Национальный исследовательский Томский государственный университет

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Nanoparticles for Applications in High Energy Materials

Tomsk State University,
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HISP

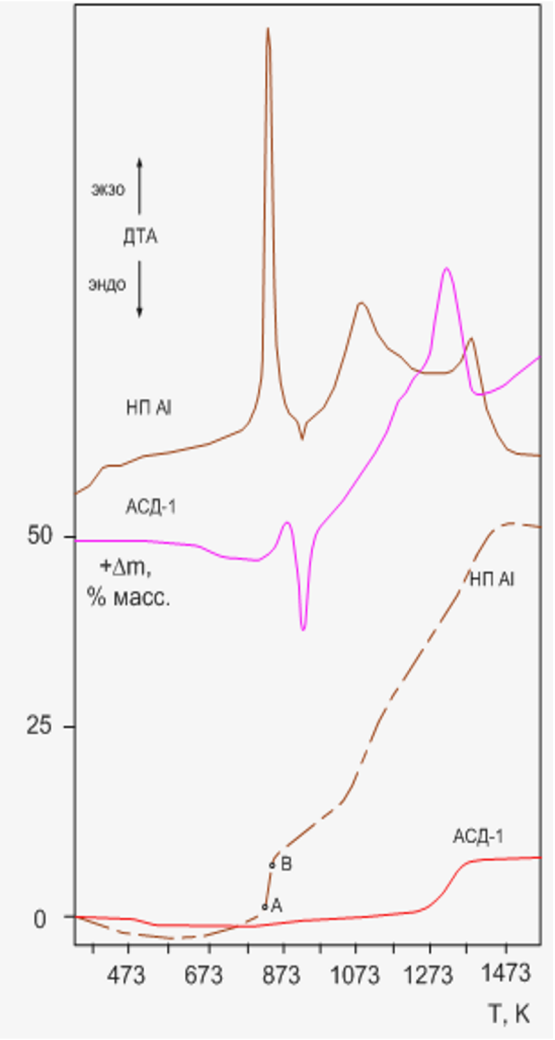
High Performance Solid Propellants for In-space Propulsion

Collaborative Project
Work programme topics addressed: SPA.2010.2.1-04 Space transportation for space exploration, (A) ADVANCED IN-SPACE PROPULSION TECHNOLOGIES

Grant agreement no: 262099

Participants	Short name
Swedish Defence Research Agency	**FOI**
Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V, Fraunhofer Institut für Chemische Technologie	**ICT**
The Inner Arch	**TIA**
Politecnico di Milano	**PdM**
The Netherlands Organisation for Applied Scientific Research	**TNO**
Tomsk State University	**TSU**
EURENCO Bofors	**EUB**
AVIO	**AVIO**
EURENCO France	**EUF**

Aluminum nanopowders have number of advantages over regular aluminum powders when used as component of high energetic materials



Parameter	NP Al	Regular Al	Parameters ratio
Averaged surface diameter of powders, microns	0,1	10	100
Thickness of oxide layer on the particles, nm	2	3-5	2-3
Temperature of intense oxidation (ignition) beginning in air at isothermal heating, K	600	1050	1,75
Degree of oxidating at nonisothermal heating in air up to 1000°C, %	60	2	30
Self-induced burning in air	+	-	

Nanoparticles for HEMs

Nanosized aluminum in space propulsion systems:

	T_{ig} in Air, K	ΔH_c, KJ/mol
Al (15-67 μm)	2223 [1]	835
Mg (44 μm)	837 ± 63	670
Alex - 100nm uncoated	865 ± 15	835

