
Welcome
to the Frantsevich Institute for
Problems in Materials Science
Kiev, Ukraine

Frantsevich Institute for Problems in Materials Science


Founded in
1952
on a territory of Kiev-Pechersky Monastery

First director - academician Ivan Frantsevich

Frantsevich Institute for Problems in Materials Science NAS of Ukraine

I	II	III	IV	V
Division of Physical Chemistry and Materials Science of High-Melting Systems 10 depts ~230 researchers & engineers	Division of Materials Science of Particulate & Composite Materials and Coatings 8 depts ~190 researchers & engineers	Division of Physical Materials Science and Physics of Strength 8 depts ~220 researchers & engineers	Division of Electronic Structure of Matter & Fine Chemical Synthesis of Inorganic Materials 8 depts ~130 researchers & engineers	Division of NanoStruc-tured Materials and Thin Films 9 depts ~220 researchers & engineers
Head academician V.V. Skorokhod, Director	Head academician A.G.Kostornov, Vice-director	Head D.Sc. S.A. Firstov, Vice-director	Head D.Sc. Yu.M.Solonin, Vice-director	Head D.Sc., A.V.Ragulya, Vice-director

IPMS today - in figures

Institute employs about 1400 people, including >500 researchers in more than 40 departments; among them:

more than 70 D.Sc.;

more than 300 PhD.;

more than 500 engineers;

around 250 young researchers;

Work area 72 000 m^2

IPMS today - in figures

Total funding in 2004

a) from budget ~ 16 M UAH

b) from other sources ~ 6.5 M UAH, including 3 M UAH from international grants.

Basic research > 12 M UAH; including 1,6 M UAH from Program “Nanosystems, Nanomaterials & Nanotechnology”

Applied research and contracts > 3 M UAH including 2.5 M UAH of Innovation projects and ~ 0.7 M UAH from Program “Resource”;

Special fund for young researchers and engineers ~ 1 M UAH;

IPMS today - in figures

International cooperation of IPMS in the period 2001-2004

Totally more than 55 international projects :

>30 grants from Science and Technology Center of Ukraine ($100-300 K, each), primarily with partners from USA;

2 grants of NATO Science for Peace Program (totally $650 K)

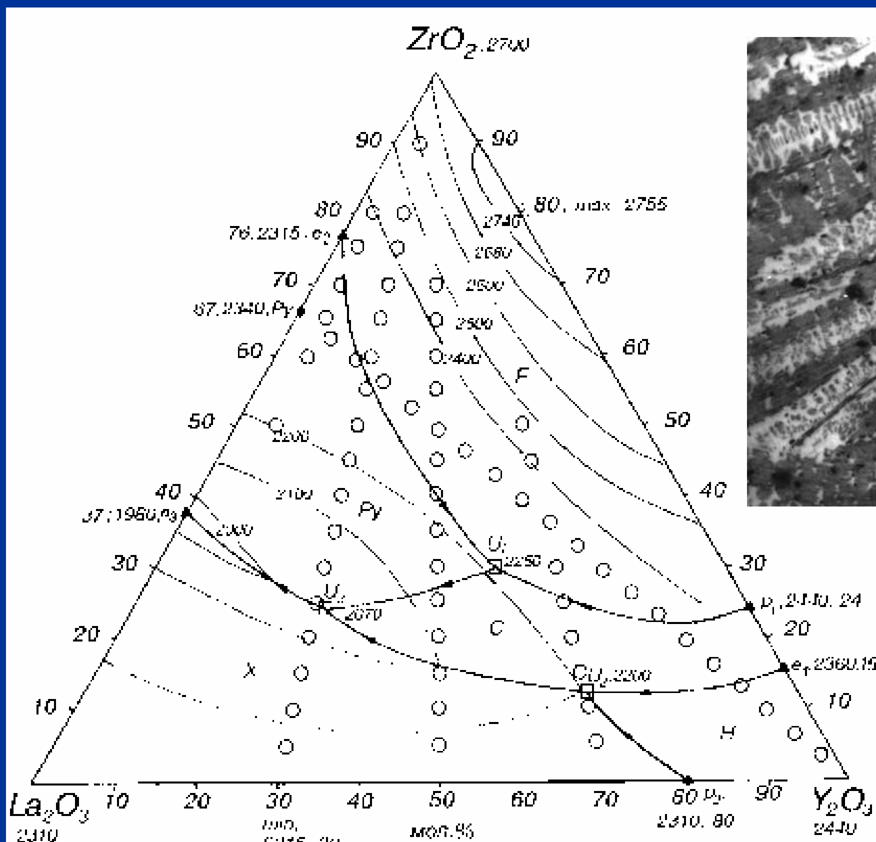
6 grants of Civilian Research & Development Foundation (totally $370 K)

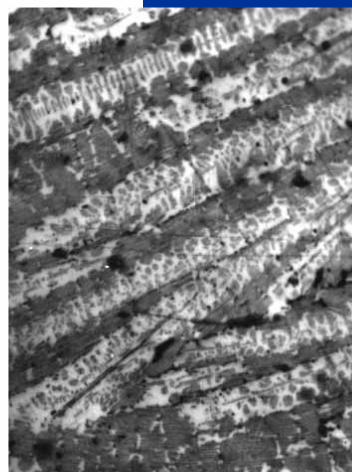
8 grants of INTAS and COPERNICUS

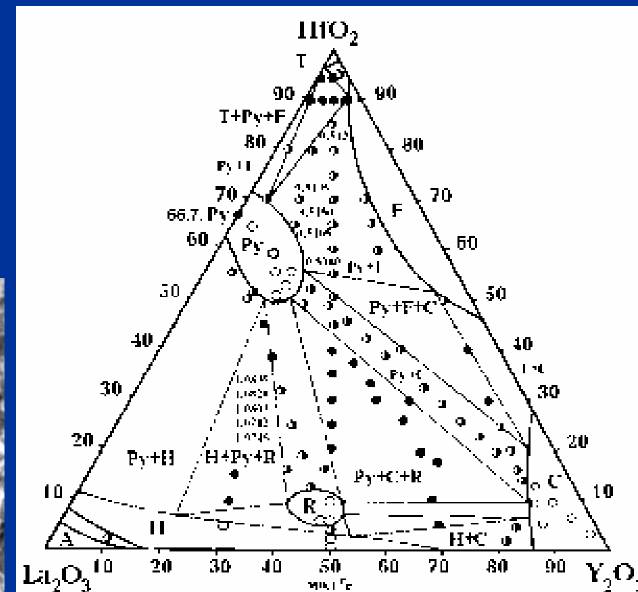
several bilateral grants with partners from France, Italy, Poland, Germany, India, Greece etc.

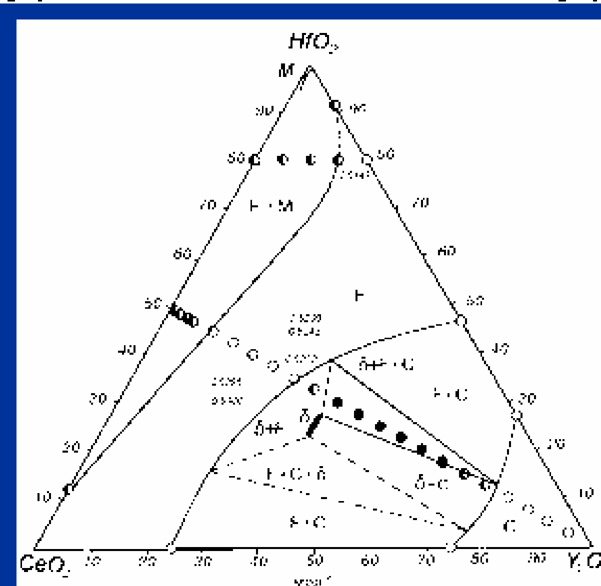
Achievements on the way of international cooperation

Ternary systems
$ZrO_2(HfO_2)-Y_2O_3-Ln_2O_3$





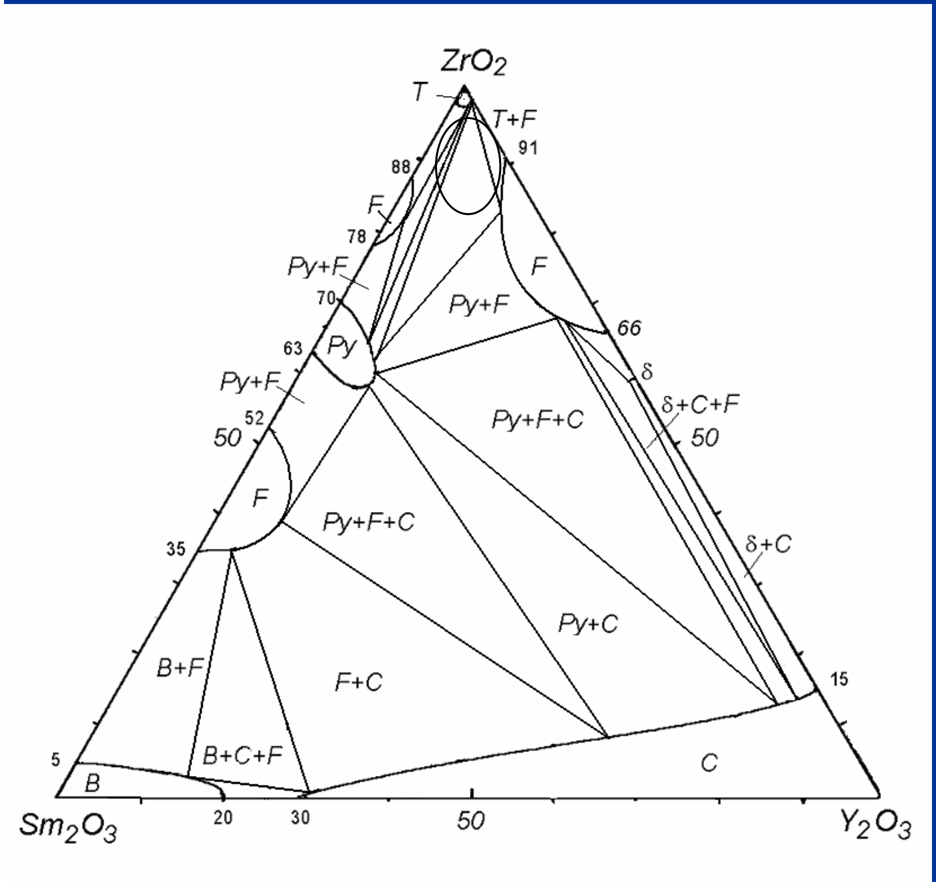




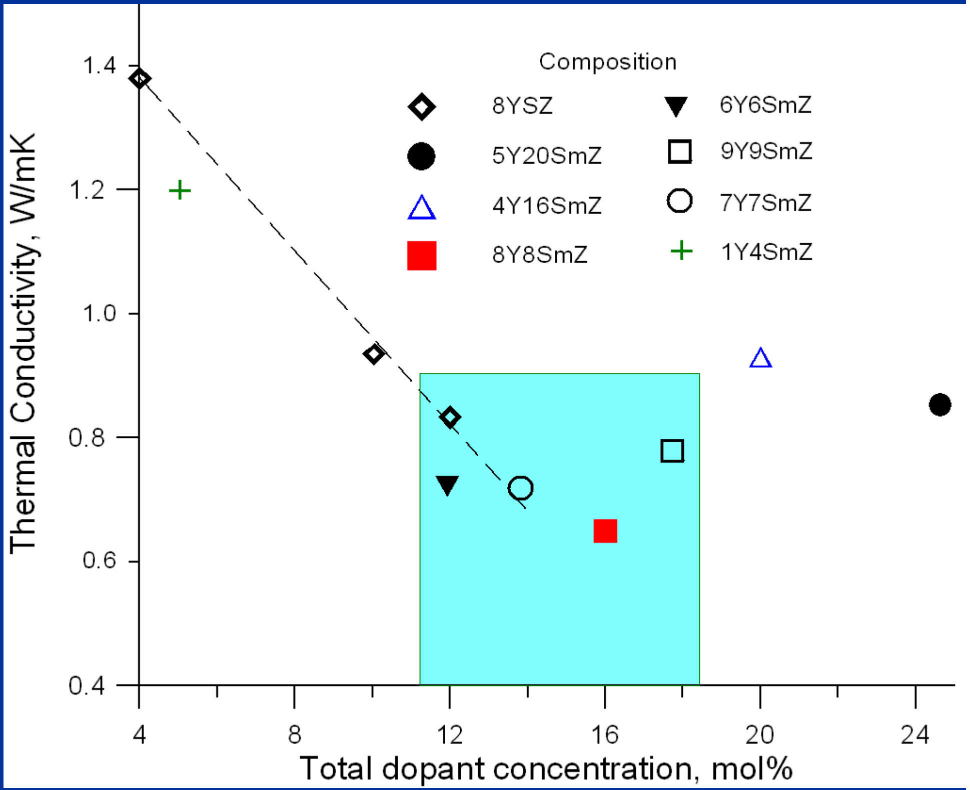
2 Projects STCU, 1 INTAS

Prof. O.R. Andriyevska

New formulation for TBCs



Tentative phase diagram of the system ZrO_2-Sm_2O_3-Y_2O_3 at 1250 C and area for potential TBCs

