# Magnesium based materials for hydrogen storage applications

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El conocimiento es de todos
Minciencias

# Overview *Of* The program

Generation

Storage

Utilization

MinCiencias: 69921 - Programa integral para la generación y uso de hidrógeno como combustible limpio que contribuya a la reducción del impacto ambiental en el transporte de Colombia.

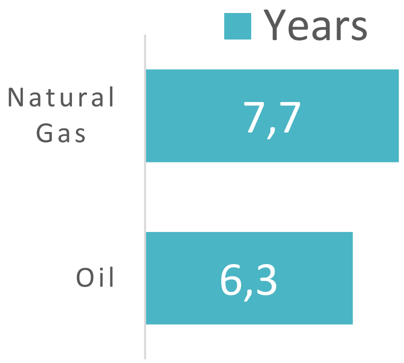
UdeA

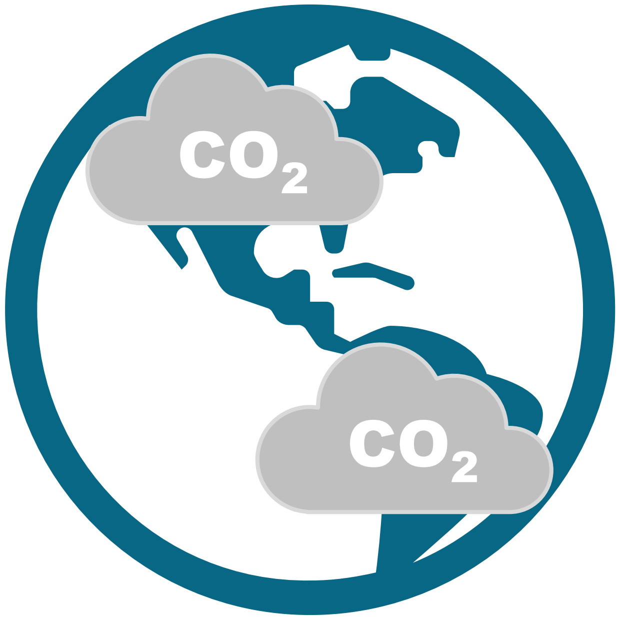
UdeA

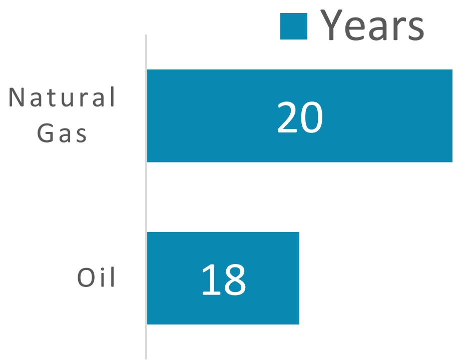
# Table of Contents



# Introduction | fossil fuels


**Sustainable alternatives are required**

Ocampo-Camargo. *La República.* 2021

# Introduction | energy transition


Inflammability
and low density

Heat power: 119,9 MJ/kg
(Gasoline: 44,5 MJ/kg)

Storage is limiting its practical applications.

Li et al. *Journal of Materials Science & Technology. 2022*

# Introduction | hydrogen storage

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| Solutions for $H_2$ storage | | |
| --- | --- | --- |
| Gases | Liquids (LHCs) | Solids |

Lower risk in transportation and higher gravimetric capacities.

| Magnesium hydrides ($MgH_2$) | | |
| --- | --- | --- |
| Lightweight, reversible and abundant on Earth's crust | Theoretical storage capacity (7.6 wt.%) | Sluggish kinetics and thermodynamic stability |

Sorption / Desorption >300 °C

Hirscher et al. *Journal of Alloys and Compounds. 2020* | US-DOE. *2023*

# Introduction | Mg modifications

Morphological modifications

Metal-oxide catalysts

Nanoparticles or nanostructures

Alloying elements and additives

Hirscher et al. *Journal of Alloys and Compounds. 2020*

# Introduction | Mg modifications

Metal-oxide catalysts

Improve kinetics or thermodynamics
But decrease storage capacity

*An approach that involves various modifications is required*

Nanoparticles or nanostructures

Alloying elements and additives

# Main **Objective**



To develop a complex nanostructured Mg-Ni based hydride through high energy ball milling for hydrogen storage applications.

# Methodology

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1 Mg-Ni

2 Al, Si, Ti

3 Na, K, Ca

+

4 $Nb_2O_5$

Emax high energy ball mill

5

- Morphological and microstructural characterization (SEM, EDS, TEM, DRX)
- Hydrogen storage performance (Sieverts, DSC, TGA)

# Results | Starting materials

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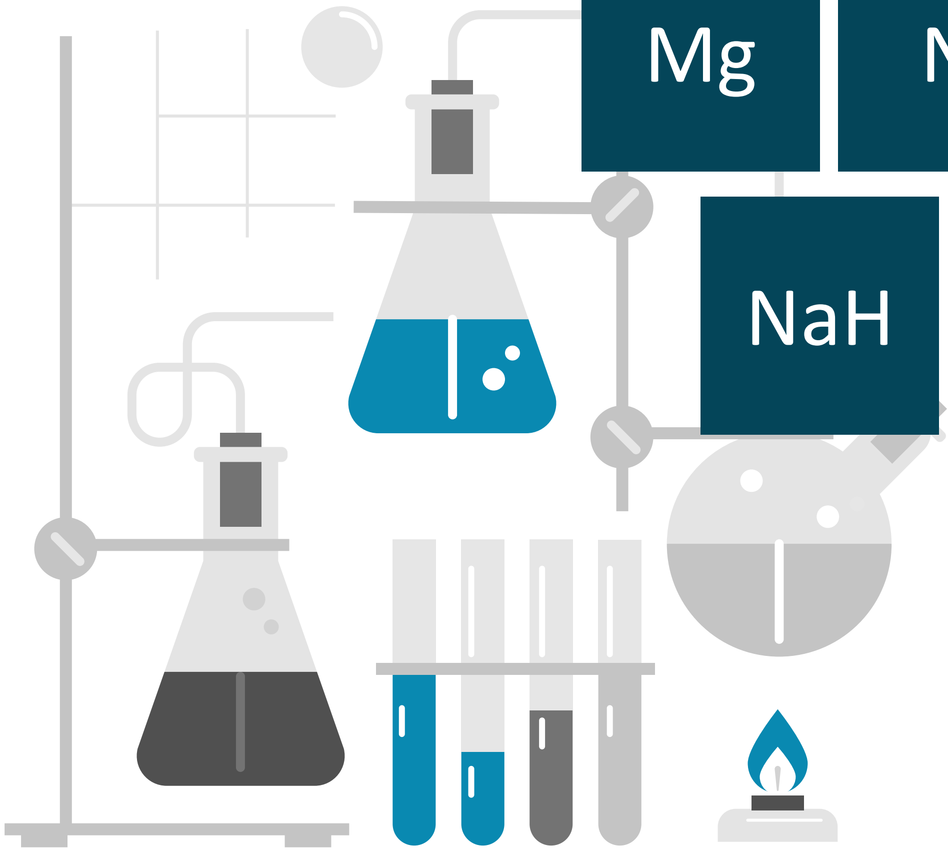
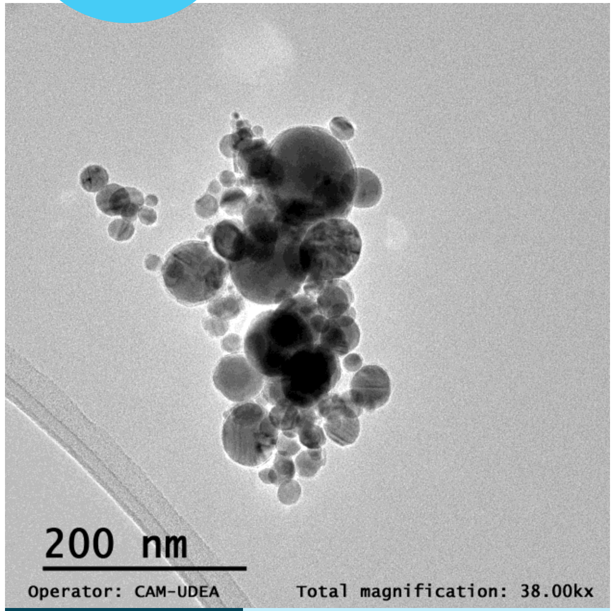
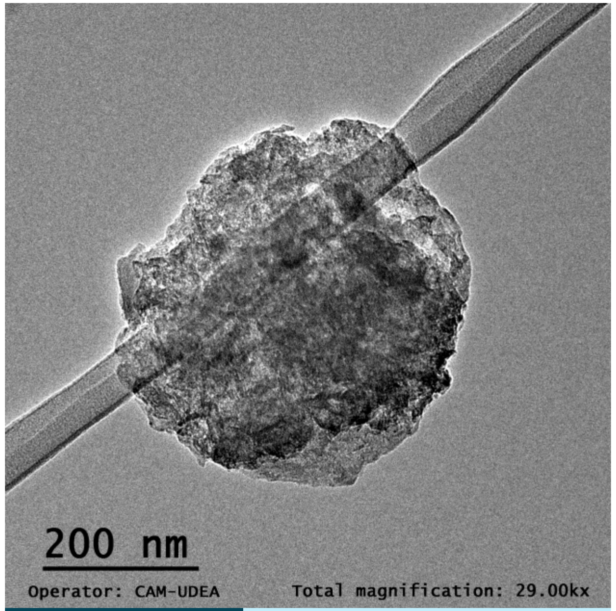
| | | | | |
|---|---|---|---|---|
| 12 Mg | 28 Ni | AlN | 14 Si | 27 Ti |
| NaH | KH | $CaH_2$ | 41 Nb | |

