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Polish Academy of Sciences

Nanoparticles with precisely regulated size

Collaboration offer for the European Nanomedicine Technology Platform Partners

- Application of nanomaterials
- Delivering of nanoparticles for modelling studies
- Studying nanoparticle size dependent properties
- Developing of new nanomaterials
- Scaling up nanomaterials
- High quality nanomaterials characterisation
- Joint projects

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Nanoparticles for research on size effects in nanoscale

Precise regulation of crystallites size permits to:

- compare real properties with these from modelling experiments
- measure size dependent properties

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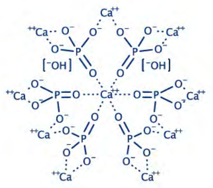
HAP with particle size from 8 to 39 nm

Hydroxyapatite
or Hydroxylapatite
HAP
$Ca_{10}(PO_4)_6(OH)_2$



Source : https://www.chromspheres.com/nano-hydroxyapatite-powder/

Crystallite (particle) size of hydroxyapatite nanoparticles (GoHAP™)
produced in the Laboratory of Nanostructures and Nanomedicine IHPP PAS

GoHAP™ type	SSA[1] [m^2/g]	Density [g/cm^3]	Grain size, from SSA[2] [nm]	Grain size, from XRD[3] d_l; d_w[4] [nm]	Grain size, from TEM, [nm][5]
GoHAP™ 1	258 ± 25	2.86 ± 0.02	8 ± 1	19 ± 9; 6 ± 2	6,5 ± 0.5
GoHAP™ 2	211 ± 20	2.92 ± 0.02	10 ± 1	24 ± 9; 7 ± 5	7.3 ± 0.3
GoHAP™ 3	149 ± 14	2.95 ± 0.01	14 ± 1	28 ± 12; 14 ± 6	11.7 ± 0.03
GoHAP™ 4	85 ± 14	3.00 ± 0.01	23 ± 2	38 ± 17; 23 ± 6	18.4 ± 0.6
GoHAP™ 5	61 ± 6	3.03 ± 0.01	32 ± 3	50 ± 20; 30 ± 9	26.9 v 0.6
GoHAP™ 6	51 ± 5	3.04 ± 0.01	39 ± 4	60 ± 20; 33 ± 9	34.8 ± 0.9

[1] Specific Surface Area; [2]Calculated from SSA; [3]Calculated from XRD patterns using Scherrer's Formula; [4] ZnO crystallites have a hexagonal structure. d_a – size along the a axis ; d_c – size along the c axis; [5] Measured by means of TEM – Transmission Electron Microscopy.

Source: Influence of hydrothermal synthesis parameters on the properties of hydroxyapatite nanoparticles
Sylwia Kuśnieruk et al. , *Beilstein J. Nanotechnol.* 2016, *7,* 1586–1601. doi:10.3762/bjnano.7.153

GoHAP™ is a synthetic nanomaterial mimicking Hydroxyapatite (HAP) in human bone. It was successfully used for bone regeneration in many veterinary operations.