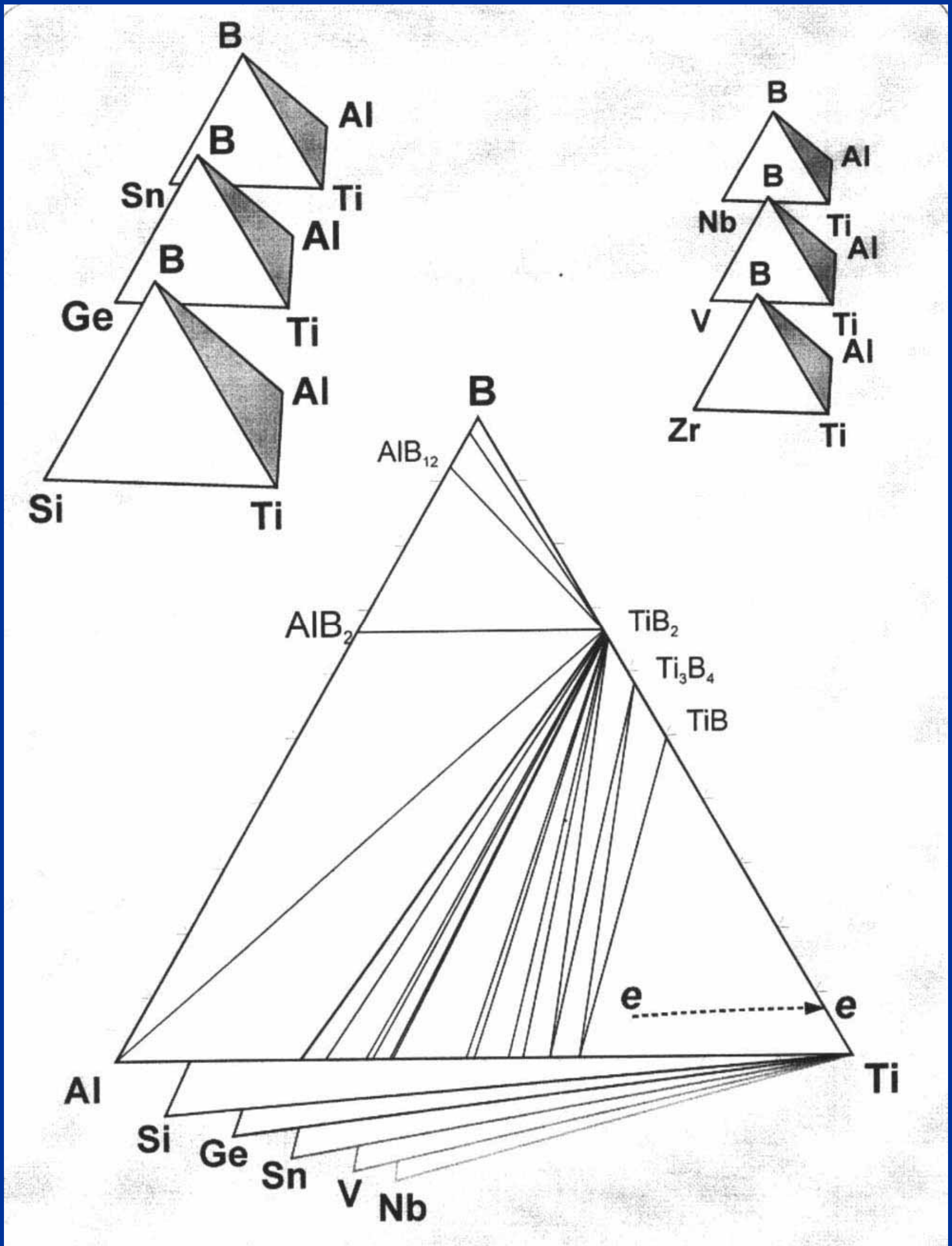


Total dopant concentration dependence of thermal conductivity of selected ceramic compositions and field of most prospective ceramics for TBCs.

New ceramic biomaterials based on hydroxiapatite and nano- ZrO_2

Projects STCU

Dr. O.V. Shevchenko, Dr. V.A. Dubok

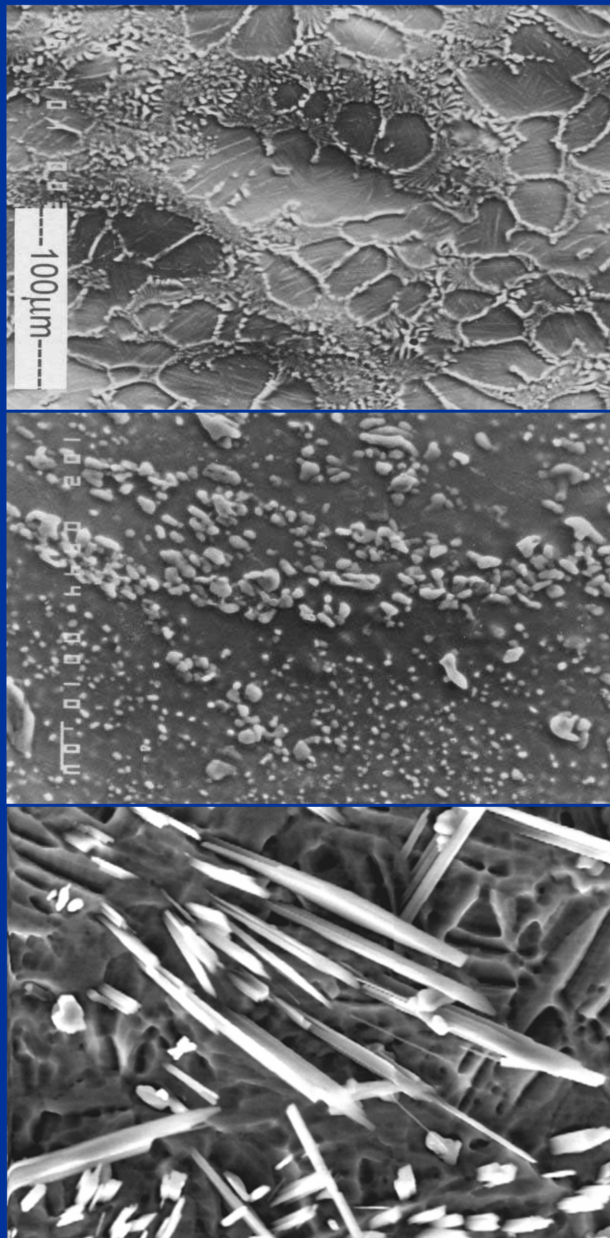


Systems Ti-B-Al-Si (Ge, Sn, V, Nb), for new generation of titanium alloys, titanium-based matrix composites reinforced with borides, silicaborides and germanides operating at 650 °C

STCU project P-60

Prof. S.A. Firstov, Prof. T.Ya. Velikanova, Dr. M.V. Bulanova

New titanium alloys Ti-Si-X and Ti-B-X



Ti-8Al-1,4Si-2,4Zr

Deformation, ε ≈ 90%		20 °C	600 °C	700 °C
$\sigma_в$, MPa	Rolling 1065°C, +800°C, 2 г	1182	923	653
δ, %		0,8-1,6	8,4	18,8
$К_{1c}$, MPa√м		19,2	-	-
$\sigma_в$, Mpa	Rolling 970°C +800°, 2 г	1234	608	409
δ, %		6,1	18	28,6
$К_{1c}$, MPa√м		50	-	-
E, GPa		125		

Ti-6,6Al-1,3Si-1,1B-3,3Zr

Deformation, ε ≈ 90%		20 °C	600 °C	700 °C
$\sigma_в$, MPa	Rolling 1065°C, +800°C, 2г	1519	590	347
δ, %		1,26	7,8	6,4
$К_{1c}$, MPa√м		-	-	-
E, GPa		158	-	

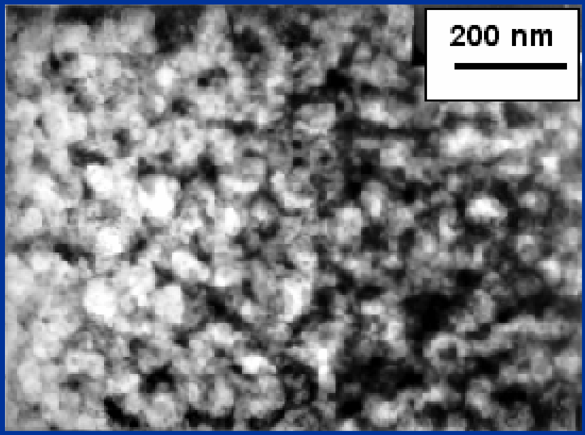
STCU P-60

Developed the technology of new aluminum-based alloys stable at high temperatures, hardened with quasicrystals:

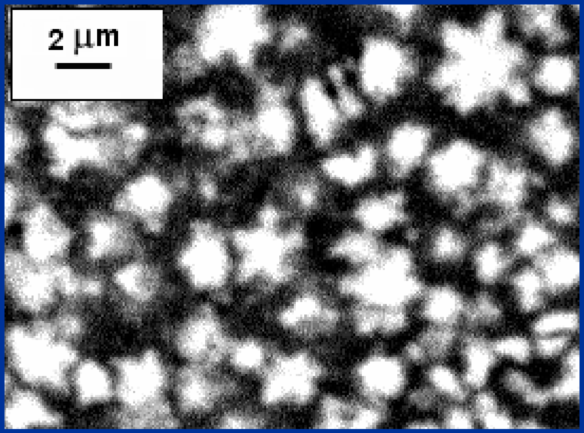
Alloys of the system *Al-Fe-Cr-Ti* respond to the requirements of today's aviation industry

$\sigma_в$ >300 MPa at 300 °C; δ > 5 % at room temperature

2 STCU projects



Aluminum matrix *Al-Fe-Ti-Cr-Sc* with *~30 %* nanosize quasicrystalline particles



Quasicrystals within the alloys *Al-Fe-Cr*

Prof. Yu.V. Milman

Achievements in NanoStructured Materials

Direction 2

Functional Nanostructured Materials

- Synthesis of oxide nanoparticles
- Synthesis of non-oxide nanoparticles
- Consolidated oxide nanoceramics and nanocomposites
- Consolidated high-melting nanoceramics and nanocomposites
- Consolidated nanostructured metals and alloys
- Synthesis of carbon and non-carbon nanoclusters
- Physics, chemistry and technology of thin films and quantum dots

Nanostructured particulate oxide-based materials

Wet chemical methods.

Hydrothermal and co-precipitation.

Systems: ZrO_2-Y_2O_3, ZrO_2-Y_2O_3-CeO_2, ZrO_2-Al_2O_3-Y_2O_3, ZrO_2-Y_2O_3-Sc_2O_3, ZrO_2-Y_2O_3-CeO_2-Al_2O_3, YSZ+Fe_2O_3(Co_3O_4) for structural ceramics and components of sensors, SOFC, TBC.