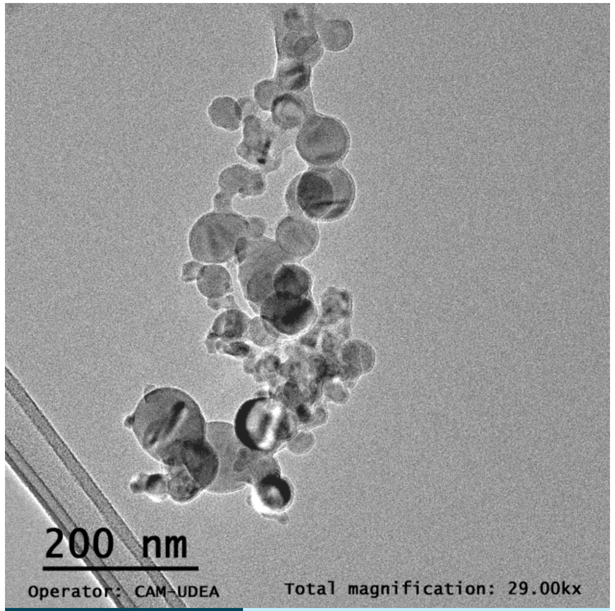


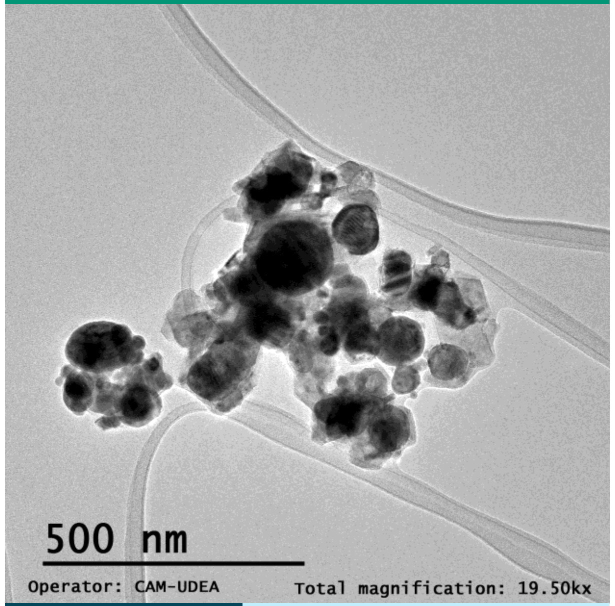
# Results | Starting materials

Controlled oxidation in oxygen rich atmosphere




| | |
|---|---|
| 28 Ni | 28,3 ± 16,1 nm |
| AlN | 362,5 ± 184,6 nm |
| 14 Si | 53,9 ± 22,2 nm |
| 41 Nb | 59,5 ± 36,5 nm |

