# MECHANICAL ALLOYING OF MG-ZN-CA-ER ALLOY

Politechnika Śląska


## ABSTRACT

Magnesium-based materials are promising alternatives for medical applications, due to their characteristics, such as good mechanical and biological properties. Which opens many possibilities for biodegradable materials to be used as less-invasive options for treatment. The degradation is prompted by its chemical composition and microstructure. Both those aspects can be finely adjusted by proper manufacturing process, such as mechanical alloying. Furthermore MA allows for alloying of elements, that normally would be really hard to mix due to their very different properties. Magnesium usually needs various alloying elements, which can further increase its. Alloying magnesium with rare earth elements is considered to greatly improve the aforementioned properties. Due to that fact erbium was used as one of the alloying elements, alongside zinc and calcium in order to obtain $Mg_{64}Zn_{30}Ca_4Er_1$ alloy via mechanical alloying. The alloy was milled in the SPEX 8000 Dual Mixer/Mill high energy mill under argon atmosphere for 8, 13 and 20 hours. It was assessed by X-ray diffraction, energy dispersive spectroscopy, granulometric analysis and hardness. The hardness values reached 232, 250 and 302 HV respectively, which is closely related to their particle size. The average particle sizes were 15, 16 and 17 μm respectively.


## AIM

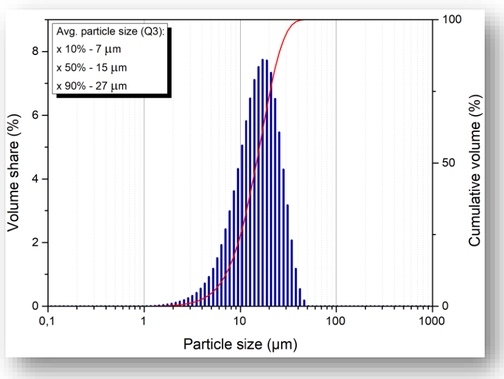
Analysis of the milling time effect on the $Mg_{65}Zn_{30}Ca_4Er_1$, and its morphology, phase and chemical composition, and hardness.

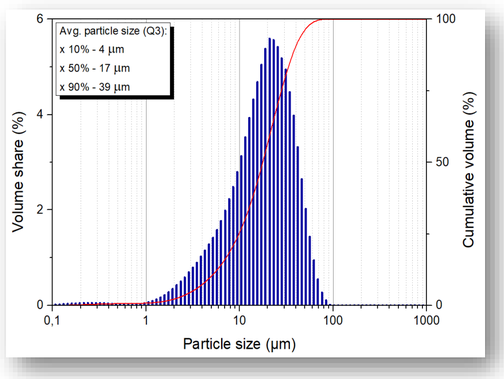
## METHODOLOGY

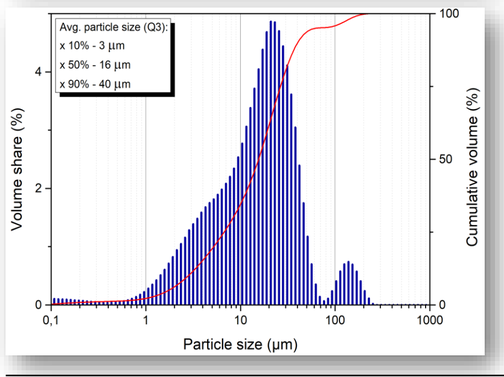
The powders were processed with a mechanical alloying process. The nominal composition of the alloy was $Mg_{65}Zn_{30}Ca_4Er_1$. The samples were alloyed in constant frequency with varying milling times of 8, 13 and 20 hours.

The phase analysis of the alloy was performed using the PANalytical Empyrean diffractometer with Cu-Ka radiation and PIXCell counter. Zeiss 35 scanning electron microscope equipped with energy-dispersive spectroscopy was used to assess the morphology of the obtained powders. Particle size distribution of the alloys powders was measured using the Fritsch Analyssette 22 MicroTec+ in ethyl alcohol. The hardness test was performed on Future-Tech FM700 Vickers hardness tester with 15 seconds dwell time and 50 grams of force (HV0.05). The phase analysis of substrates and milling products were performed with a High Score Plus PANalytical software integrated with the ICDD PDF4+ 2016 data base.