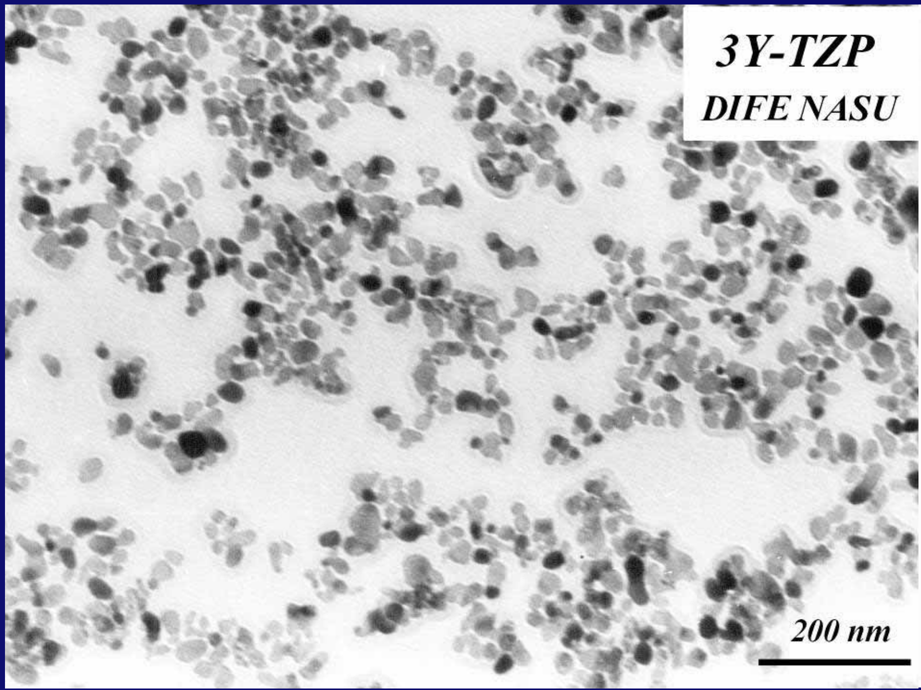
Synthesis in micro/nanoreactors.

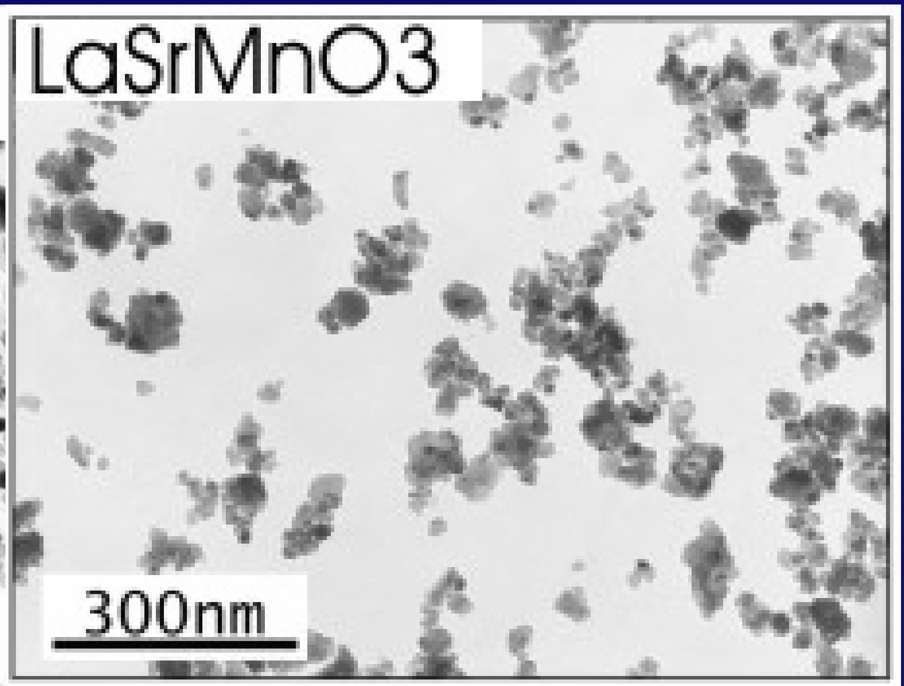
Rate-controlled thermal decomposition of unstable precursors and sonochemical synthesis.

Systems: $BaTiO_3$-based X7R dielectrics, ZrO_2-Y_2O_3, ZrO_2-Y_2O_3-Nd_2O_3(Sm_2O_3) for TBCs, YSZ-Pt, YSZ-Au catalysts, perovskite-type phases like La(Nd)SrMn(Co,Ni)O_3 for SOFC.

Combined synthesis

Synthesis combines colloidal processes, microwave treatment and powerful ultrasonication to get unisized nanoparticles





Particle size of 6 to 12 nm

Particle size of 20 to 40 nm

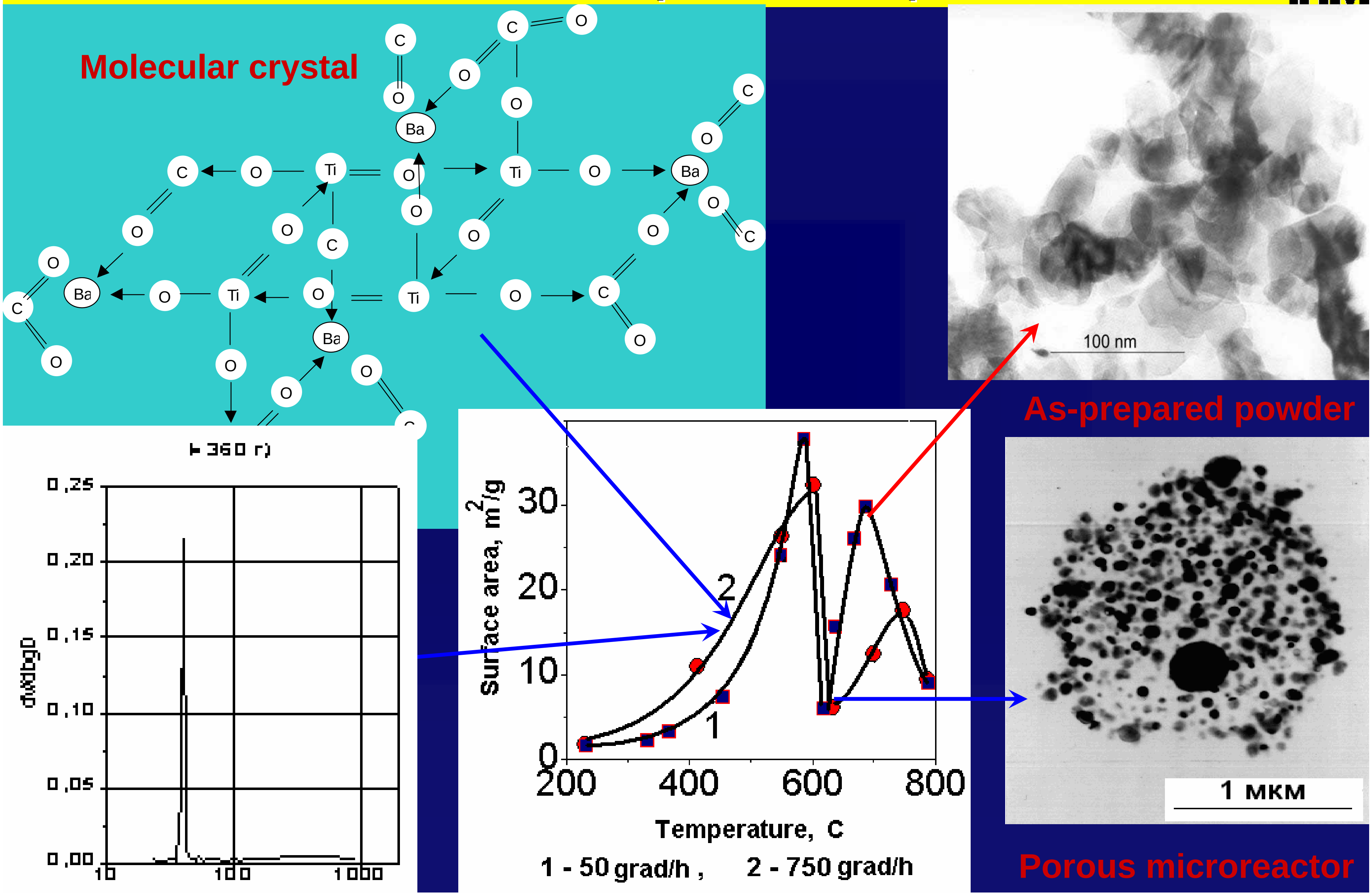
Pilot production developed of both products for SOFC techn.

Dr. Konstantinova et al.

Patent of Ukraine

Synthesis in micro/nanoreactors

Rate-controlled decomposition of precursors

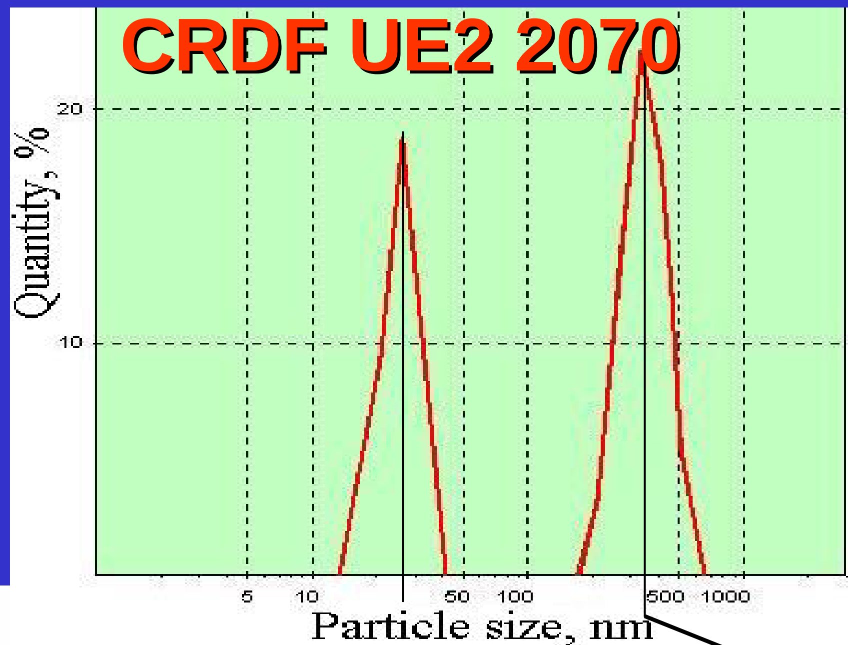


The Nanocrystalline Barium Titanate Powder

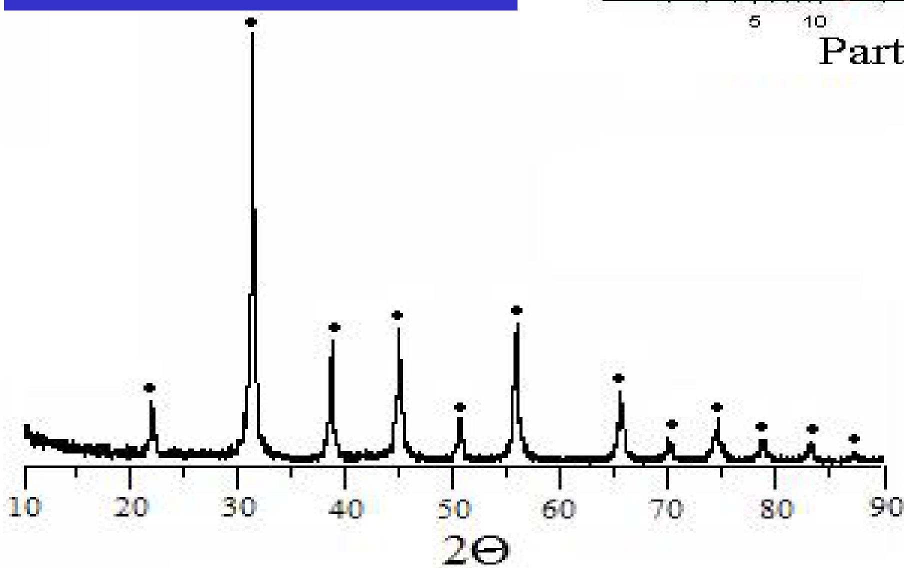
(in cooperation with Pennsylvania State University)

