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ADVANCED RESEARCH IN NANOTECHNOLOGY:

Synthesis and Study of Zn Ultrafine Particles Manufactured via the Flow-Levitation Method

Background

Ultrafine Zn powders (Zn UFPs) are used in a wide variety of applications in **medicine, engineering and science**. They prove to be useful, for example, in medicine to combat diarrhea, in engineering for the manufacturing of rechargeable alkaline zinc-air batteries, metal cladding lubricants, cold zincing compounds for corrosion protection, semiconductor electronics, optoelectronics, photo-catalysis, catalysis for fuel conversion, in microbiology science, etc. Application success depends highly on structural characteristics and morphology of constituent nanoparticles which in turn depend on manufacturing factors present during the synthesis.

The study of physical properties of Zn UFPs, their characterization, and innovative techniques to synthesize them have been themes of extensive research worldwide.

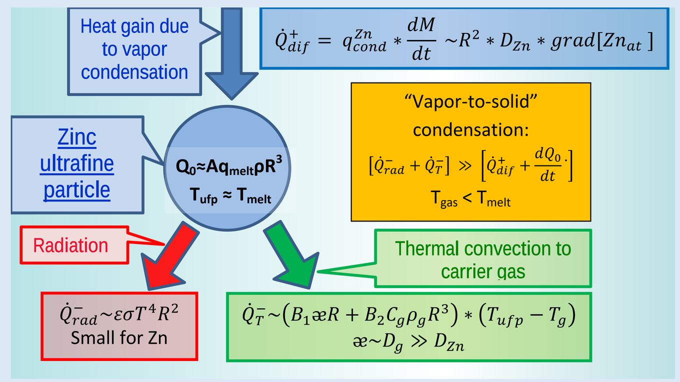
Extensive research has also been published about manufacturing methods to synthesize metal Zn UFPs and nano-scaled powders.

The Guen-Miller FL method proves to be a highly versatile manufacturing technique to achieve customized and uniform characteristics of constituent nanoparticles of Zn UFPs

Abstract

Samples of **Zn UFPs** with average **nanoparticle** sizes ranging between 0.175 µm and 1.24 µm were synthesized under various fabrication conditions. The influence of **thermo-physical properties of the carrier gas, operating pressure, flow regimes and rate of feed metal** on the particle growth of Zn UFPs were identified via characterization and analysis adduced from scanning electron microscopy **(SEM)** and X-ray diffraction **(XRDA).**

Mathematical model of Zn nanoparticles condensation process



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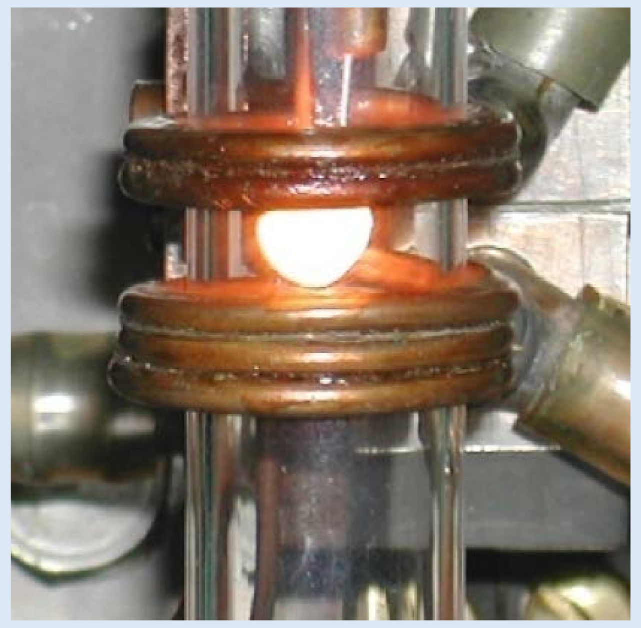
Objective of this research: Identify and evaluate the effects of manufacturing factors influencing size, shape and structure of nanoparticles in Zn UFPs synthesized via the ***Guen-Miller Flow-Levitation*** (FL) method.



The Guen-Miller FL method: **invented in Russia** and **unknown in the US**.