## RESULTS



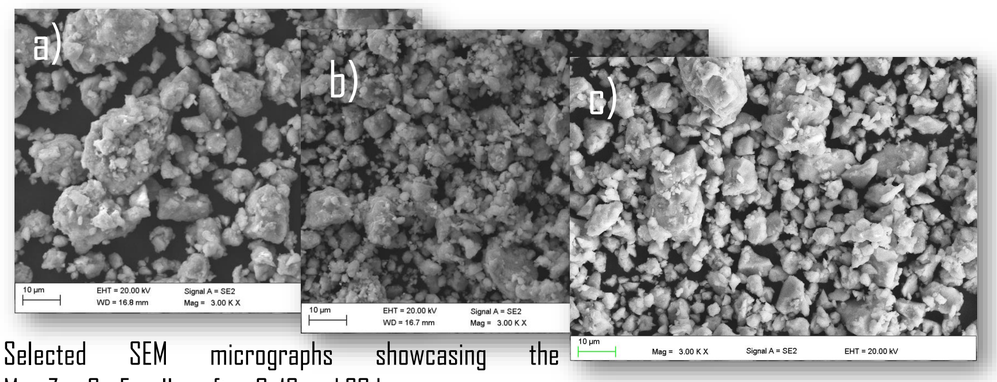



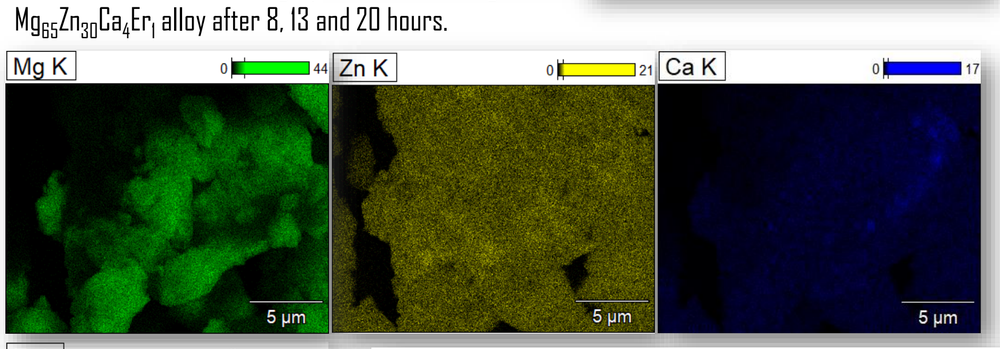

Particle size volume share (histogram) and their cumulative distribution (curve) for $Mg_{65}Zn_{30}Ca_4Er_1$ alloy milled for a) 8, b) 13 and c) 20 hours.

Hardness test results and average particle size for samples milled for 8, 13 and 20 hours.

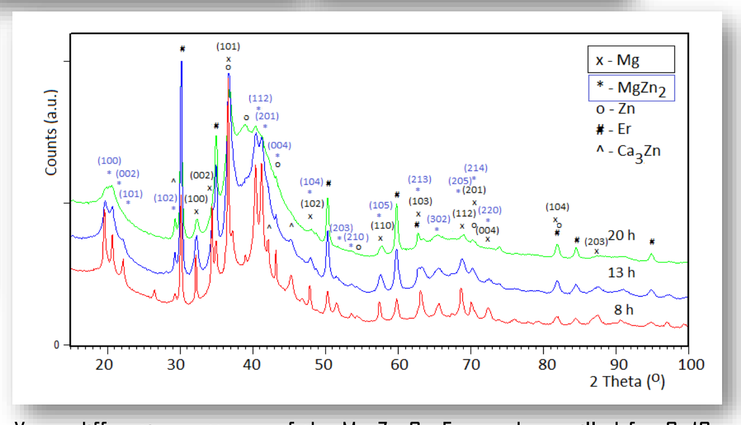
| Sample | Hardness (HV 0.05) | | | | Avg. particle size [μm] |
|---|---|---|---|---|---|
| | Exp.1 | Exp.2 | Exp.3 | Avg. | |
| **$Er_1$8** | 198 | 246 | 253 | 232 ± 24 | 15 ± 0.8 |
| **$Er_1$13** | 253 | 265 | 233 | 250 ± 13 | 16 ± 1.8 |
| **$Er_1$20** | 302 | 294 | 309 | 302 ± 6 | 17 ± 1 |




Selected SEM micrographs showcasing the $Mg_{65}Zn_{30}Ca_4Er_1$ alloy after 8, 13 and 20 hours.




EDS elemental mapping for $Mg_{65}Zn_{30}Ca_4Er_1$ milled for 20 h featuring unreacted erbium phase (Fm3m).




X-ray diffraction patterns of the Mg-Zn-Ca-Er powders milled for 8, 13 and 20 h.

## CONCLUSIONS

$Mg_{65}Zn_{30}Ca_4Er_1$ was prepared and milled for 8, 13 and 20 hours. As following, the effect of milling time on $Mg_{65}Zn_{30}Ca_4Er_1$ alloy was investigated, as well as its morphology after milling, hardness, chemical and phase composition.

The particles of the milled powders are characterized by size in range of 10 to 60 μm, with 15, 16 and 17 μm of average values for 8, 13 and 20 hours of milling time. Although different the average values are in the error range, hence it can be said that they are statistically similar. Basing on this statement it can be concluded, that the powders reached the moment of further refining instead of decreasing in size, although the finer particle share increases with milling time. The Vickers hardness tests yielded results of 232, 250 and 302 HV respectively, showing that the hardness increases with the milling time. The EDS studies revealed the stability of chemical composition, and SEM micrographs show an uniform distribution of fine particles. SEM analysis has confirmed the presence of unreacted erbium (Fm3m, cubic structure).

## AUTHORS


Bartłomiej Hrapkowicz, Sabina Lesz, Marek Kremzer, Małgorzata Karolus, Wojciech Pakieła

*bartlomiej.hrapkowicz@polsl.pl*



**ACKNOWLEDGEMENT**

This research was funded by the National Science Center, Poland, grant no. 2017/27/B/ST8/02927.


APMME 2021