Nanometric Aluminum: low ignition temperature, high heat release

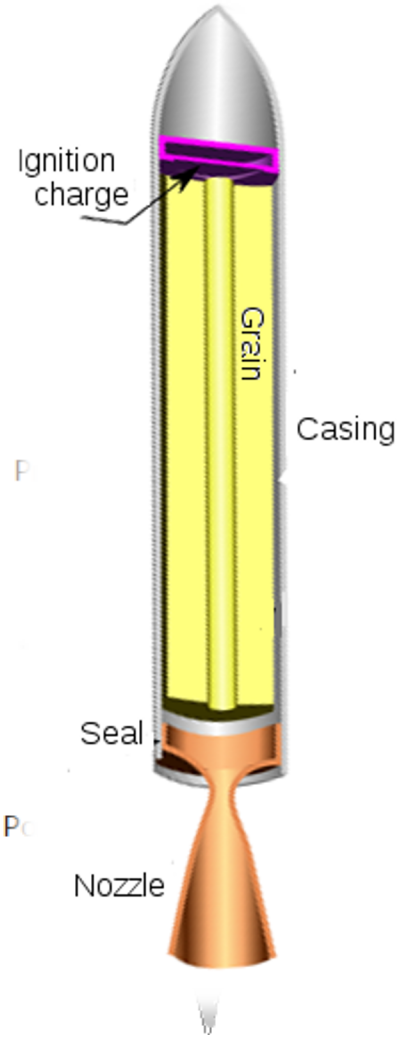
- **Hybrid Rocket Engines:** Oxidizer and fuel in different states

→ **Possible solution for low regression rate problem**

- **Solid Rocket Motors:** Both oxidizer and fuel in solid state

→ **Burning rate enhancement**

Agglomerates formation reduction



Nanometals :The original design of device

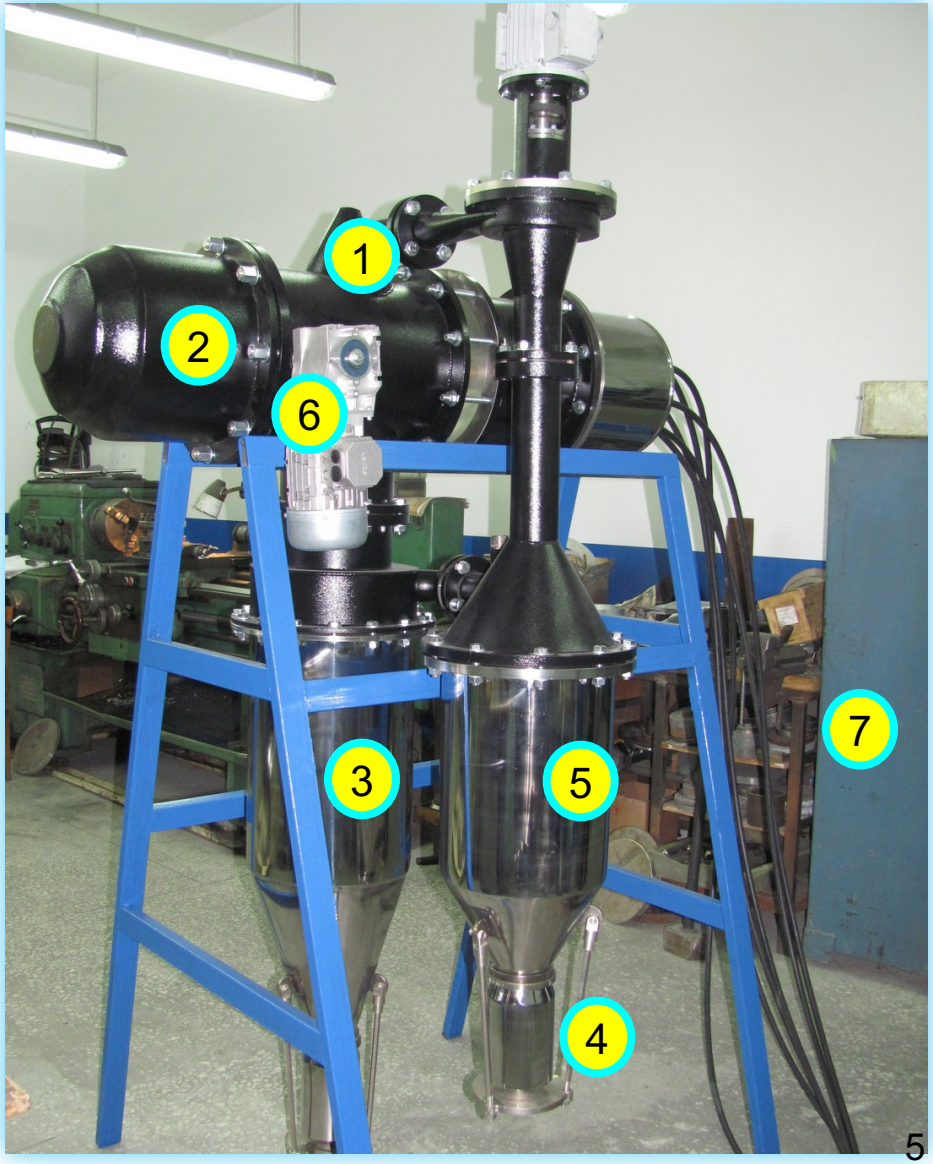
In the section 2 is reel of wire. Gear 6 put wire into section 1 where dispersion of wire done by current 10^7 A/sm^2.