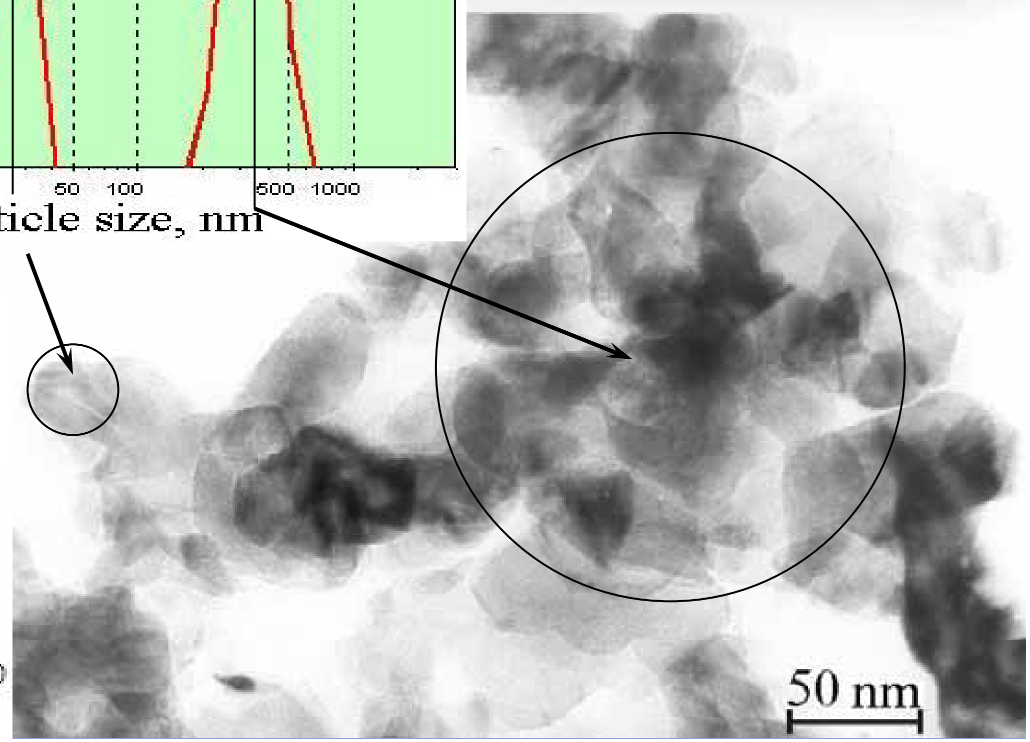
CRDF UE2 2070

No barium carbonate was revealed in final barium titanate nanosized powder

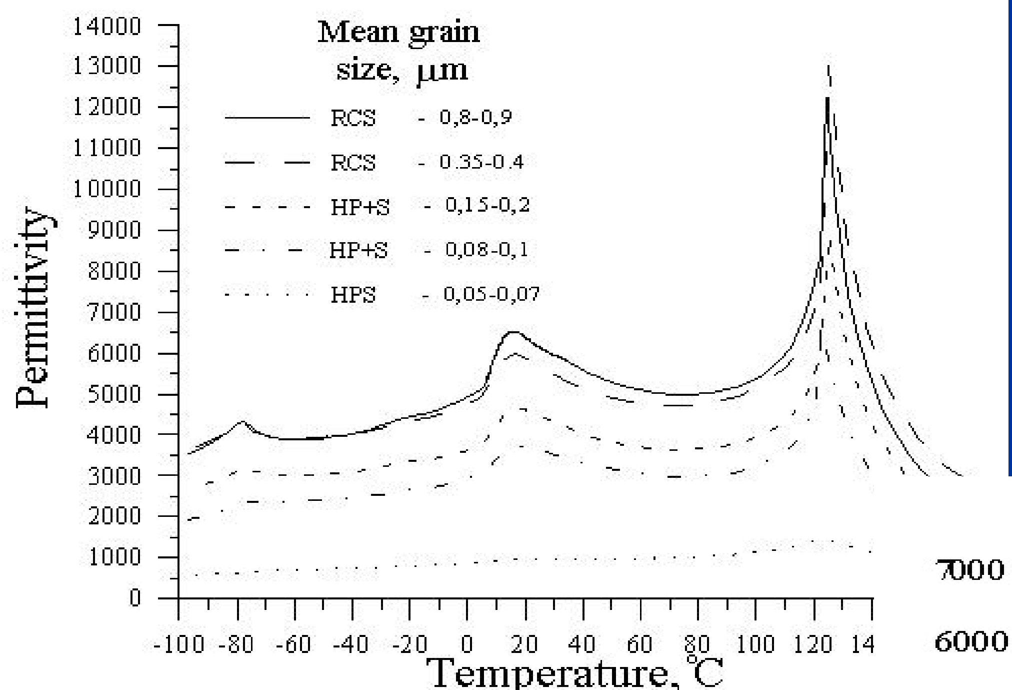


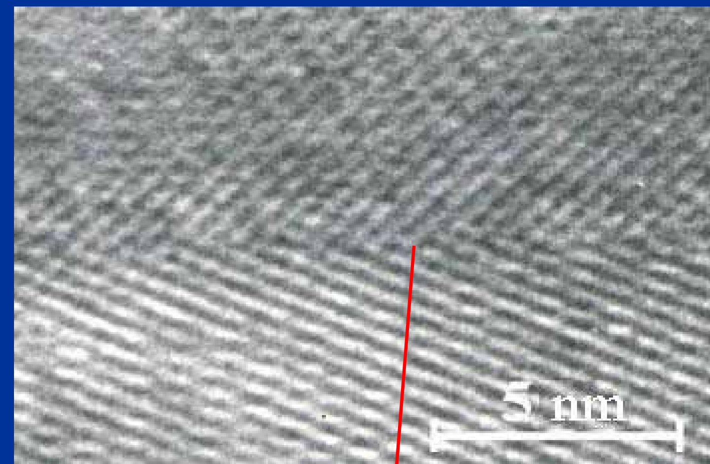
Mean agglomerate size correlates with the final mean grain size

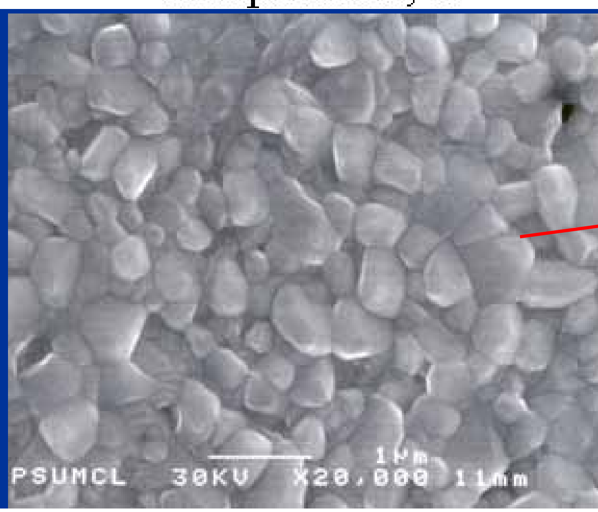


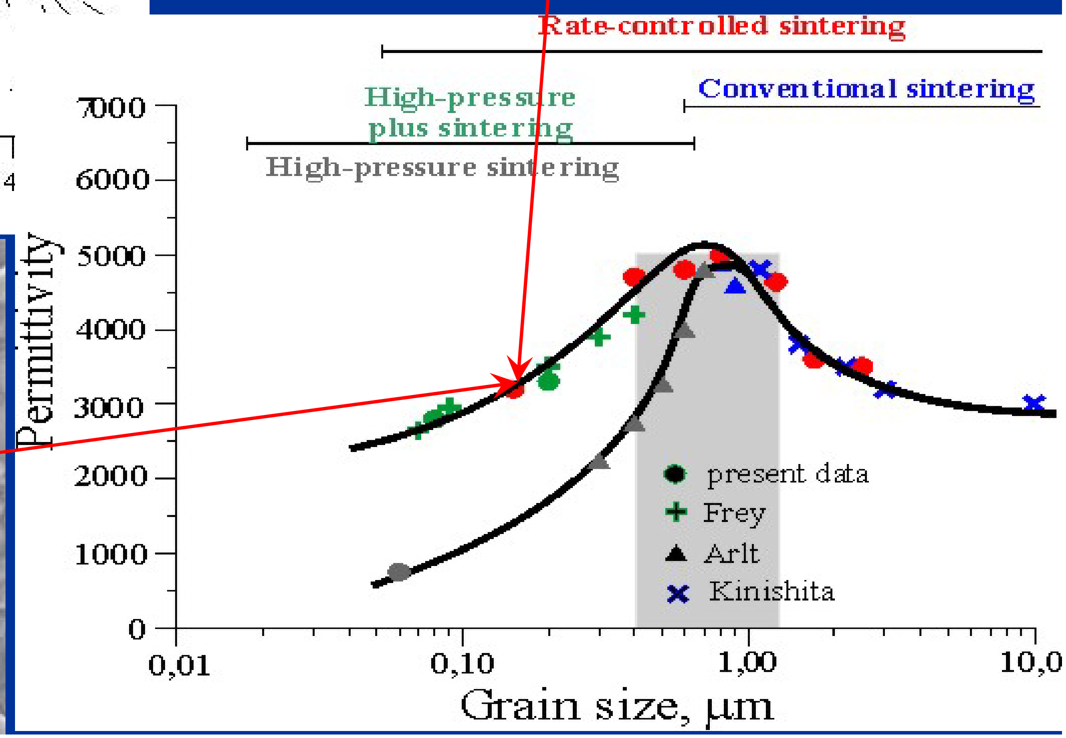


Dielectric Properties of the fine Barium Titanate Ceramics (CRDF UE2 2070)









Synthesis of nanosize particles based on nitrides, borides and carbides

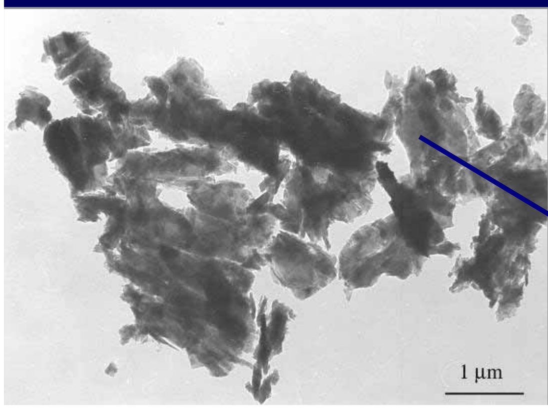
INTERNATIONAL EFFORTS
through NATO SfP and 3 STCU projects and 2 contracts with Israel and Sweden

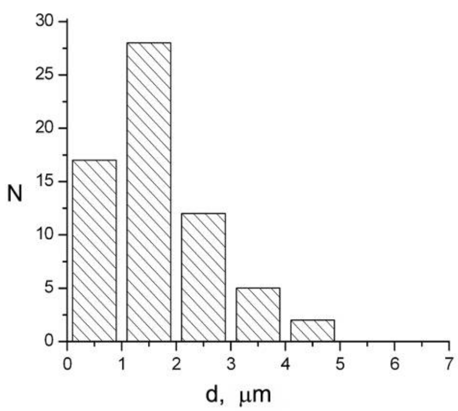
- **Detonation synthesis of nanoscale c-BN powders**
- **SHS of nanosize SiC-C powders;**
- **Plasma-chemical synthesis of single-phase nitrides and nanocomposites (Si_3N_4-TiN, Si_3N_4-TiB_2, TiN-AlN etc.)**
- **Chemical vapor deposition from chlorides**
- **Splitting of micron-sized particles of solid solutions Ti-N-C-O with boron additives.**

Shock-wave Synthesis of nano-BN

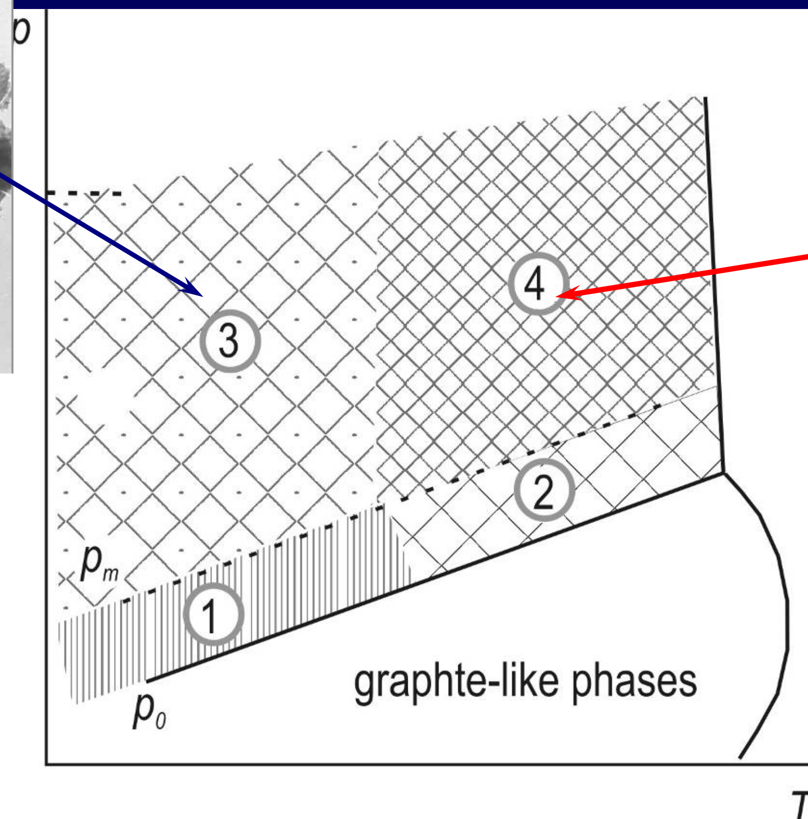
Fragmentation by martensitic trasformation to 50 nm

NEW! Competition of martensitic and diffusion transformations (4).