NaH

KH

$CaH_2$

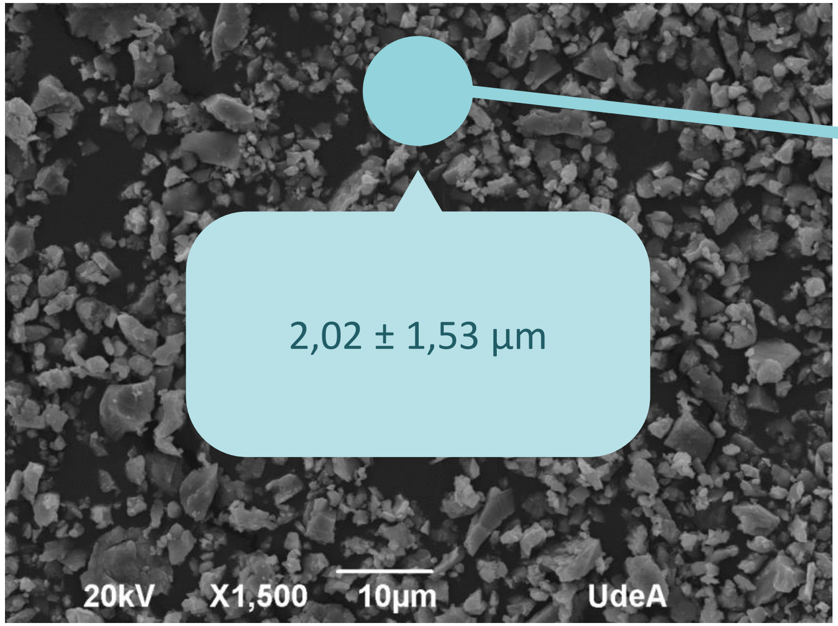
No NPs

# **Results** | Titanium NPs

Restrepo et. al. *Int J Adv Manuf Technol.* 2020

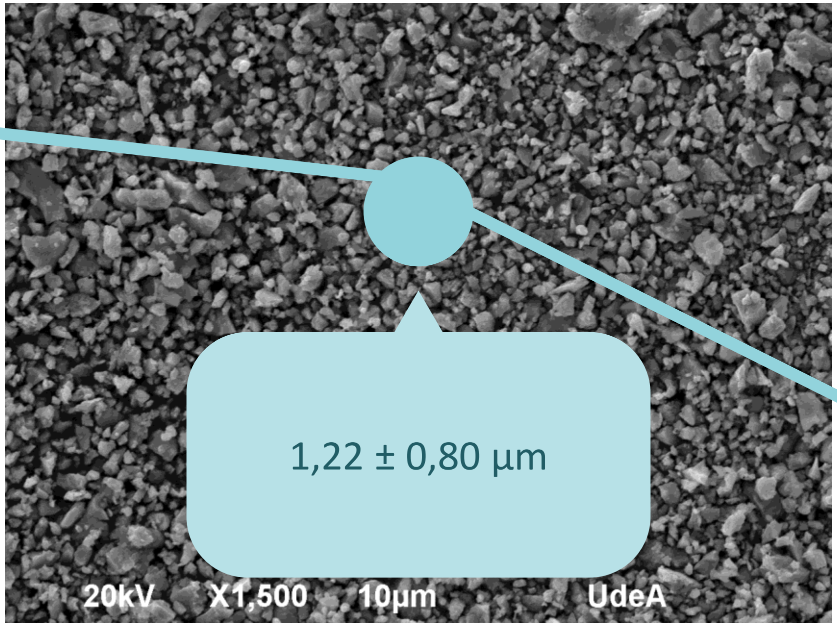


**10 mm, 6h**



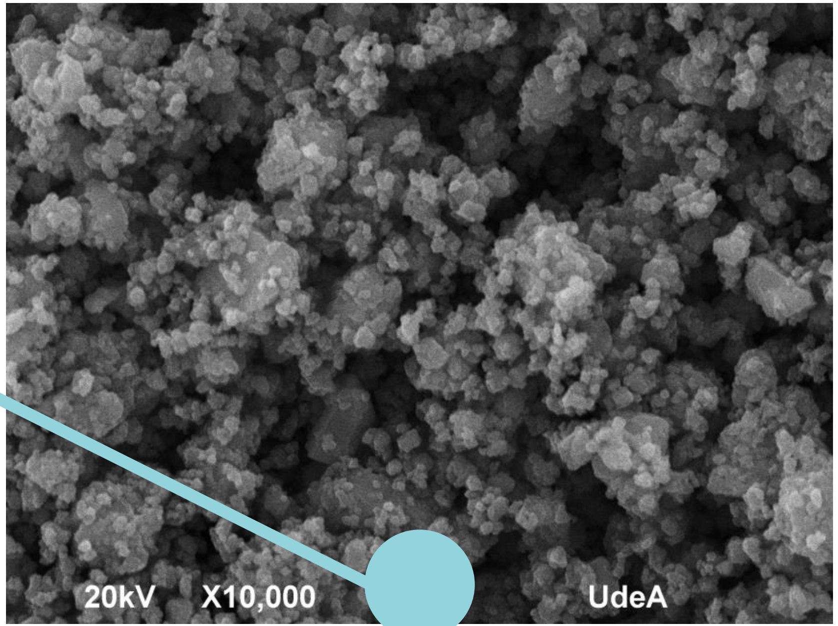

2,02 ± 1,53 µm

**3 mm, 6h**

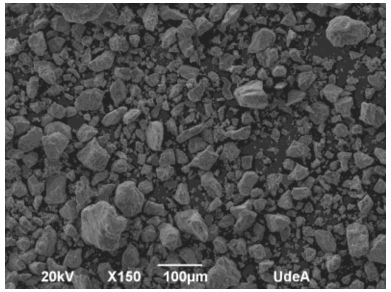



1,22 ± 0,80 µm

**1 mm, 6h**




171 ± 122 nm




Starting material

12
Mg

# Results | Magnesium HEBM

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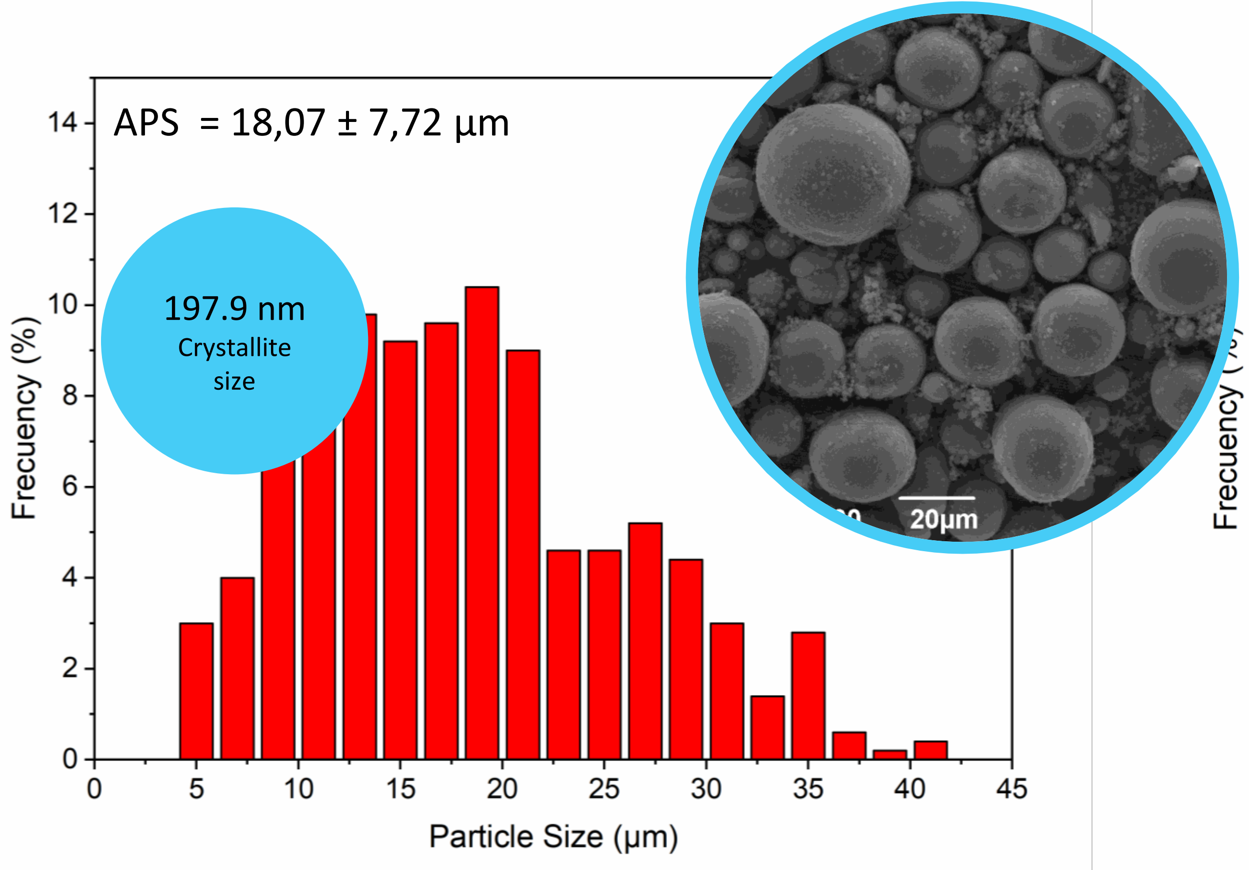