Aerosol from explosion put into separator 3 for separation of particles with size more 500 nm.

Then aerosol goes into filter 5 for sedimentation of powder and accumulation in bunker 4.

Impulse of high voltage forms by generator of impulse current 7.

Circulation of argon is put into effect by centrifugal blower 8.



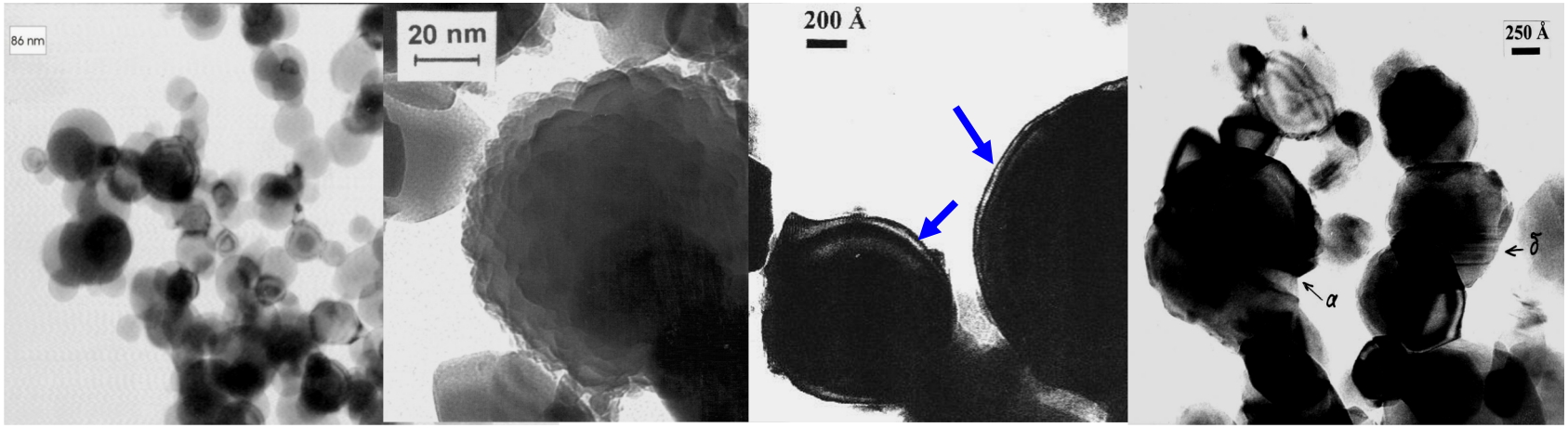
EEW technique

Powder processing routes

- **Electro-explosion of wire technique**
- **Passivation/activation of metal powder by a thin oxide or nitride layer, or possible metal and polymeric coatings**

Powder

- **Synthesis of nanoparticles with size 10 – 100 nm, coated and uncoated, dual composite nanoparticles**
- **Particles characterisation after production**
- **Safety problems**
- **Research for different applications**