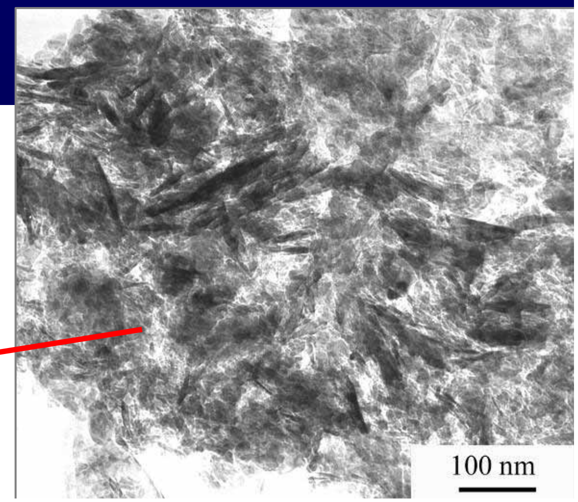


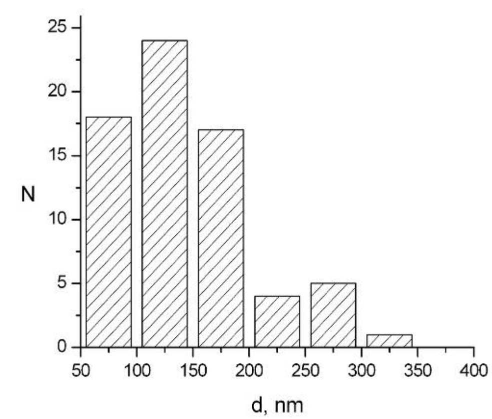


Size distribution



Phase diagram

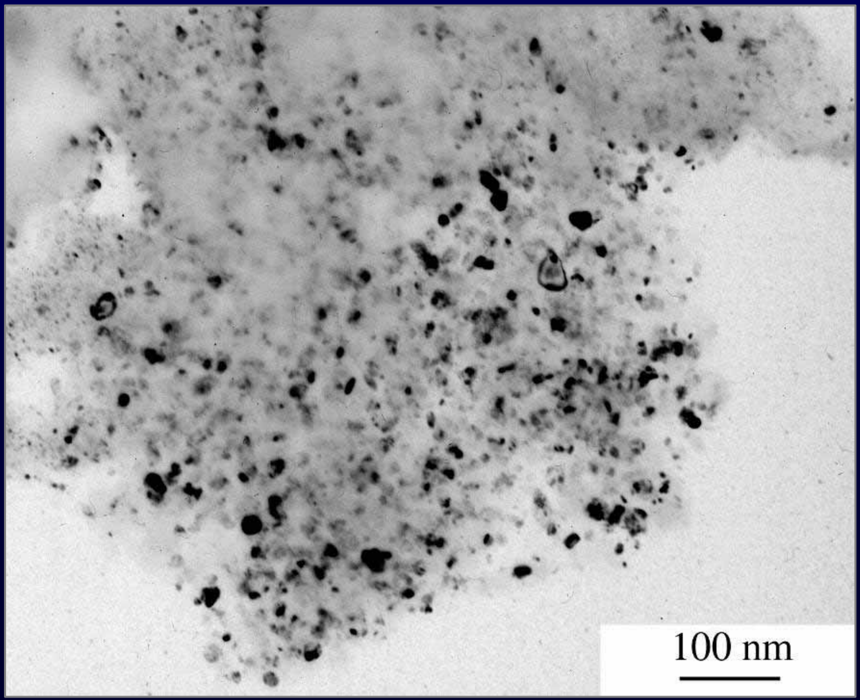




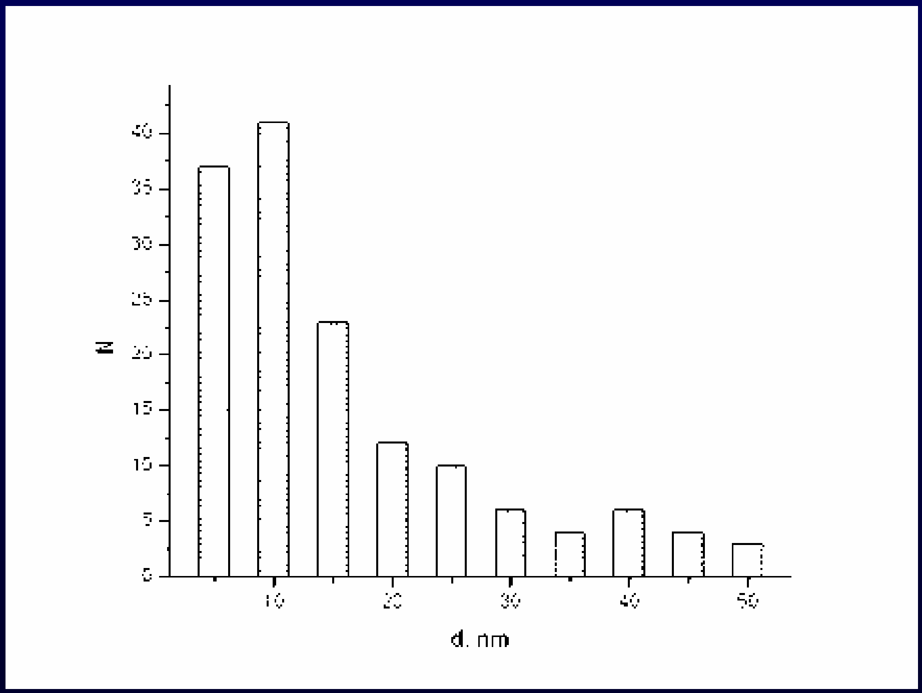
Size distribution

Shock-wave Synthesis of nano-BN from amorphous Nanoreactors

Usage of disordered precursors (3-D ordering degree $p_3 \approx 0$) allows obtaining the cubic BN phase, in the area of diffusion controlled transformation.



Dark field image of cubic BN phase



Particle size distribution

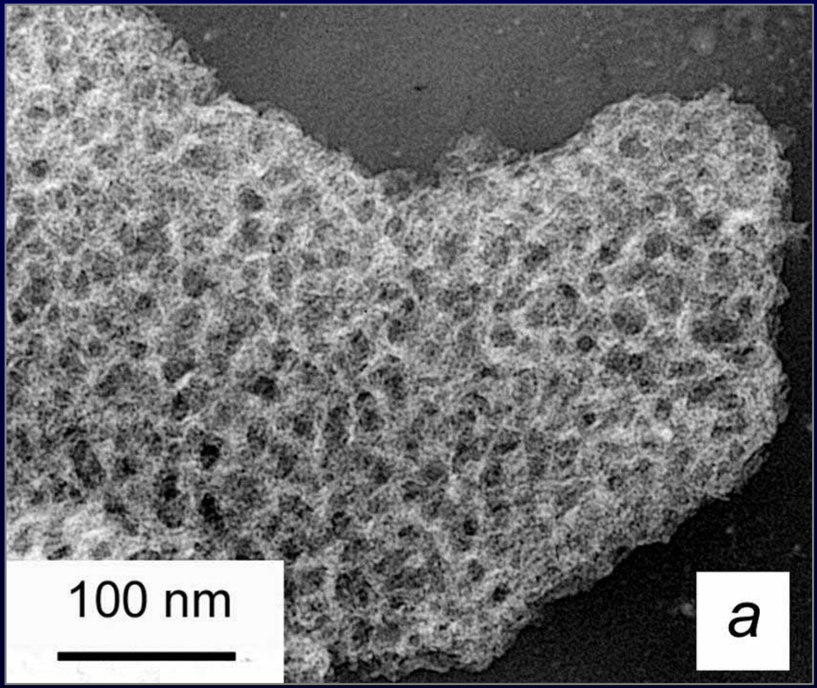
Patent of Ukraine

Shock-wave Synthesis of nano-BN

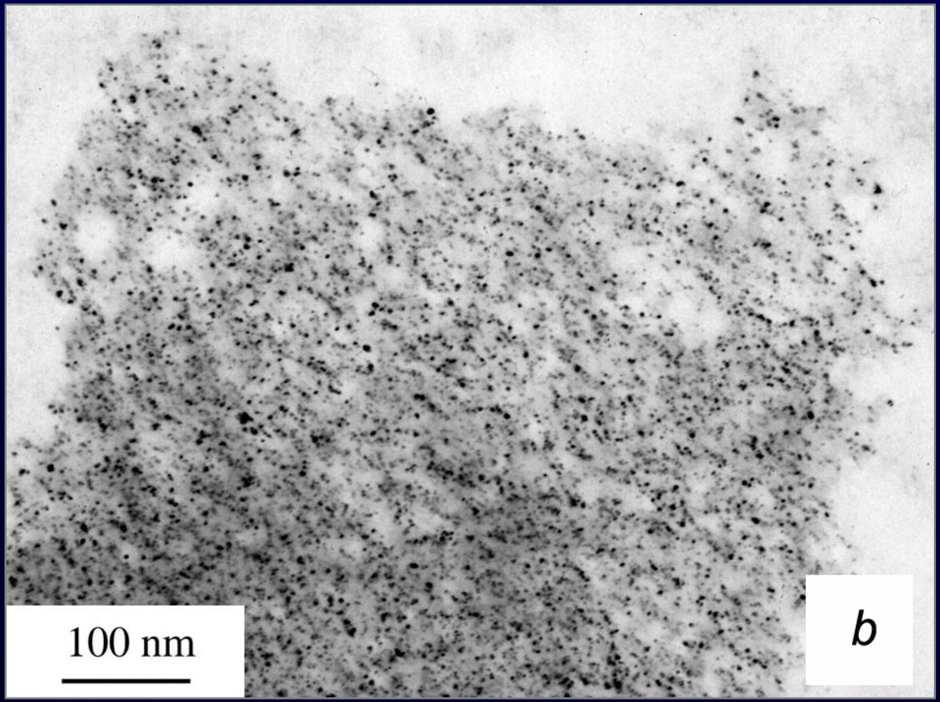
Synthesis of disordered graphite-like BN from unstable precursors. **Patent of Ukraine**

Rate-controlled synthesis gives particles of 1-20 nm in size (we can control the average size).

The best structure of intermediate product consists of crystallites (1-5 nm) divided by pores of 30 nm.