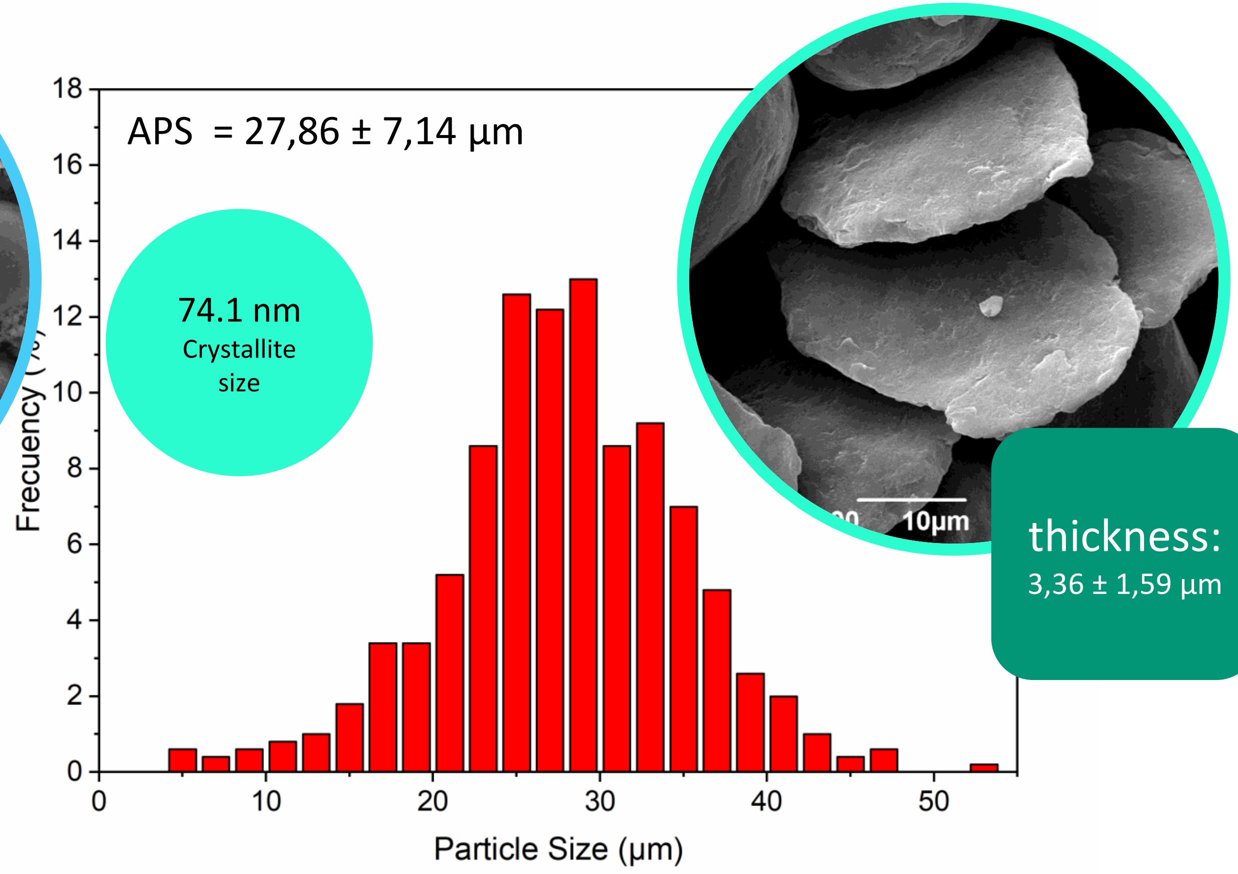


thickness:
3,36 ± 1,59 µm

12
Mg

# Results | Synthesis routes

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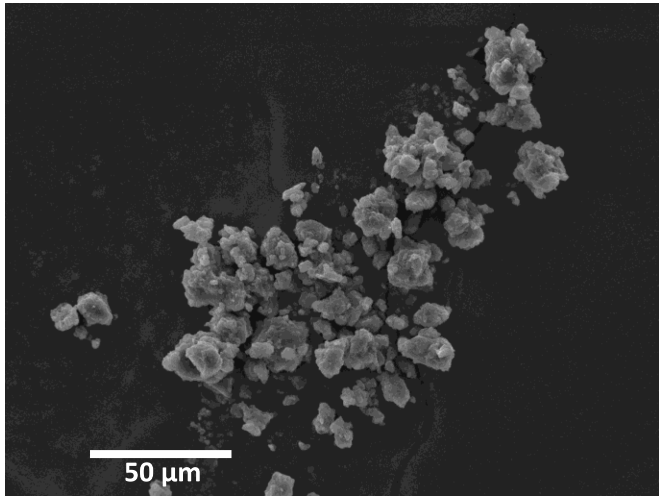
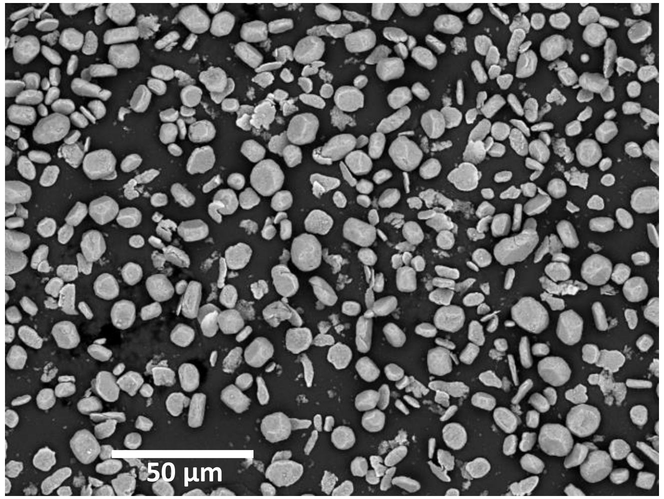
Sieverts type apparatus




| Sonochemistry | Cryo-milling | Three-step process |
|---|---|---|
| • Ultrasound probe<br>• $MgCl_2$ + LiH | • Milling with $LN_2$<br>• cp-Mg | • Emax - Sieverts<br>• cp-Mg |

12
Mg

# Results | Three-step process

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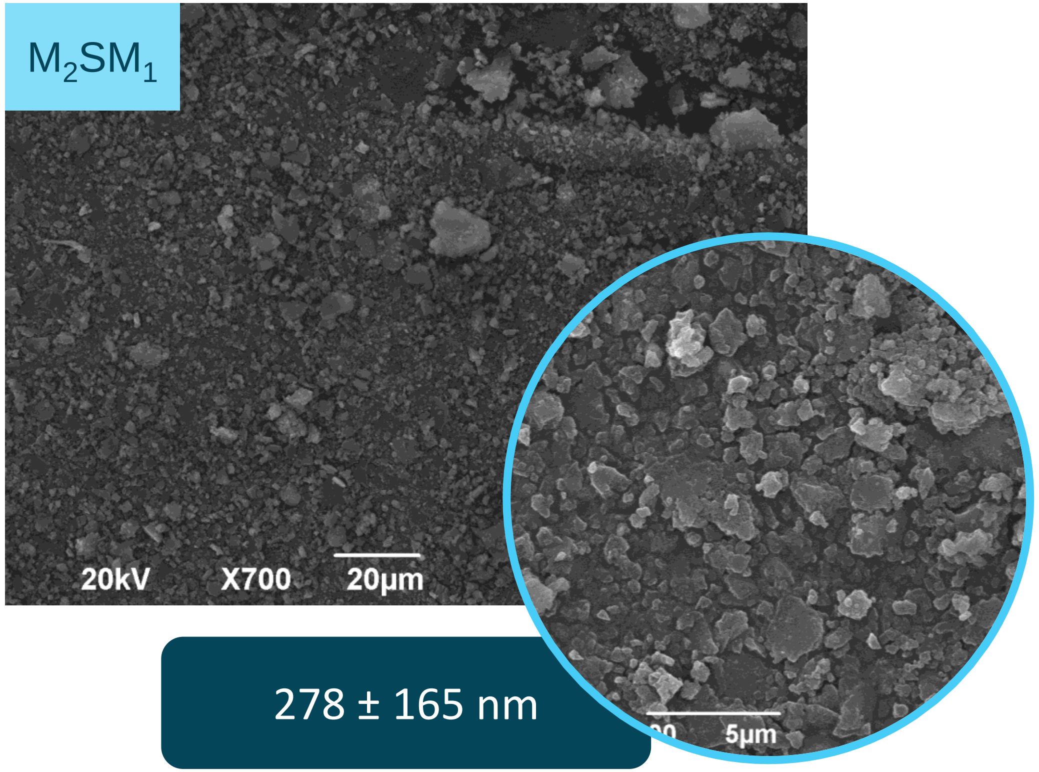
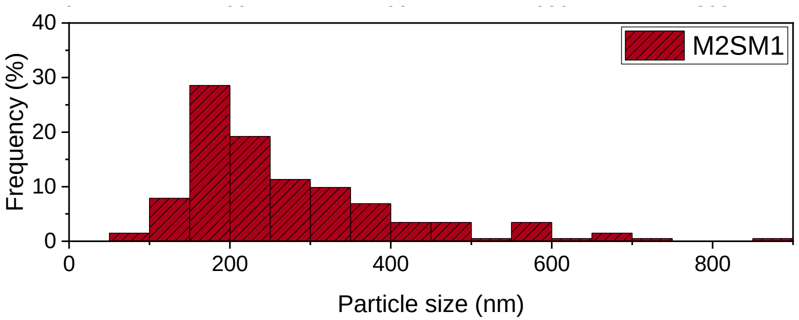
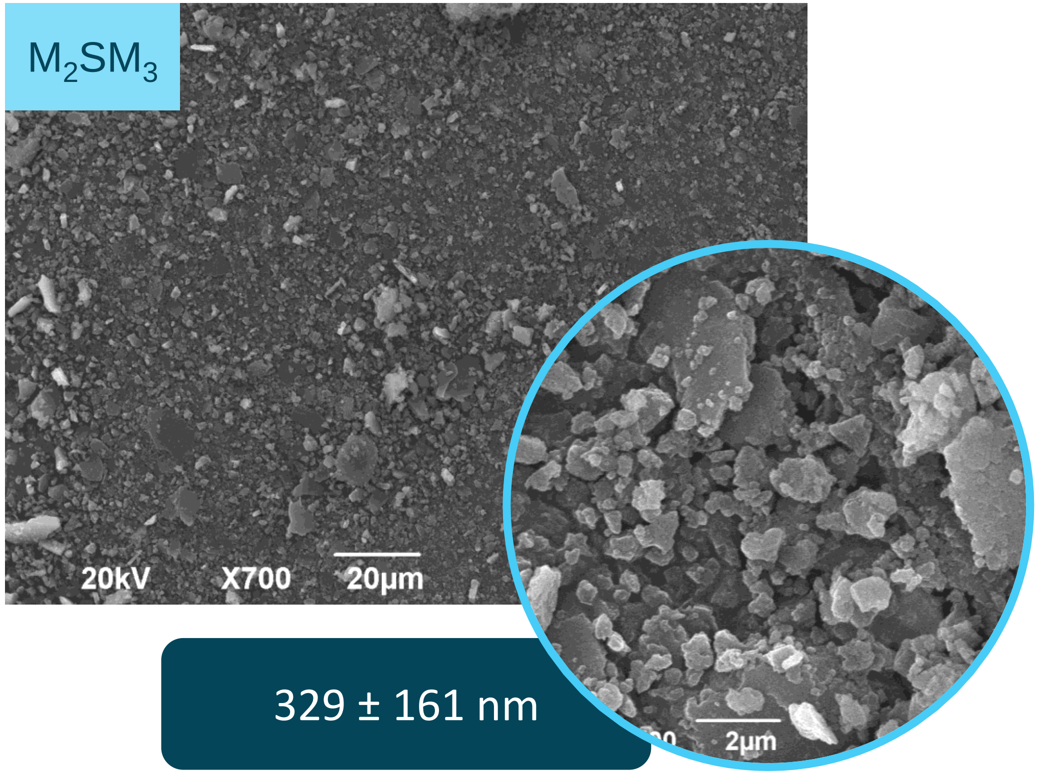
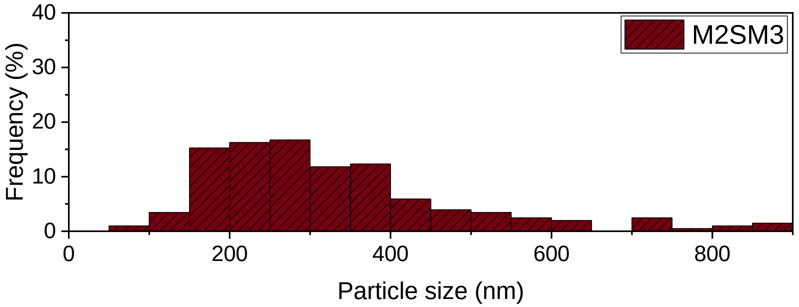