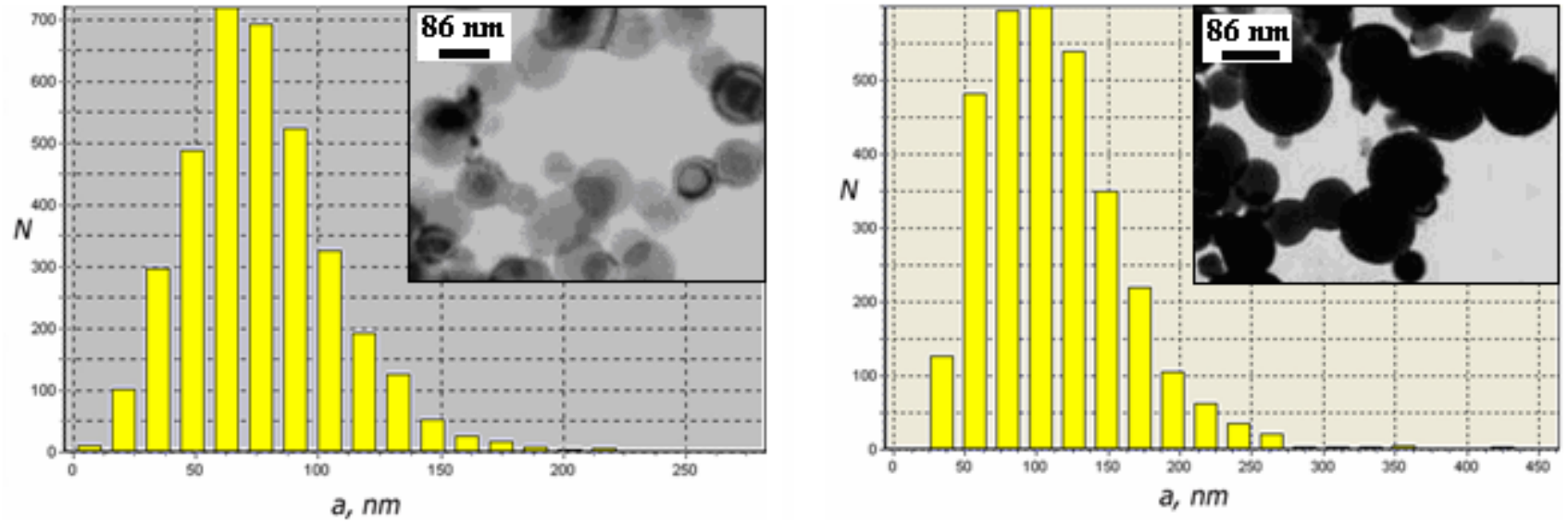


Production of nanopowders

Li	Be										B	C
Na	Mg										Al	Si
K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge
Rb	Sr	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn
Cs	Ba	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb

Characteristics of Metal Nanoparticles

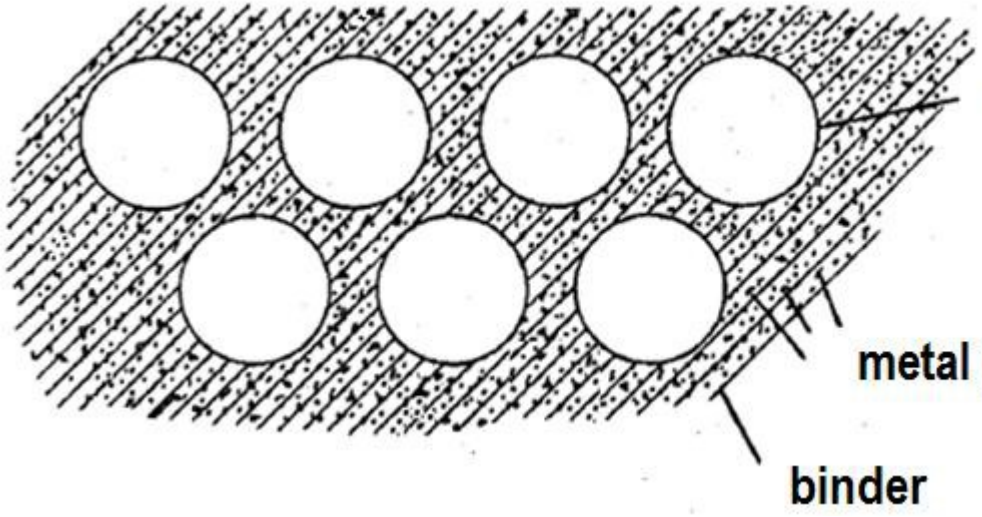
Parameters of nanoparticle characteristics control during EEW: charging voltage (*U*); working gas pressure (*P*); wire diameter (*d*); working gas temperature (*T*)