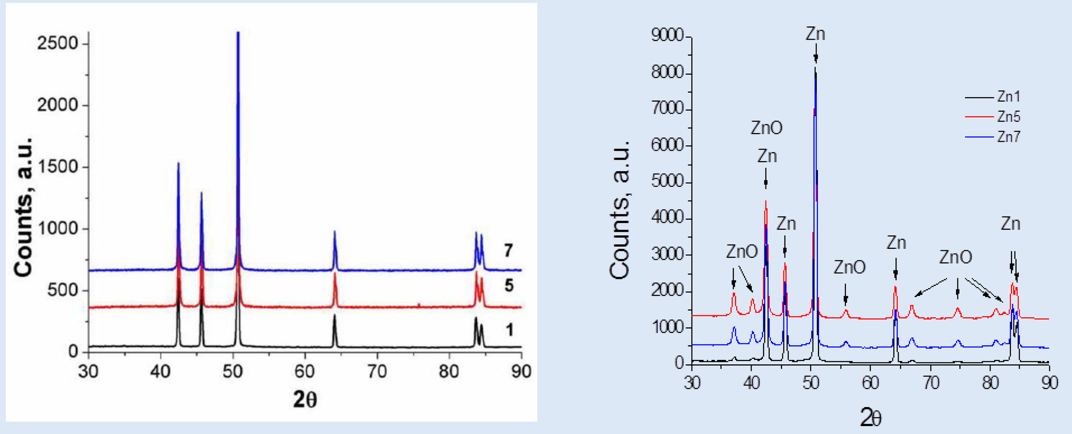
A drop of molten material levitates in a high-frequency electromagnetic field. Vapors then condense homogeneously into nanoparticles in an inert carrier gas flow.

Zn particles manufacturing parameters and particles characteristics

Sample	$\langle D\rangle/\langle D\rangle_m$, µm	S_{sp}, m^2g^{-1} and $\langle D\rangle_s$, µm	Manufacturing parameters			
			P, atm	H_2 feed rate, st. ccm	Inert gas type and feed rate, st. ccm	Zn wire feed rate g h^{-1}
Zn1	1.24/3.17(spheres) 0.269/0.48(crystal)		1	670	**Ar,** 6700	15
Zn2	0.46/1.58 (spheres) 0.24/0.41 (crystal)	2.16±0.16 0.390	0.5	1600	**Ar,** 4100	20.3
Zn3	0.24/0.56	3.5±0.5 0.24	0.5	24000	0	20.3
Zn4	0.21/0.766	5.0±1.0 0.170	0.25	15000	0	20.3
Zn5	0.175/0.230		0.25	3900	**He**, 7800	27.1
Zn6	0.198/0.30		0.25	11700	0	27.1
Zn7	0.21/0.33		0.25	11700	0	27.1

* The temperature of levitating drop was slightly higher than Zn melting point (420°C).

Methods of Characterization and Analysis, and apparatuses used: **SEM:** Phylips SEM515, Helios **TEM, HRTEM:** Tecnai G230ST ; **STEM HAADF, EDX:** Tecnai G230ST; **XRDA:** ADP-1; **BET:** by nitrogen adsorption