278 ± 165 nm




329 ± 161 nm



12 Mg

# Results | Two-step ball milling

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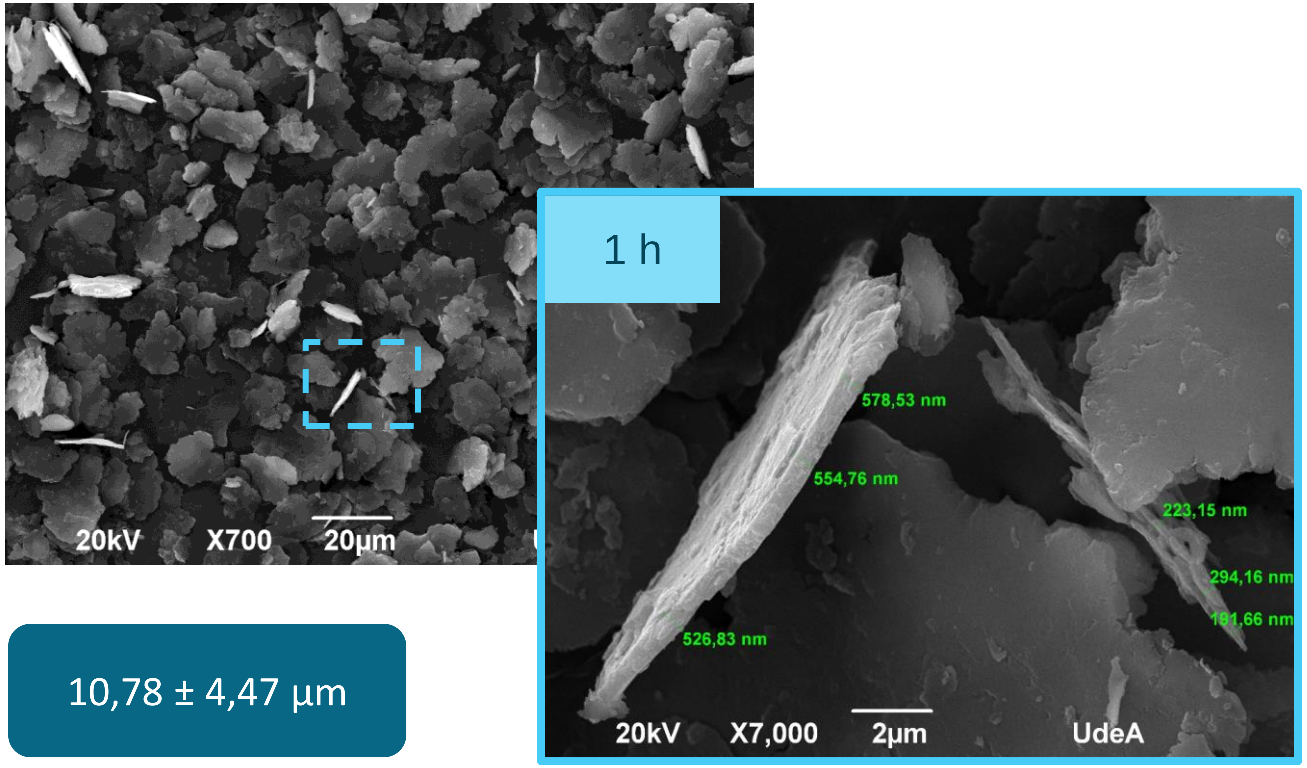
- Mg cp
- $ZrO_2$ Balls and Jar
- 1400 rpm

**1st milling**

**2nd milling**

- Mg from 1st step
- $ZrO_2$ Balls and Jar
- 1400 rpm




10,78 ± 4,47 μm

Rios et. al. *Int J Adv Manuf Technol.* 2022

12 Mg

# **Results** | Two-step ball milling

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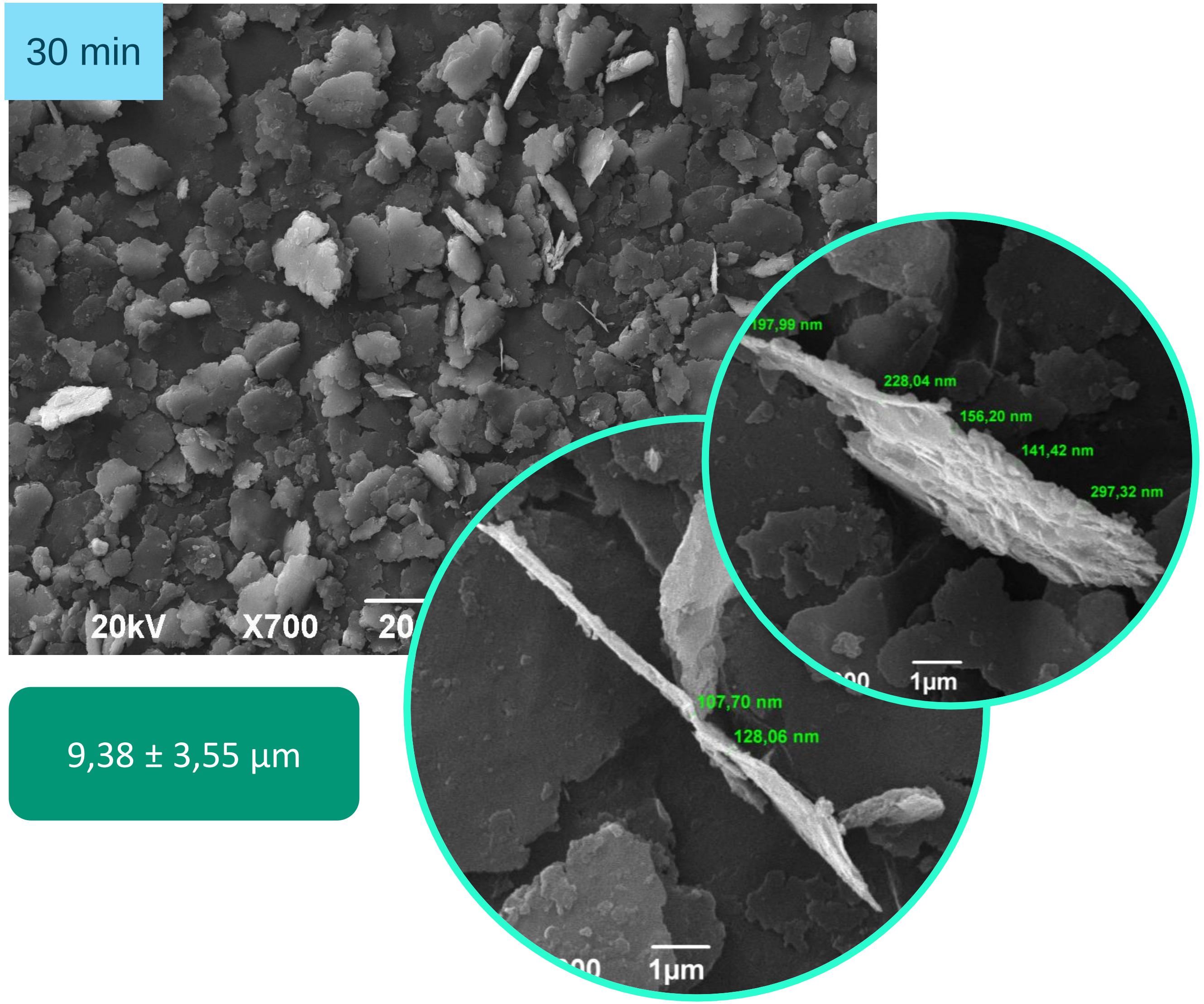
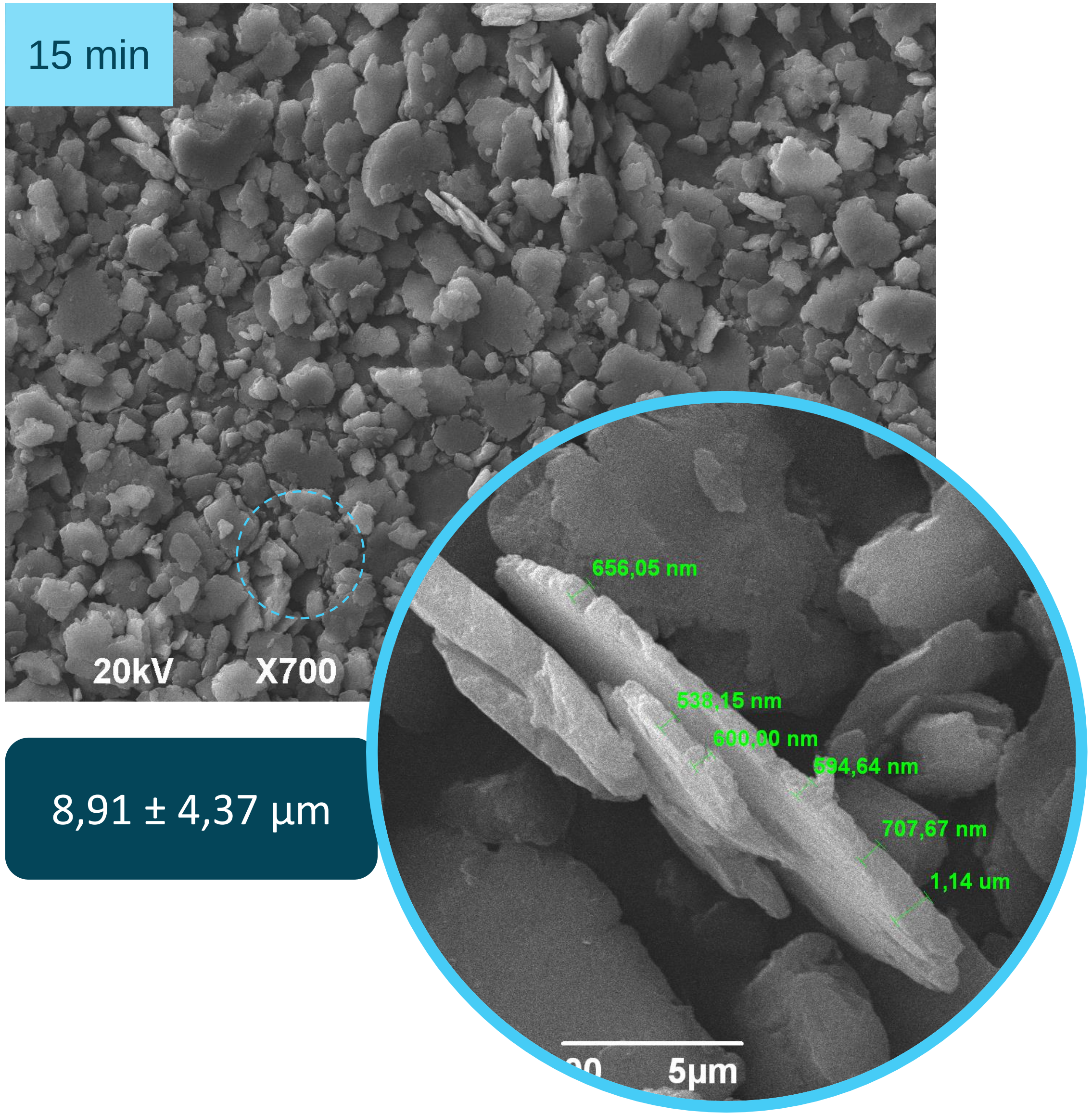
30 min