a b

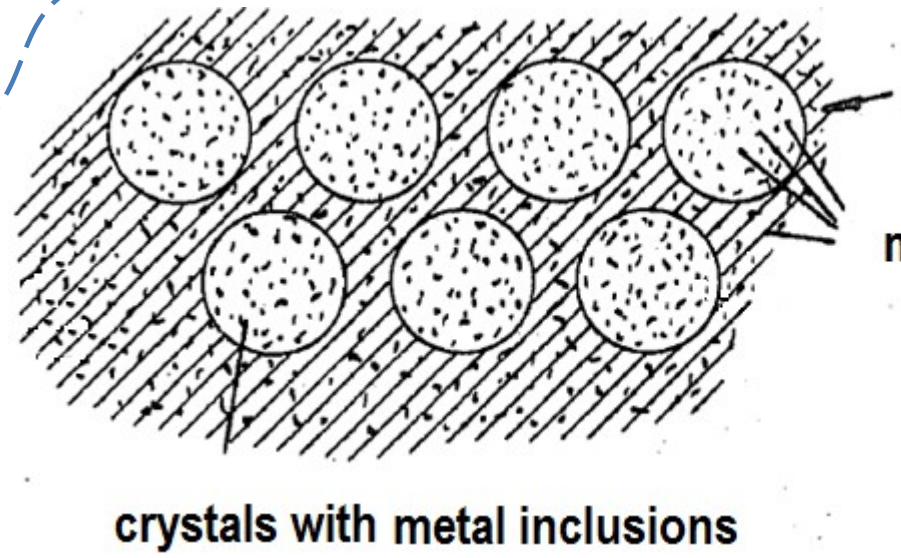
Size distribution of Al particles: (a) – a_n = 77 nm; a_s = 89 nm; a_m = 103 nm; *Sуд* = 24.5 m2/g**;** (b**)** – a_n = 113 nm, a_s = 136 nm; a_m = 160 nm, *Sуд* = 15.5 m2/g; *N* – number of particles, *a* – particle size (nm)