Bright field TEM image of c-BN



Dark field TEM image of c-BN

New structural form of carbon ($C_{пр}$)

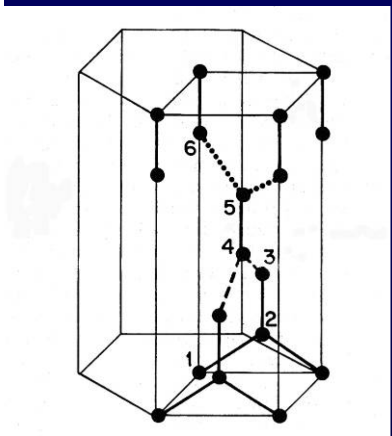
Synthesis from charcoal by high-temperature shock wave compression at:

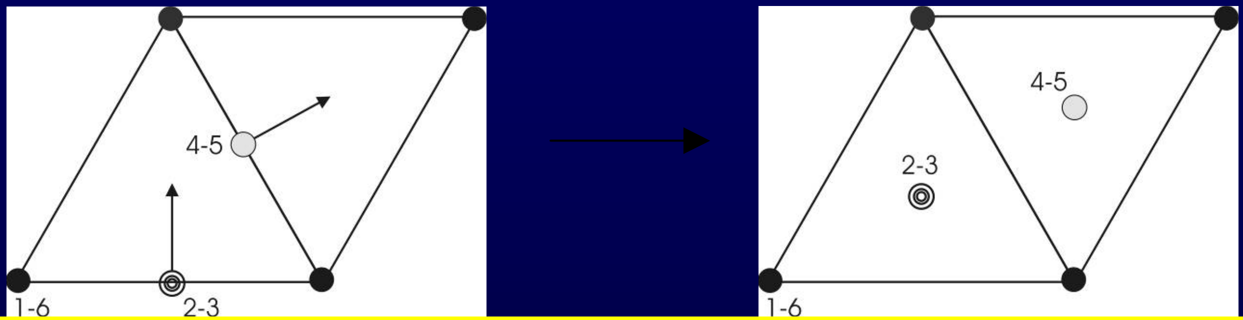
P = 30 GPa, T > 2500 K

$C_{пр}$ shows density of 2,9 g/cm^3 – which is intermediate between one of graphite (2,2 g/cm^3) and diamond (3,5 g/cm^3)

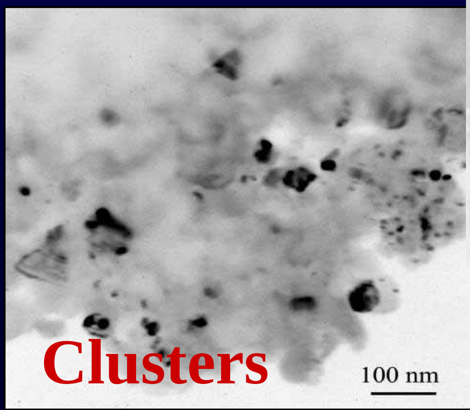
The basis of lattice of $C_{пр}$ – cubic cell with strong *sp*^{2} bonds (κ = 3)

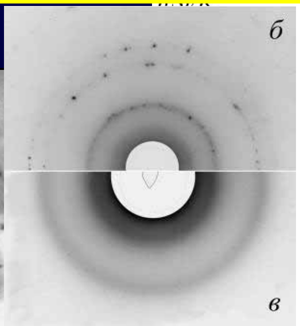
Lattice of $C_{пр}$ (Cohen model of H-6) easily transforms to diamond lattice (κ = 4)

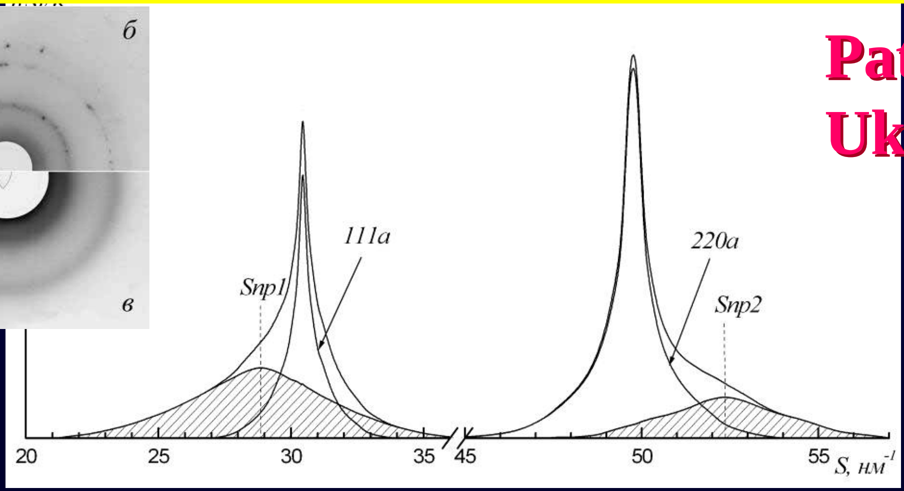




$C_{пр}$ forms together with diamond and has a lattice structure



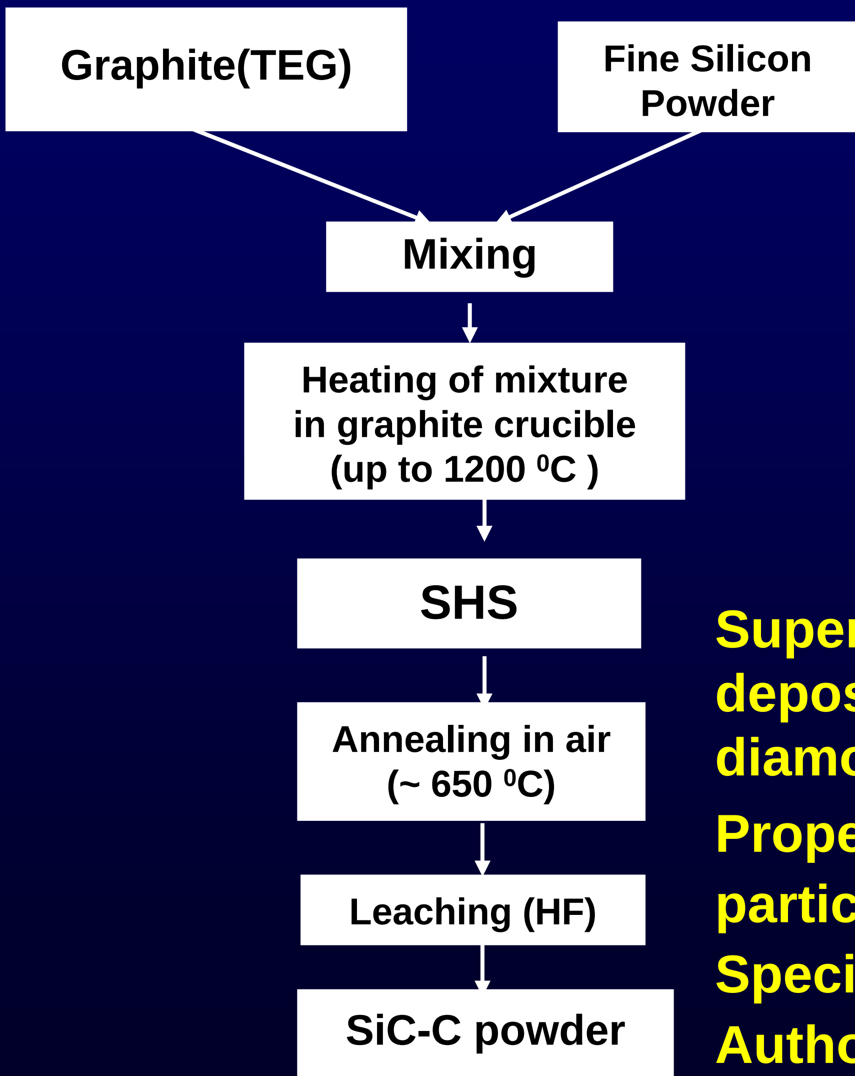


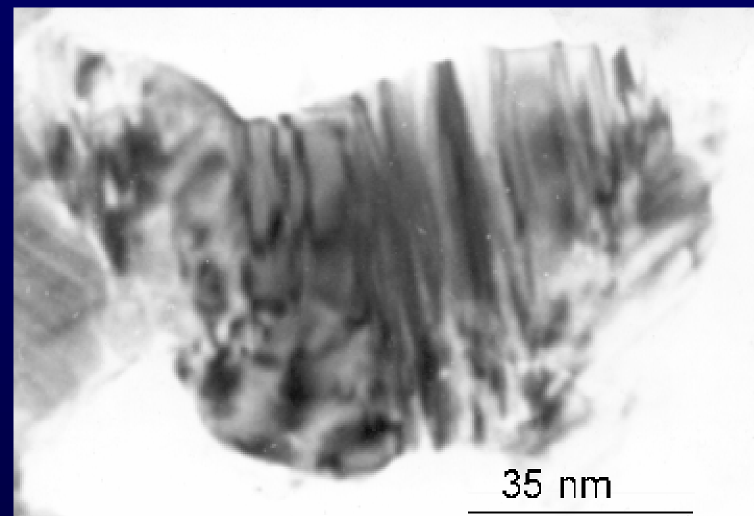


Patent of Ukraine

Prognosis of properties: bulk modulus is expected to be $C_{пр}$ (390 GPa) close to the bulk modulus of diamond (440 GPa)

SHS of SiC-C nanoparticles in nanoreactors





Superstoichiometric carbon atoms are deposited onto facets of SiC lattice forming diamond-like planar clusters inside SiC.

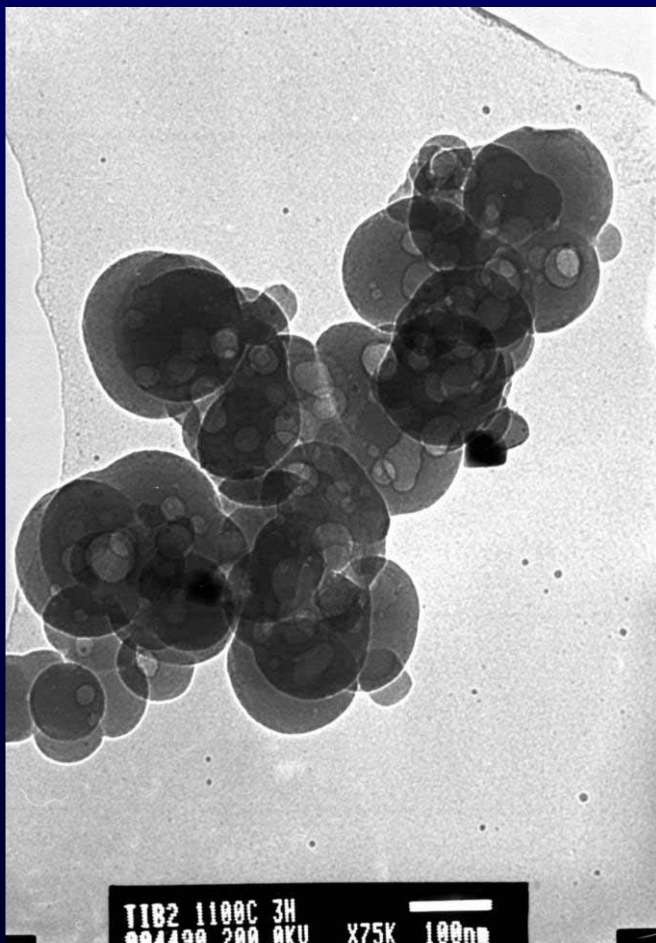
Properties:

particle size 70-200 nm

Specific surface area 17-25 m^2/g

Authored by N. Gadzira and G. Gnesin

Synthesis of TiB_2 and TiB_2-TiN nanocomposite particles in Ti-O-N-B system

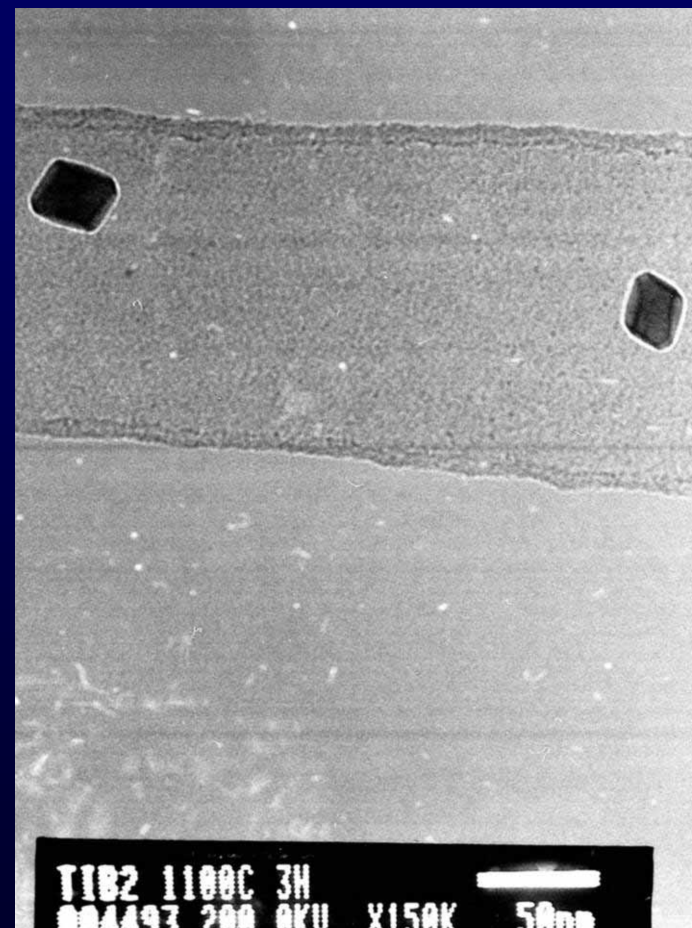


Nano-TiO_2+ B+H_2

Nucleation and growth

in mesopores

of TiO_2 and splitting with excess of boron



Nano-TiB_2 particles or nanorods

Synthesis of Nanoclusters

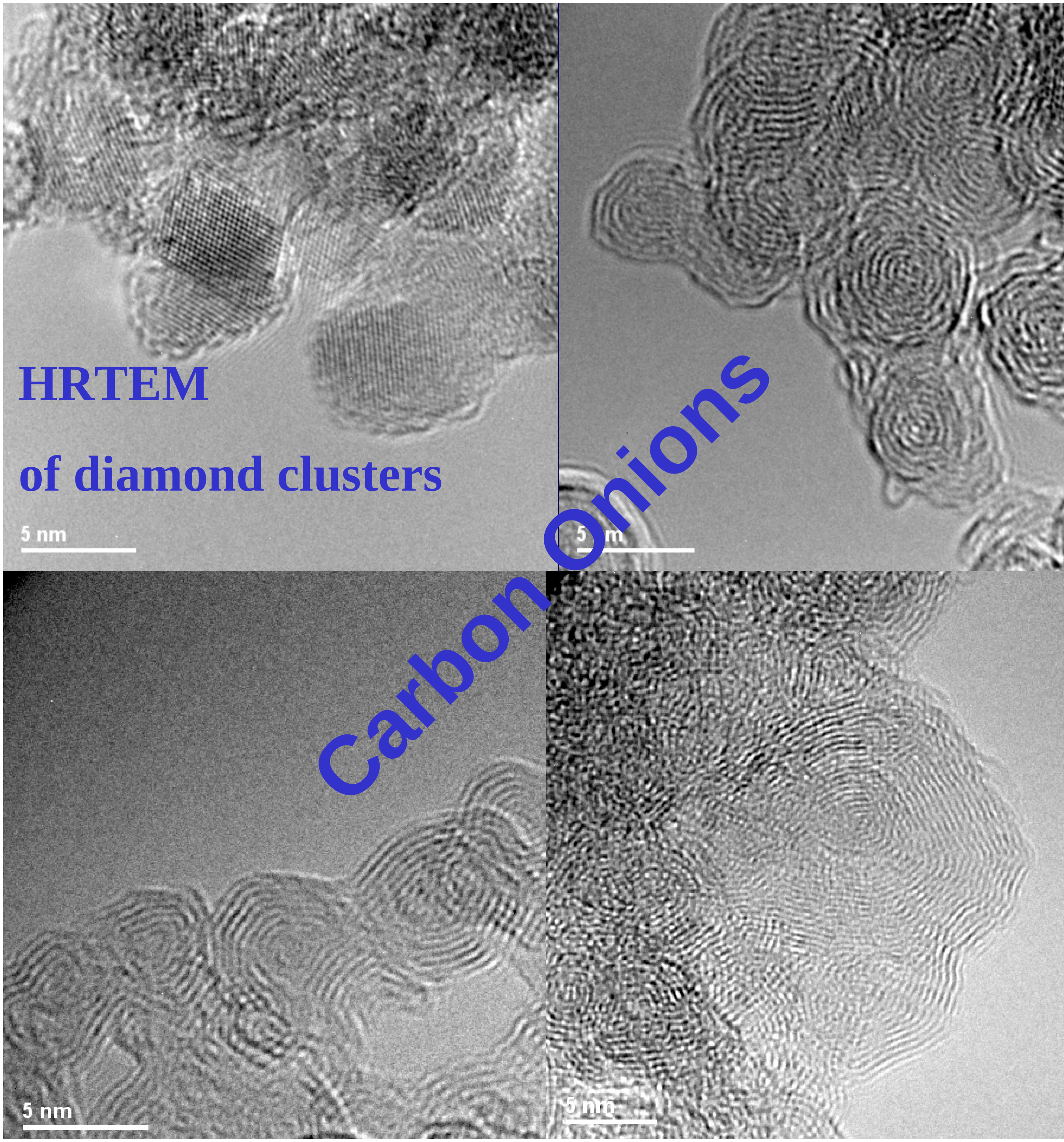
Carbon Onions

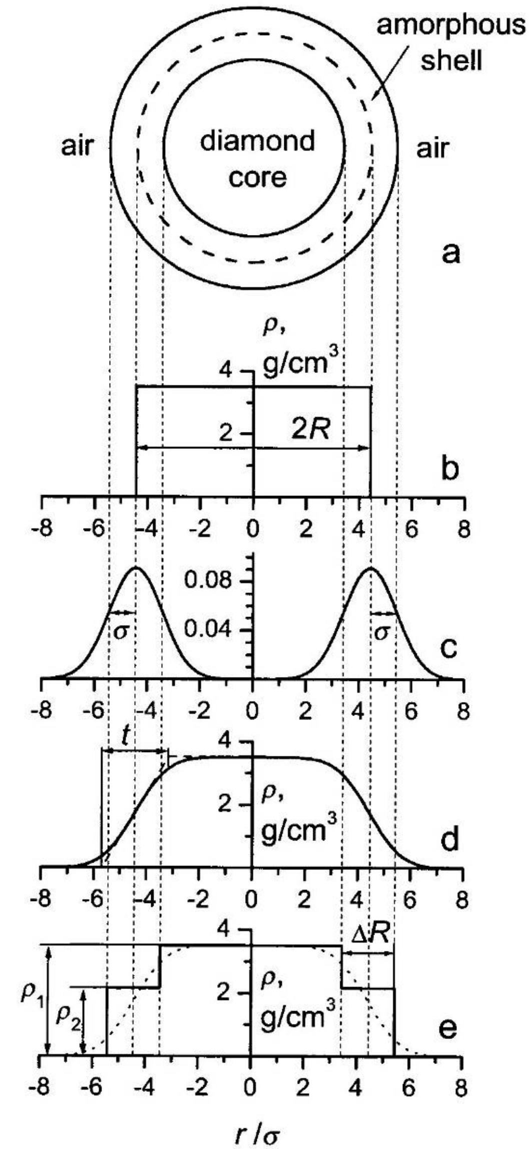
Carbon Nanotubes

Non-carbon elongated nanostructures

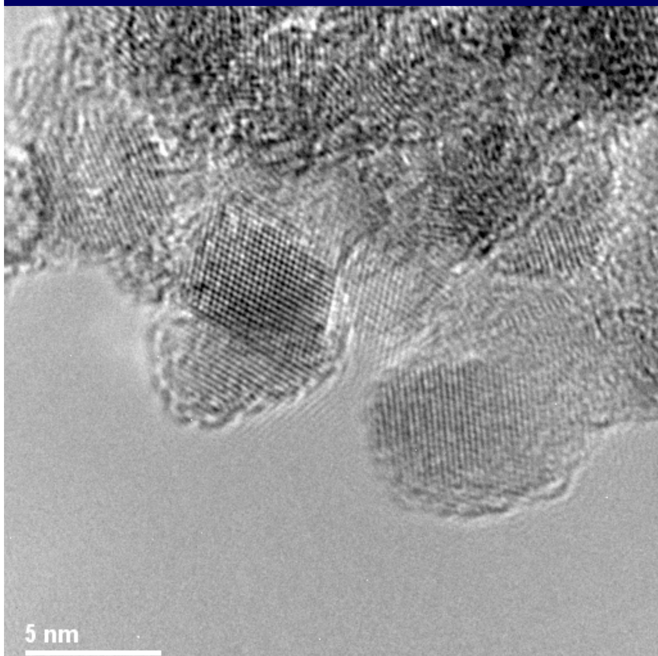
H_2-intercalated objects

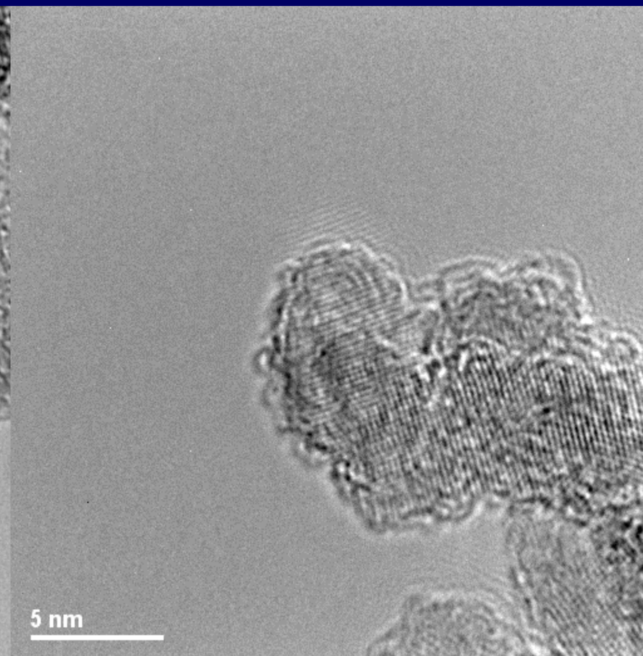
Core-Shell model of diamond-onion transition

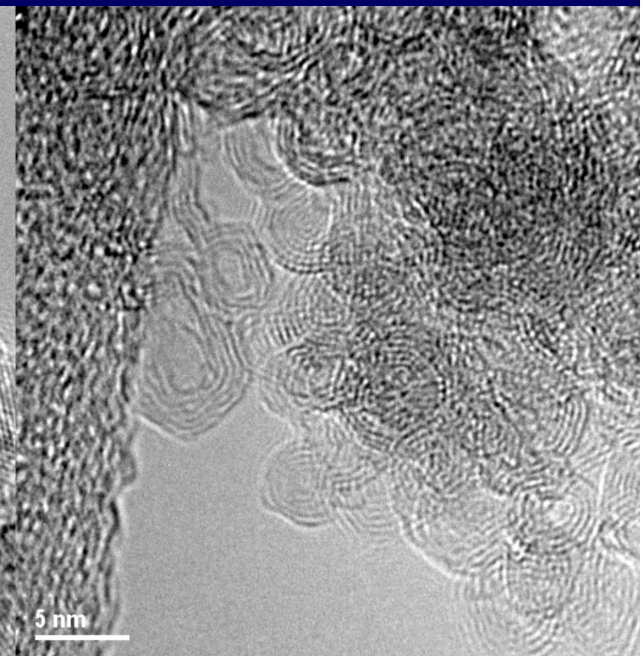


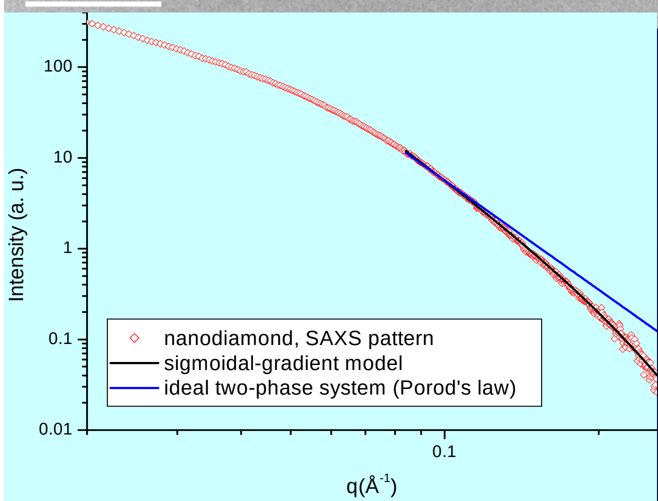


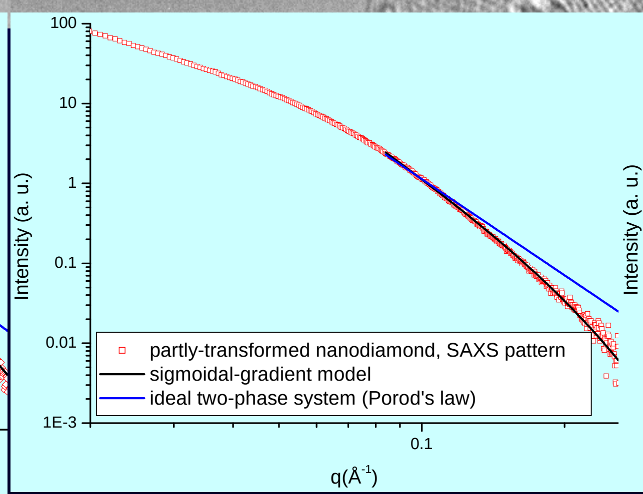
Small-angle X-ray Scattering (SAXS)