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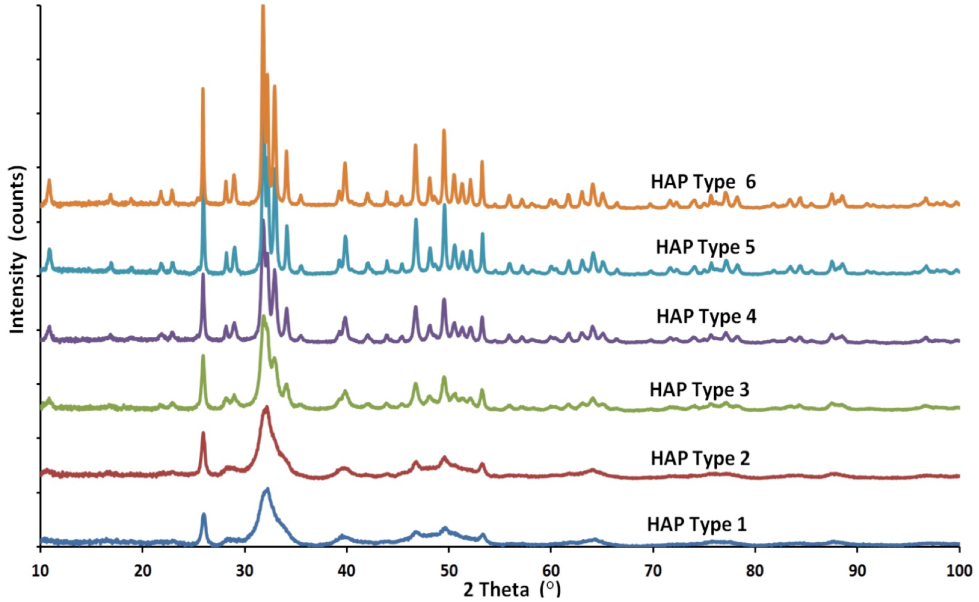
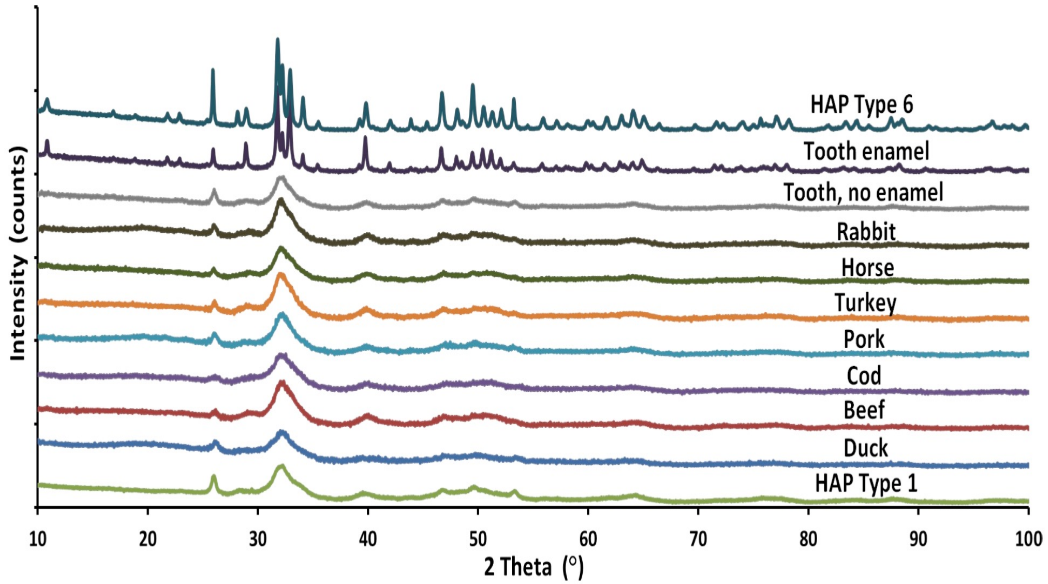
XRD patterns of synthetic GoHAP™ 1-6 and natural HAP





GoHAP™ 1 = natural bone. GoHAP™ 6 = tooth enamel

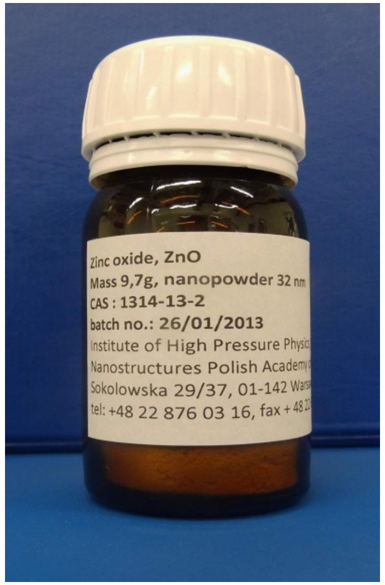
ZnO with particle size regulated from 16 to 43 nm

Crystallite (grain) size of ZnO nanoparticles produced in the Laboratory of Nanostructures and Nanomedicine IHPP PAS

ZnO type	SSA[1] [m^2/g]	Density [g/cm^3]	Grain size, from SSA[2], [nm]	Grain size, from XRD[3] d_a; d_c[4] [nm]	Grain size, TEM, [nm][5]
ZnO 1	74.7	5.12 ± 0.03	16 ± 1	16_a; 20_c	
ZnO 2	44.9	5.32 ± 0.03	25 ± 1	26_a; 37_c	
ZnO 3	28.9	5.40 ± 0.02	29 ± 1	34_a; 51_c	
ZnO 4	26.5	5.42 ± 0.04	43 ± 1	35_a; 51_c	
ZnO 5	25.9	5.42 ± 0.03	43 ± 1	35_a; 53_c	39.5 ± 0.5

[1] Specific Surface Area; [2]Calculated from SSA; [3]Calculated from XRD patterns using Scherrer's Formula; [4] ZnO crystallites have a hexagonal structure. d_a – size along the a axis ; d_c– size along the c axis; [5] Measured by means of TEM – Transmission Electron Microscopy.

Source: *Size control mechanism of ZnO nanoparticles obtained in microwave solvothermal synthesis*, Jacek Wojnarowicz *et al* 2018 *Nanotechnology* **29** 065601



Up to 115 nm achievable

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ZnO doped with Co^{2+} up to 10 wt%

Crystallite (particle) size of $ZnO_{0.9}Co_{0.1}$: nanoparticles produced in the Laboratory of Nanostructures and Nanomedicine IHPP PAS.