THE MODEL OF METALLIZED SOLID PROPELLANT

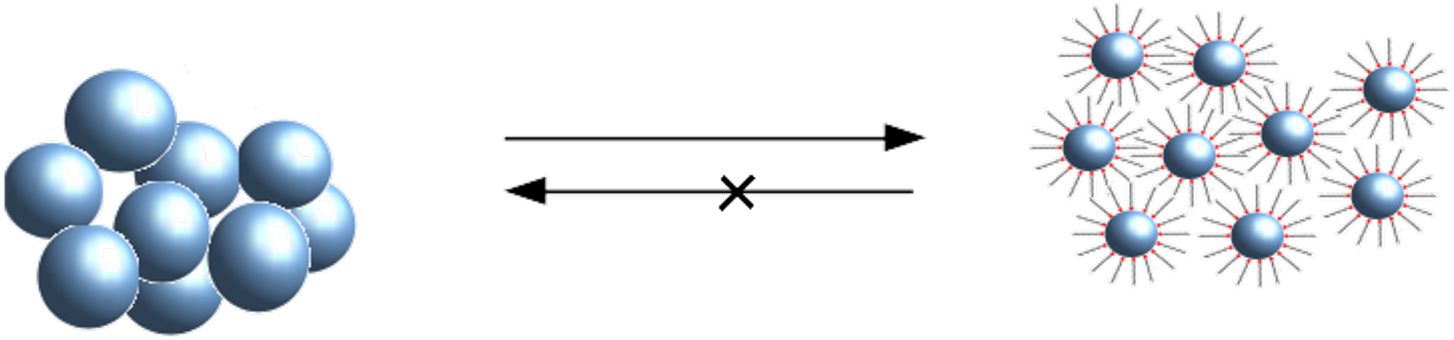


Traditional layout of solid propellant

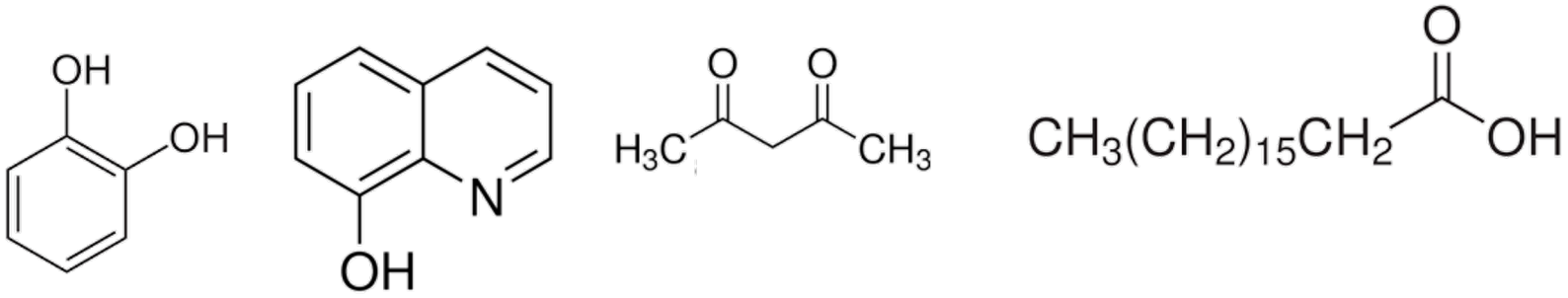
The modified layout of solid propellant



One of the most promising approaches to solving the problem is to coat the surface of nanoparticles, in particular with organic substances.

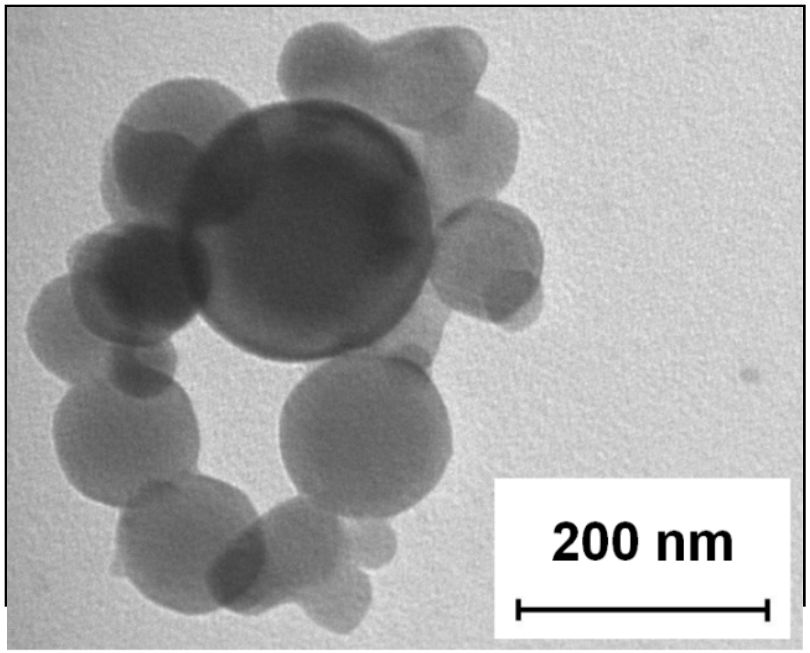


Molecules of the organic substance must contain functional groups forming strong chemical bonds with ions on the surface of nanoparticles.
These are oxygen and nitrogen containing groups.

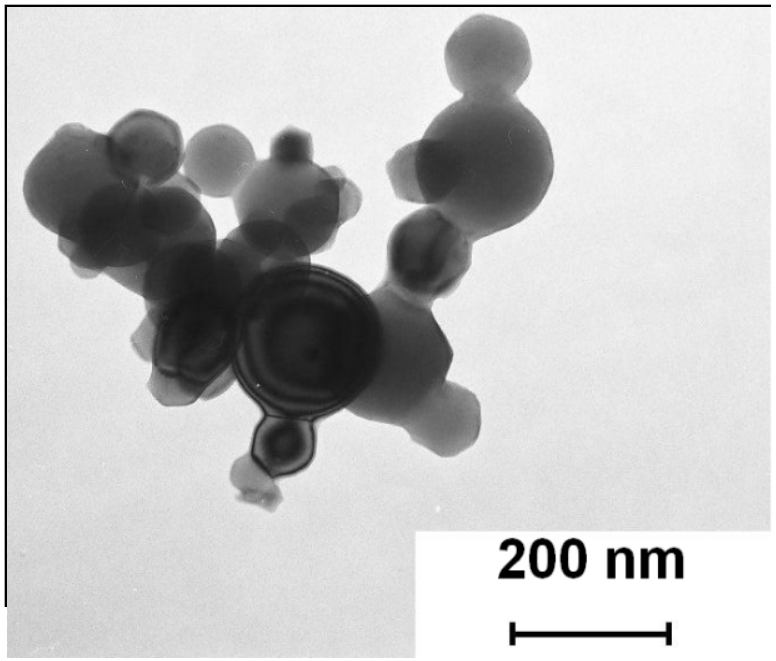


Typical organic substances are catechol, oxyquinoline, acetylacetone, stearic acid, respectively. As well as polymers.