9,38 ± 3,55 µm

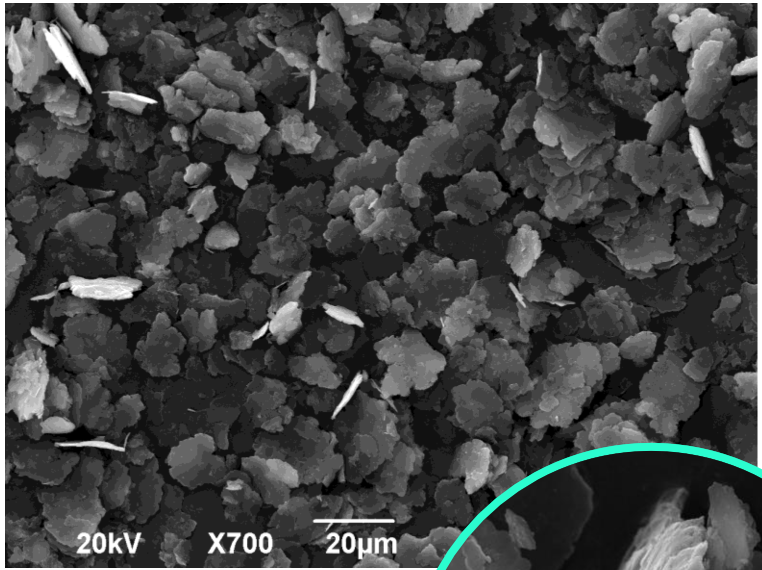
15 min

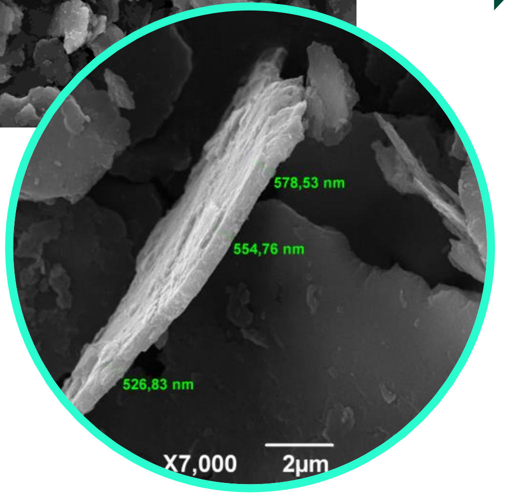



8,91 ± 4,37 µm

# Results | Mg-15%Ni (flakes)

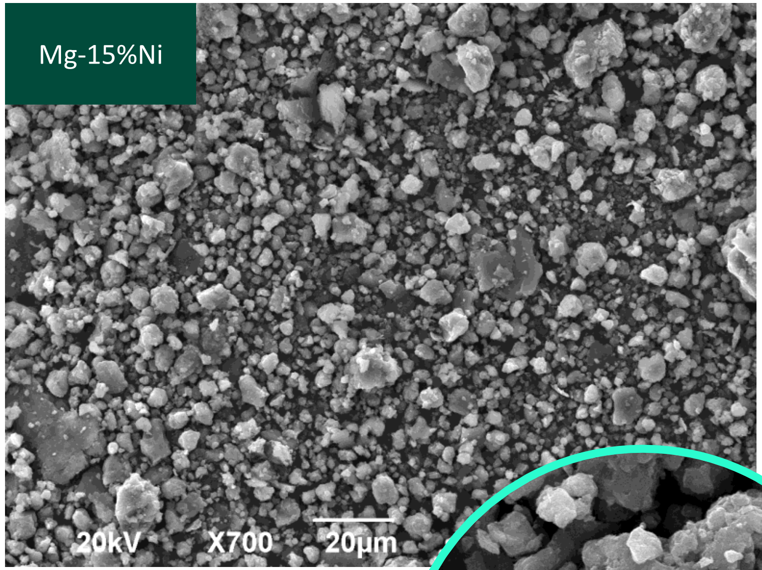
UdeA

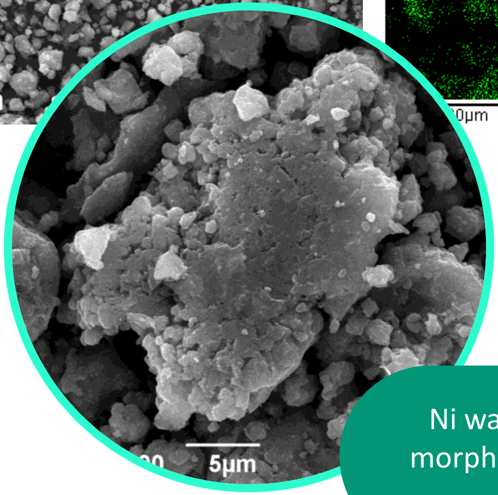


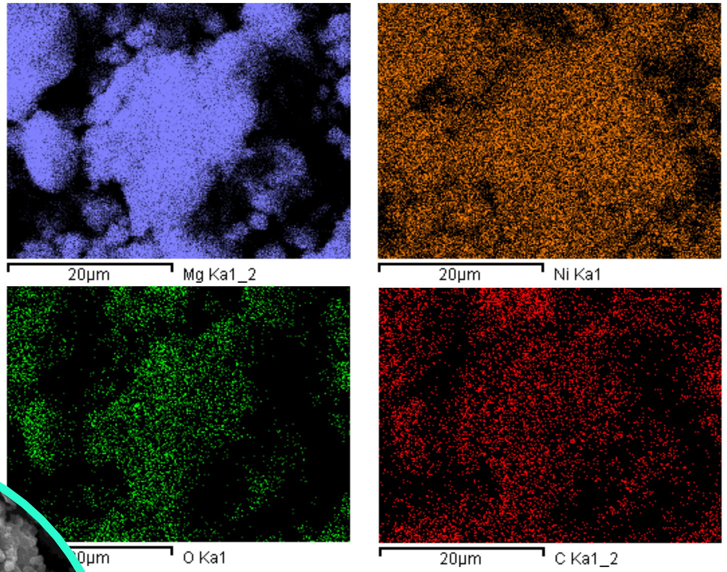

10,78 ± 4,47 µm

+Ni



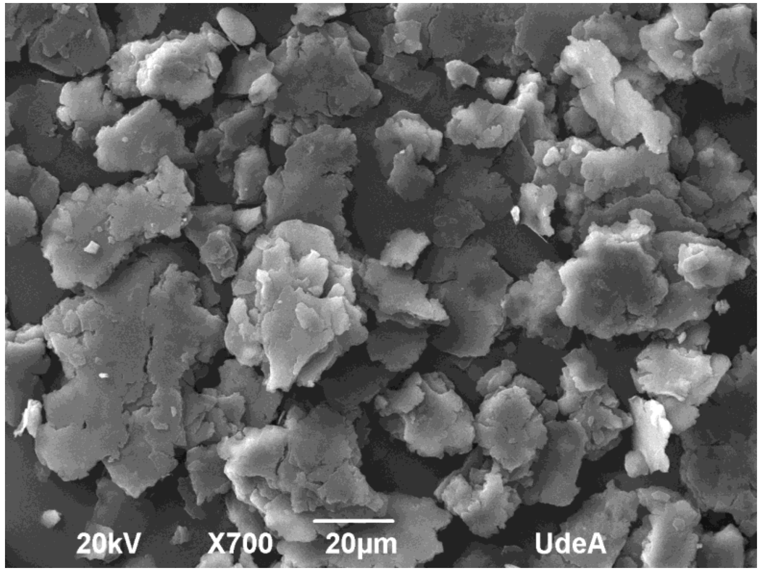

2,46 ± 1,26 µm




Ni was dispersed but morphology underwent alteration

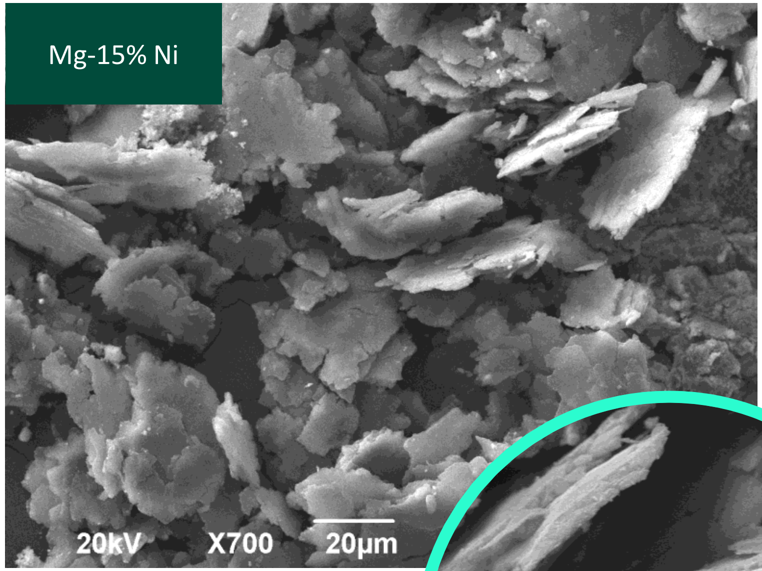