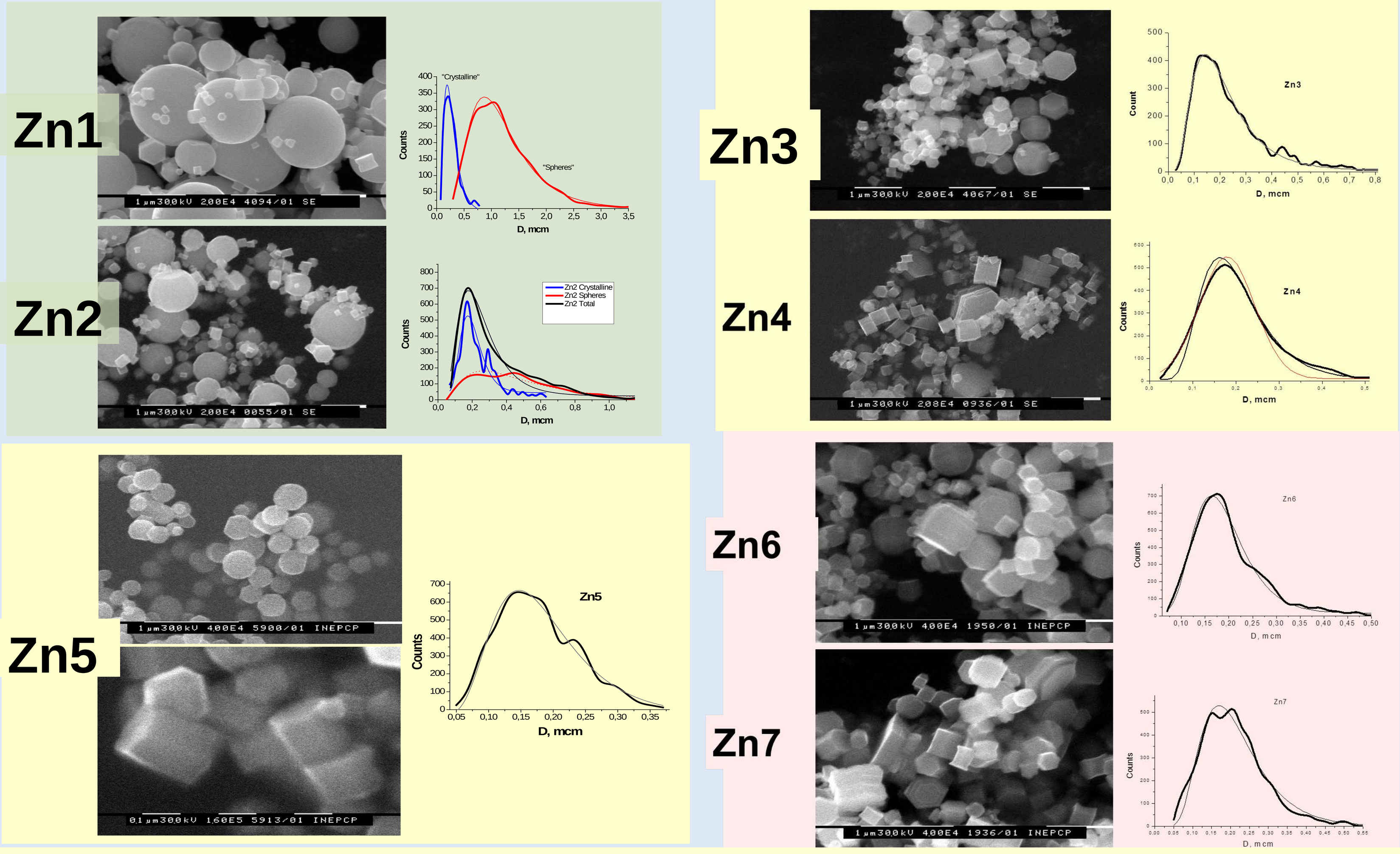
Sample XRD patterns of Zn UFPs ("freshly" manufactured-left- and "stored" in ambient air-right)

Relevancy Across Disciplines

Research about methods to control characteristics and properties of Ultrafine Zn powders have extensive applicability in **medicine, engineering and science such as microbiology.**

Quasi 1-D distribution fit model, SEM figures and shape distribution of samples

$$Y = Y_0 + \frac{A}{\sqrt{2\pi}\,WD}\exp\left(-\frac{\left(\ln\frac{D}{D_{Lnorm}}\right)^2}{2W^2}\right)$$



CONCLUSIONS

- The Guen-Miller **FL-method is highly versatile** and allows a **wide combination of manufacturing condition**s to study the effects on shape and size of the constituent nanoparticles of Zn UPFs.
- The **main parameter** that influences the nanoparticles **size** in the synthesis of Zn UFPs is the rate of metal vapors removal from the molten drop.
- Zn nanoparticles sizes investigated ranged between **0.18 µm and 1.24 µm** and it was determined that increasing the diffusion coefficient, decreasing the total pressure, and increasing the gas flow linear rate results in the decrease of the particles mean size in a consistent manner.
- The main factors determining the particles **shape** in the synthesis of Zn UFPs, are the **thermo-physical properties** of the carrier gases due to their direct effect on the cooling rate and condensation characteristics of the nanoparticles.
- **Spherically-shaped and crystal-shaped Zn nanoparticles** were observed during synthesis of Zn UFPs. Their proportion in the samples depends on the condensation mechanism determined by the thermal capacity and thermal conductivity of the carrier gas.
- Higher heat conductivities and heat capacities of carrier gases result in a direct transition from Zn vapor to solid phase with predominant formation of **crystal-shaped nanoparticles**.
- Lower heat conductivities and heat capacities of the carrier gas result in a step transition from Zn vapor to liquid phase and subsequently to solid phase and the predominant formation of **spherically- shaped nanoparticles**.
- Irrespective of the nanoparticles shape and the synthesis regimes, all resulting nanoparticles possess the **structure of crystalline metallic** zinc with small traces of zinc oxide in samples stored in ambient air for 2 months or more..
- The formation mechanism of nanoparticles on a **substrate** is asymmetrical and the resulting **morphology is highly irregular** unlike the homogenous shapes obtained using the FL method.

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