Passivation/activation of nanoparticles



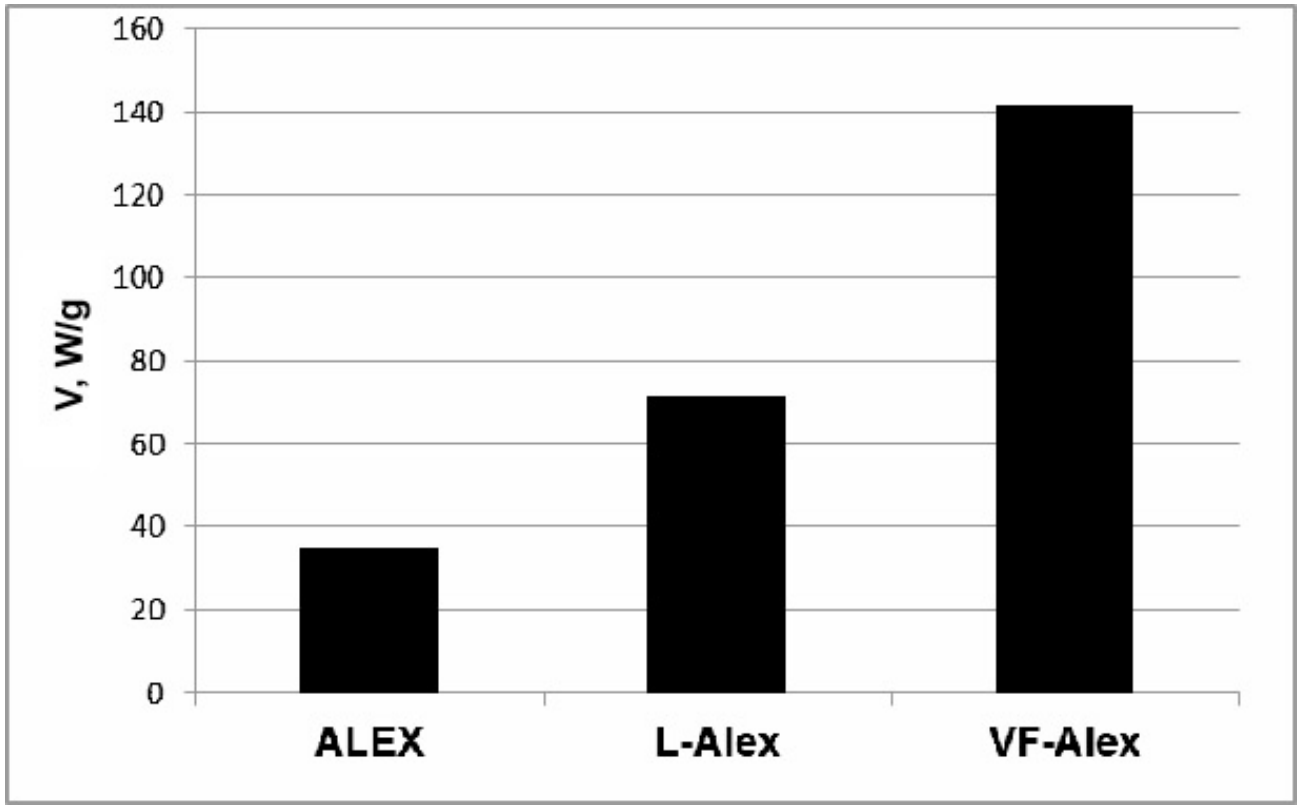
(a)



(b)

Characteristic TEM images of microencapsulated nanopowders coated with stearic acid (a)
and Viton (b)