# Results | Blending vs. milling



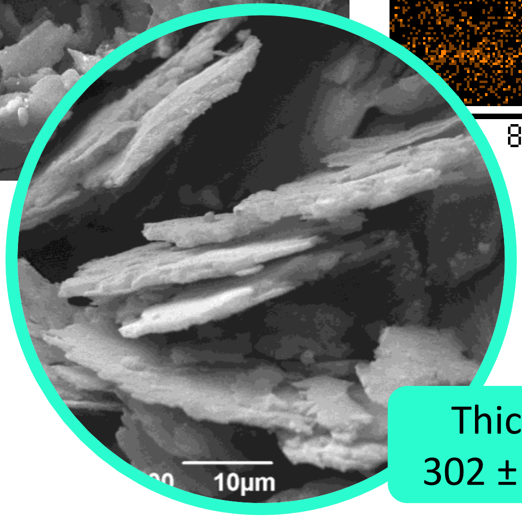



14,42 ± 5,94 μm

+Ni

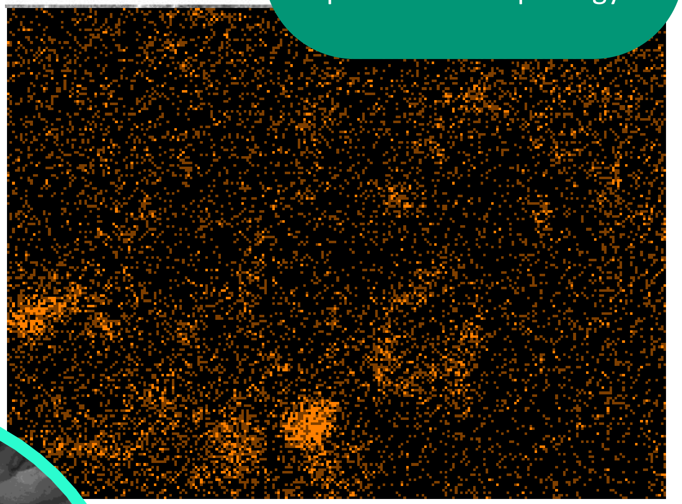



18,92 ± 7,59 μm




Thickness:
302 ± 127 nm

Dispersed Ni and preserved morphology



# Results | Preliminary hydrogen tests

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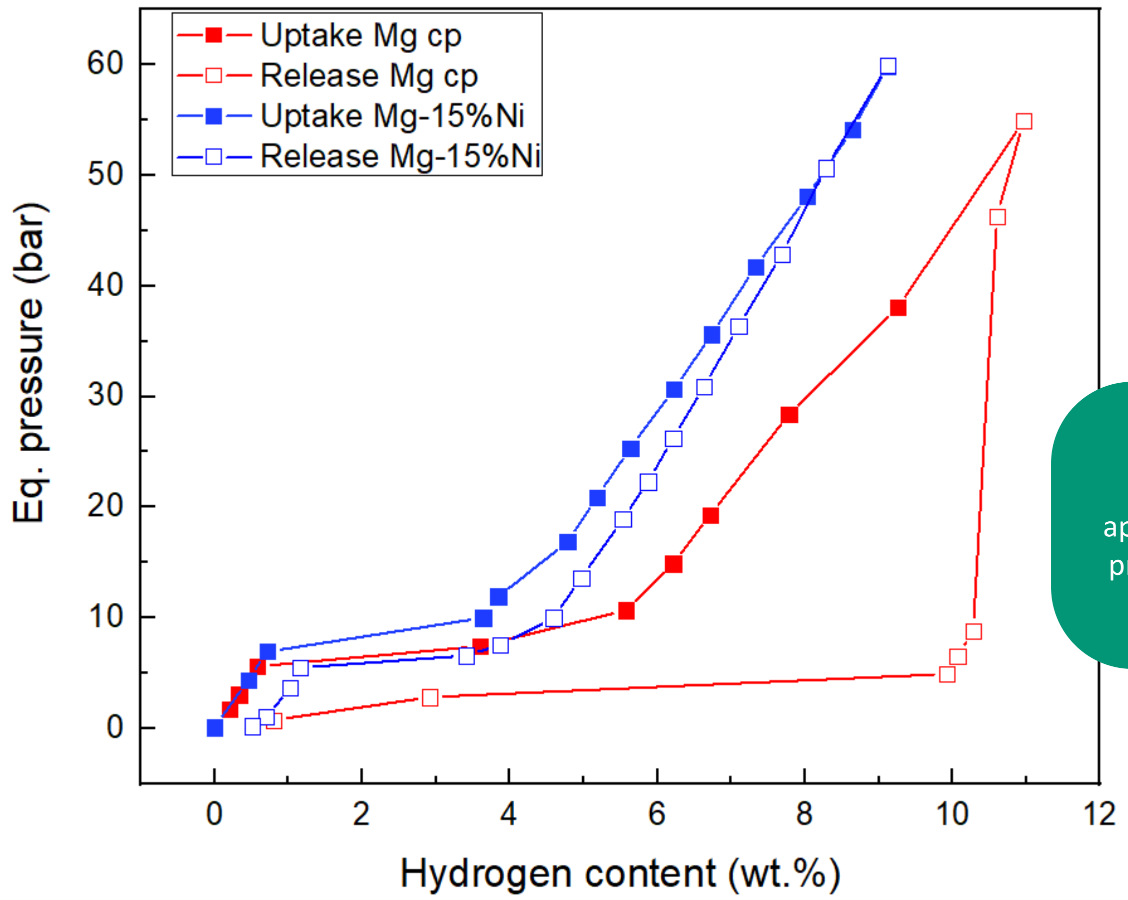
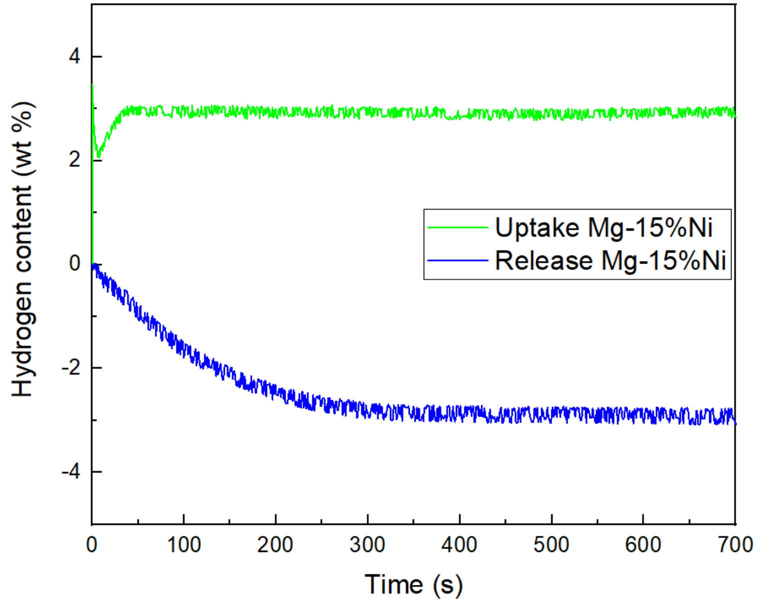
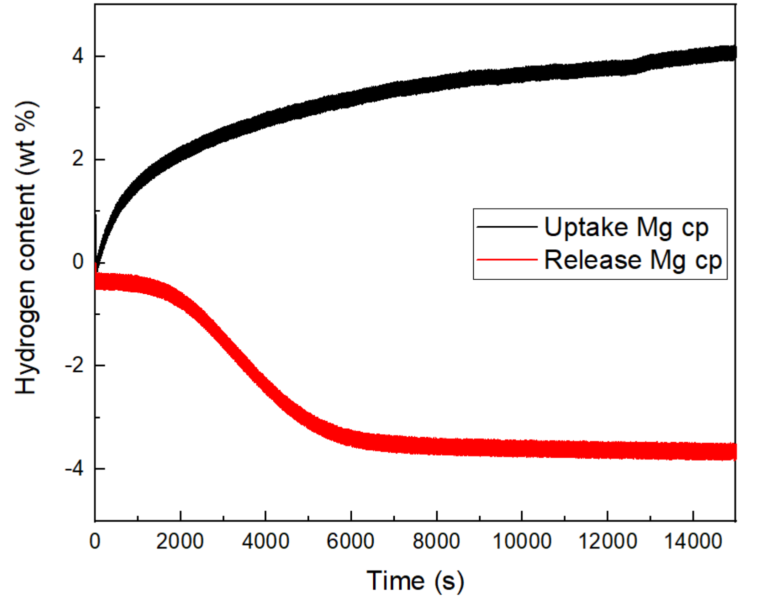
350°C