ZnO type	SSA[1] [m²/g]	Density [g/cm³]	Grain size, from SSA[2], [nm]	Grain size, from XRD[3] d_a; d_c [4][nm]	Grain size, TEM[5], [nm]
ZnO 1	42.6 ± 0.1	5.05 ± 0.04	28 ± 2	23_a; 26_c	23 ± 1
ZnO 2	37.3 ± 0.1	5.13 ± 0.03	31 ± 3	27_a; 27_c	31 ± 1
ZnO 3	31.7 ± 0.1	5.26 ± 0.03	36 ± 3	28_a; 33_c	34 ± 1
ZnO 4	28.8 ± 0.1	5.30 ± 0.03	39 ± 3	30_a; 37_c	38 ± 1
ZnO 5	21.2 ± 0.1	5.35 ± 0.02	53 ± 3	36_a; 50_c	52 ± 3

[1] Specific Surface Area; [22]Calculated from SSA; [3]Calculated from XRD patterns using Scherrer's Formula; [4] ZnO crystallites have a hexagonal structure. d_a – size along the a axis ; d_c– size along the c axis; [5] Measured by means of TEM – Transmission Electron Microscopy.
Source: Size Control of Cobalt-Doped ZnO Nanoparticles Obtained in Microwave Solvothermal Synthesis; Jacek Wojnarowicz et al. 2018 *Crystals* ***8***, 179; doi:10.3390/cryst8040179

Mn^{2+} as well as
Mn^{2+} &Co^{2+} cooping
Available

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Antibacterial ZnO: 2 wt% Ag nanoparticles with grain size from 22 to 38 nm

Crystallite (particle) size of ZnO: 2 wt% Ag nanoparticles produced in the Laboratory of Nanostructures and Nanomedicine IHPP PAS.

ZnO type	SSA[1] [m^2/g]	Density [g/cm^3]	Grain size, SSA[2], [nm]	Grain size, XRD[3] d_a; d_c; d_{Ag}[4] [nm]
ZnO 1	50.7 ± 0.1	5.32 ± 0.01	22 ± 2	21_a; 25_c $28\text{-}57_{Ag}$
ZnO 2	38.4 ± 0.1	5.40 ± 0.03	30 ± 3	25_a; 38 $25\text{-}57_{Ag}$
ZnO 3	31.8 ± 0.1	5.40 ± 0.03	35 ± 3	31_a; 45_b $25\text{-}57_{Ag}$
ZnO 4	29.0 ± 0.1	5.43 ± 0.01	38 ± 3	34_a; 52_b $25\text{-}57_{Ag}$

[1] Specific Surface Area; [2] Calculated from XRD patterns using Scherrer's Formula . [2] ZnO crystallites have a hexagonal structure. d_a – size along the a axis ; d_c – size along the c axis; d_{Ag} – size of the Ag nanocrystalsSource: Internal report of Laboratory of Nanostructures, IHPP PAS, author J. Wojnarowicz

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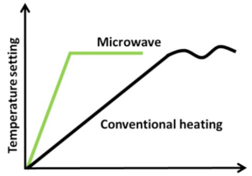
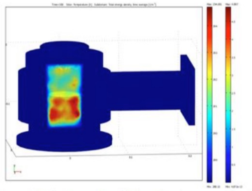
Particle size control and high yield production using MSS Reactors for Microwave Solvothemal Synhesis

MSS-4 reactor

MSS -2 reactor

- T max = 250°C, P max = 6 MPa,
- Teflon vessels volume 0,3 l
- Heating rate up to 1,8 K/s
- Process duration is controlled with high accuracy
- High power density delivered in the reagents: approximately 10 W/ml
- Developed in collaboration with Lukasiewicz – Institute of Sustainable Technologies





. Postprocessing plot of total energy density [J/m³] in model and temperature [K] inside the cup with water at time 300 seconds

The production process is clean, in a rigid technological regime, reproducible and scalable

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Nanomaterials characterisation services offered by Labnano

- Particle size distribution, by several methods
- Specific surface, surface energy, nano and micro porosity
- Zeta potential
- Suspensions stability
- Chemical composition, Phase composition
- TEM, FE SEM, EDS, XRD
- TG+DSC+FTIR+MS
- Selected optical properties
- Other

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Collaboration offer
Bilateral or in joint EU projects.

- Delivering of nanoparticles for modelling studies and size dependent properties
- Developing of new nanomaterials
- Investigation of size dependent properties
- Scaling the nanomaterials rial production to industrial scale
- Joint projects on nanomaterials application
- High quality characterisation of nanoparticles

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