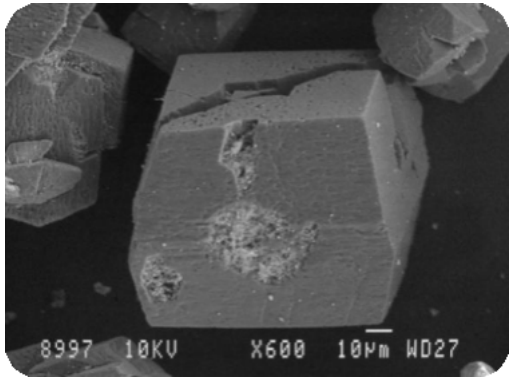
Passivation/activation of nanoparticles



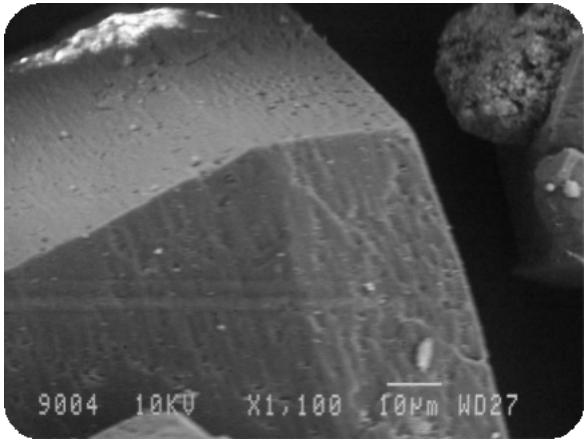
Heat release rate of nanopowders according to thermal analysis data

CL-20 CRYSTALS WITH Alex ALUMINUM AND FERRIC OXIDE INCLUSIONS

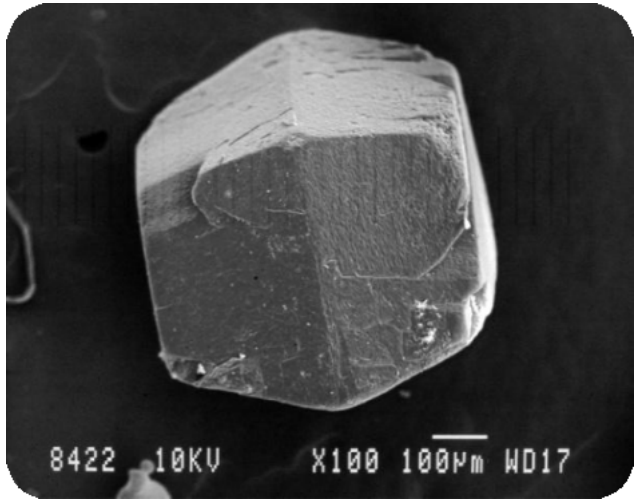
With the purpose of studying the influence of metal size and type on the structure and properties of the obtained CL-20 crystals, a research into Alex disperse aluminum ($S_{sp.}$ = 15 m^2/g) and ferric oxide (III) ($S_{sp.}$ = 9,4 m^2/g) was made.



A)



B)



C)

Picture. The surface of CL-20 crystals with Alex aluminum particles inclusions (A, B) and ferric oxide (III) (C).

Conclusion

- Large-scale production of metal nanopowders opens a prospect of their widespread use in HEMs.
- The use of nano-sized particles in real HEMs and systems is limited mainly due to their chemical instability and incompatibility with components of high-energy materials.
- Proper chemical treatment of metal nanoparticles makes it possible to overcome limitations peculiar to nano-sized powders and thus to expect the progress in their commercial use, not only in laboratory study.

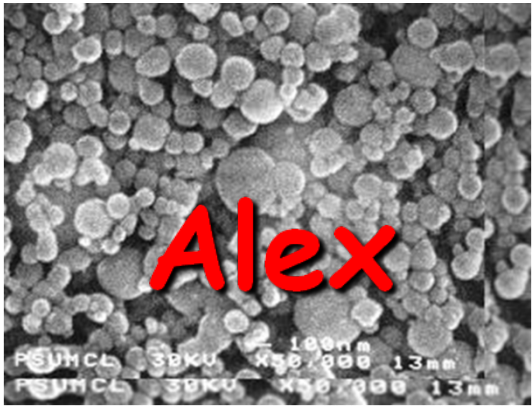
EXPERIENCE

Solid Propellants — Alex/Catalysts

Explosives — Combinations of nanometals

Gelled Propellants — Alex+H_2O

Hydrogen Generation — Alex+H_2O



Thank you for your attention!