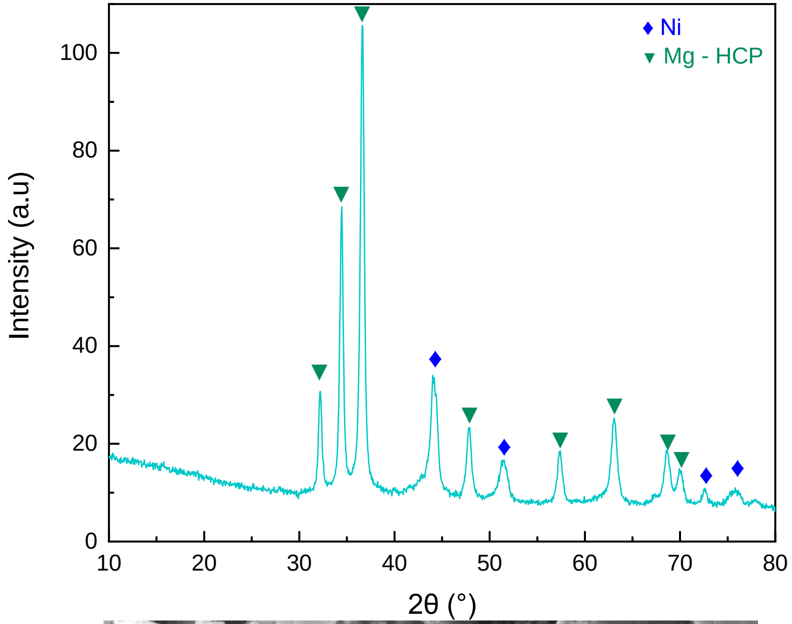


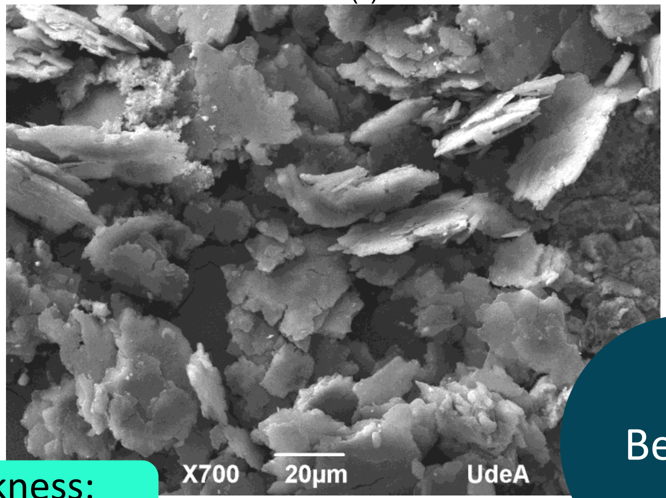

Sieverts type apparatus requires proper calibration



# Results | Preliminary hydrogen tests

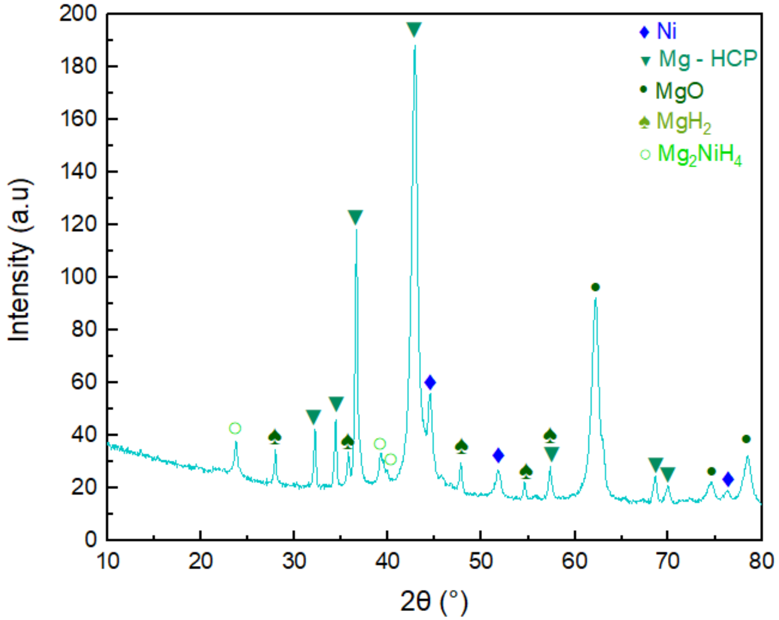


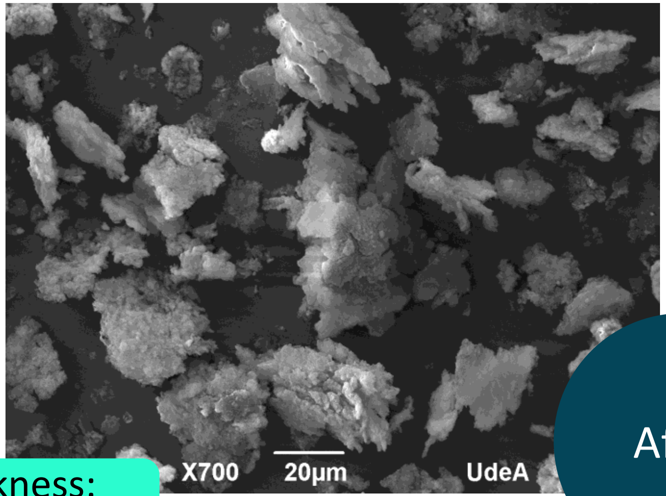




Thickness:
302 ± 127 nm

Before

$H_2$
tests




Thickness:
426 ± 111 nm

After

# Future steps



| | | | |
|---|---|---|---|
| **Preliminar** | Sieverts calibration | Flakes - Ni system evaluation | |
| **Materials** | Flakes - Si, Ti, AlN blending | Flakes - NaH, KH, $CaH_2$ blending | $Nb_2O_5$ addition |
| **Characterization** | Storage performance (Sieverts) | XRD, SEM-EDS | |

UdeA

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