after calcination.*

*Figure 13. Scanning electron micrographs of produced Np oxide, at various magnifications.*

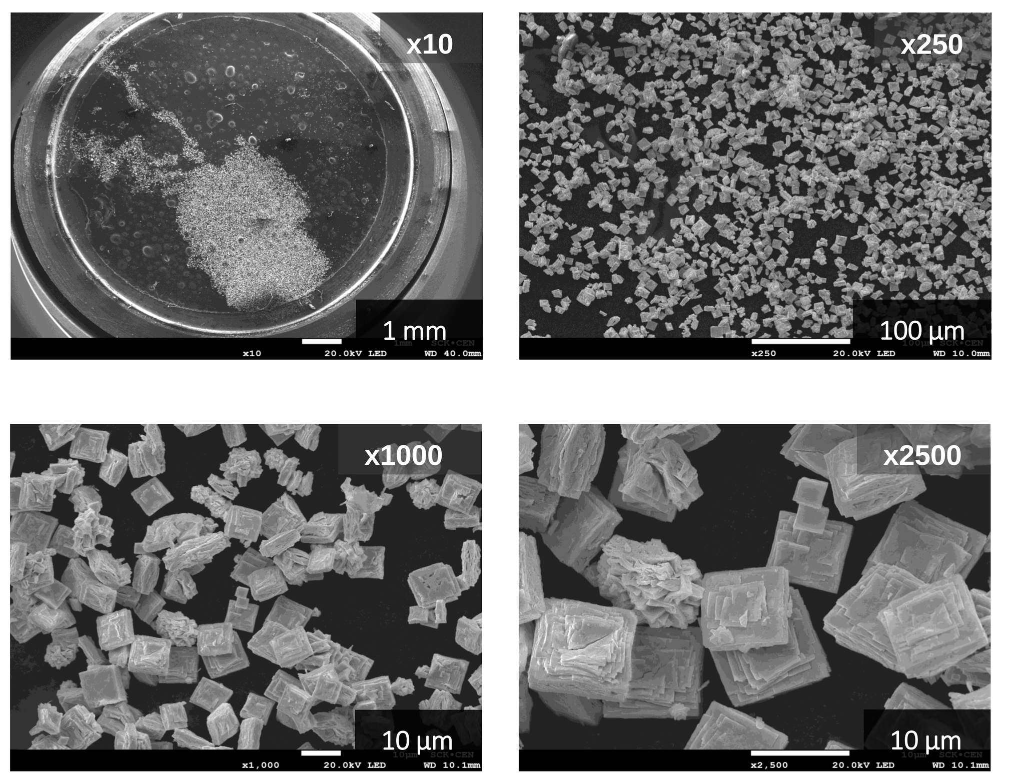



*Table 2. Brunauer–Emmett–Teller method assessment of specific surface area of Np oxide powder.*

| BET surface area ($m^2.g^{-1}$) $P/P_0 = 0.05 - 0.3$ | C | Correlation coefficient | Sampling mass (g) | Total surface |
|---|---|---|---|---|
| 3.446 ± 0.012 | 102 | 0.999950 | 1.1318 | 3.9 |

Characterisation of obtained $NpO_2$ powder contributes to pressing and sintering conditions elucidation.

*Figure 14. Photos of $NpO_2$ pressed pellet in different light conditions.*

## Conclusion

The demonstration of fabrication process yielding dense $NpO_2$ pellets in Europe within Optimus Pro project represents a significant advancement in the development of an independent $^{238}$Pu production chain, supporting future deep-space missions.

### Acknowledgements

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