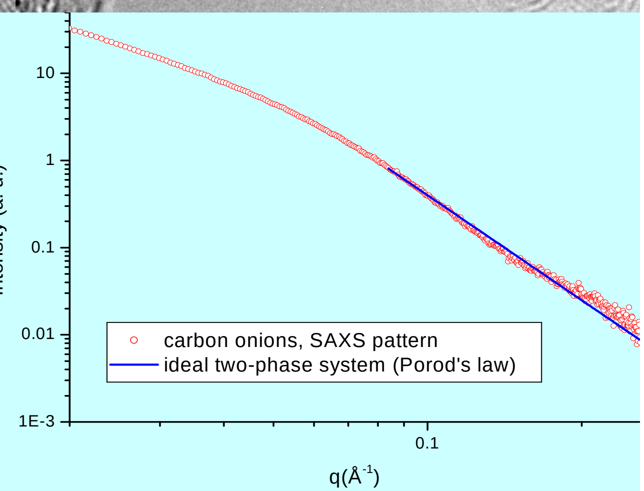




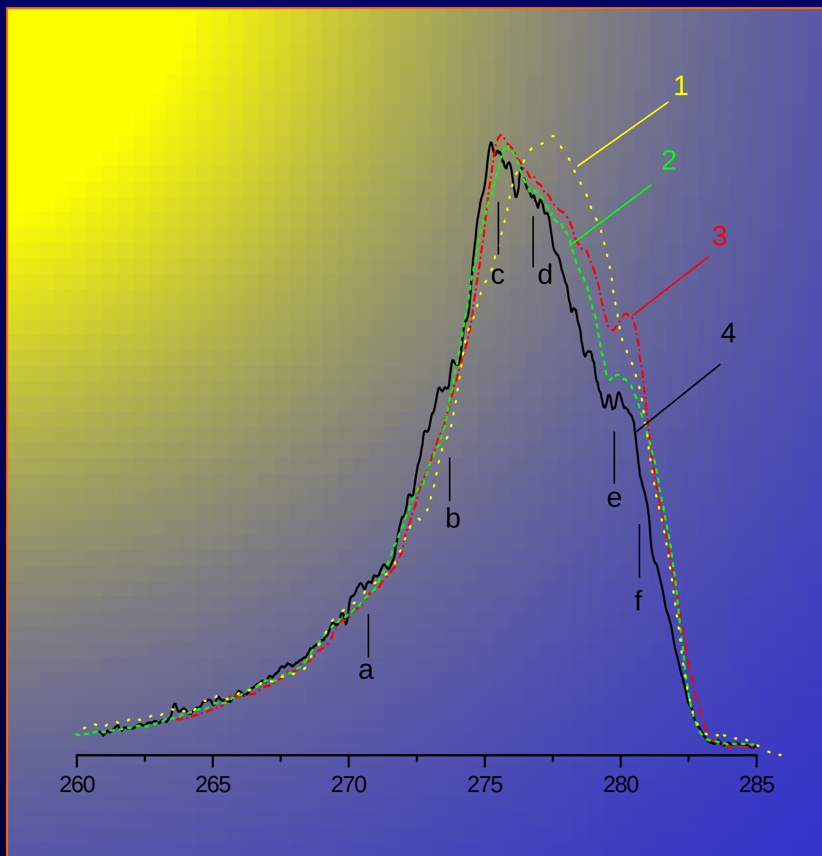


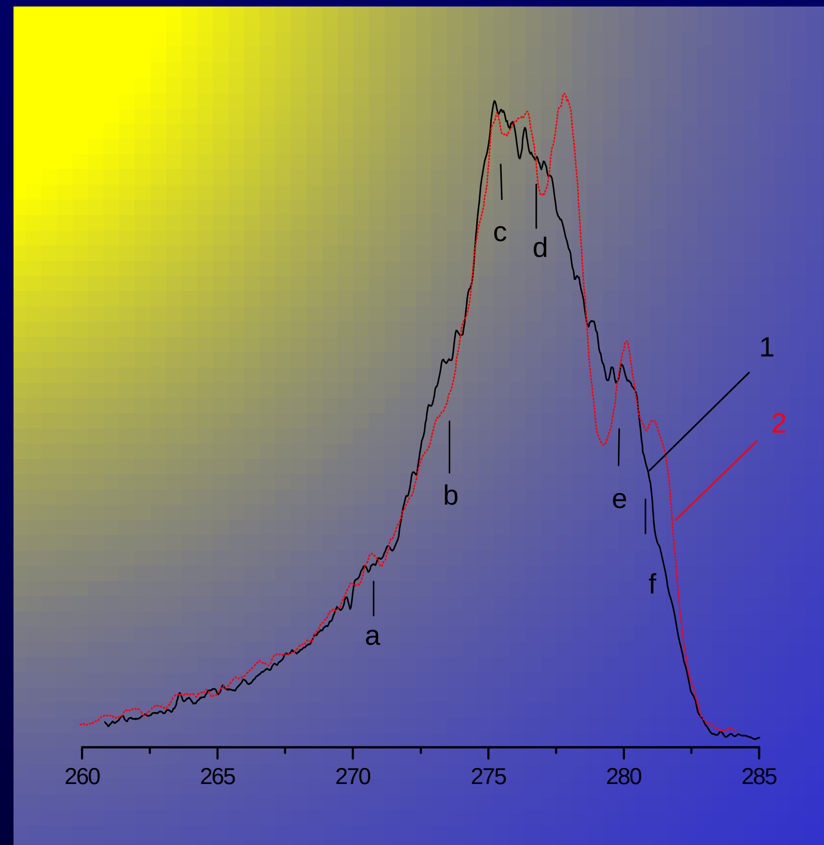






Carbon onions





Equal intensity peaks CK*α*-emission:

1 – nano-diamond,

2 – pyrolitic graphite,

3 – thermally exfoliated graphite,

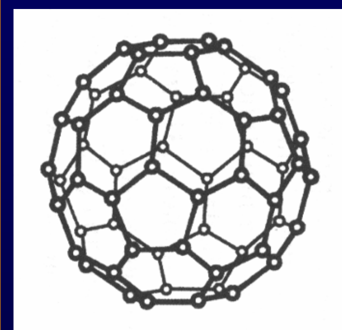
4 – carbon onion

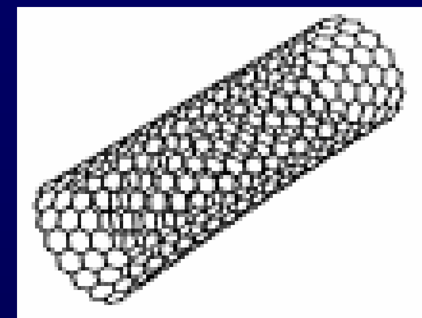
Photoelectron emission spectra CKα- from:
onions (1) fullerite (2).

HYDROGEN ADSORPTION BY CARBON NANOMATERIALS

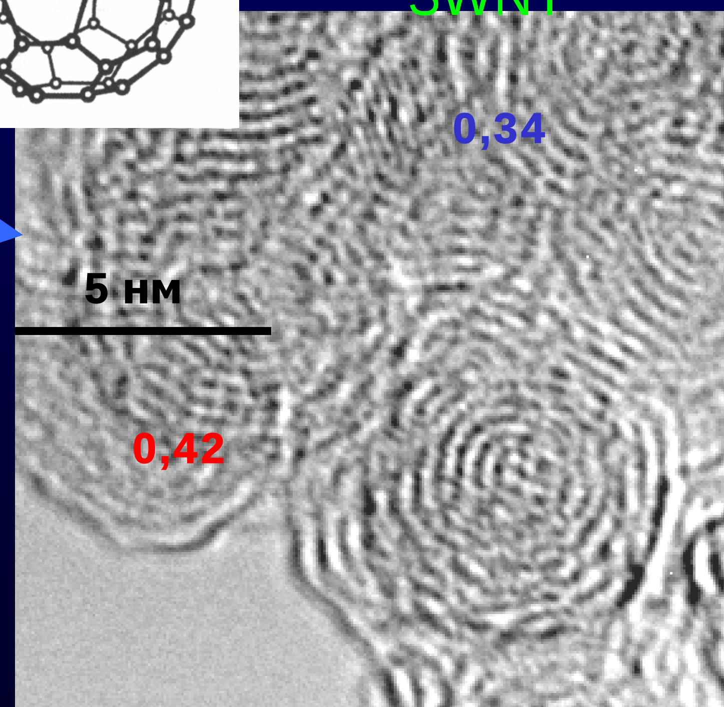
Material	Specific Surface Area m^2/g	Hydrogen , wt.% 77 K, 3 MPa
SWNT	180	1.23
MWNT	18	3.35
Activated:		
C60	3100	3.54
Carbon	3000	5.4
Onions	700	9

C60





SWNT



Carbon onions demonstrate highest physical adsorption capacity

(to 9 wt.%)!

Due capillary condensation of hydrogen in the surface layers of onion particles with increased d (002)

Patent of Ukraine

PREPARATION OF MWCNT

SWCNT and MWCNT prepared by CO conversion

- Method of low temperature (500-600 ºC) catalytically conversion of CO results in the creation of carbon nanotubes and onions. Carbon nanotubes and onions prepared do not demand purification from carbon black usually formed in other processes.
- The weight ratio between nanotubes and onions is about 70…80 / 30…20.
- A typical nanotube diameter size depends on catalyst particle size and equals to 20…60 nm. The length is commonly about 3…5 μm.

Carbon and noncarbon nanotubes;

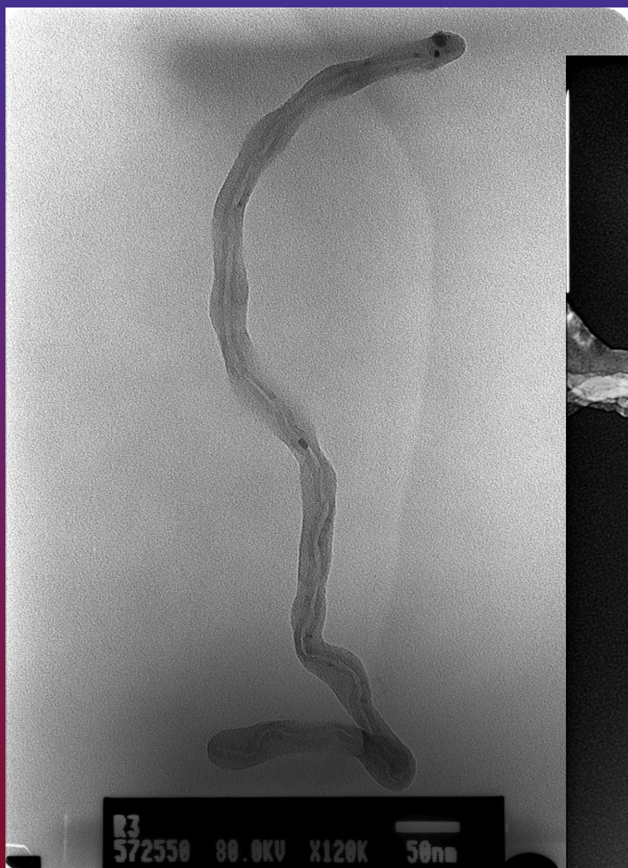
In cooperation with Clarkson University NY,

CRDF UE2-2356

SWCNT and MWCNT prepared by CO conversion

- Low temperature preparation of carbon nanotubes and onions free from black carbon.
- Morphology of nanotubes and onions prepared with using of different catalysts.
- HP sintering of nanotubes and onions on Ni catalyst.
- Morphology of powders sintered.
- Nanoindentor tests.

PREPARATION OF MWCNT
with different catalysts

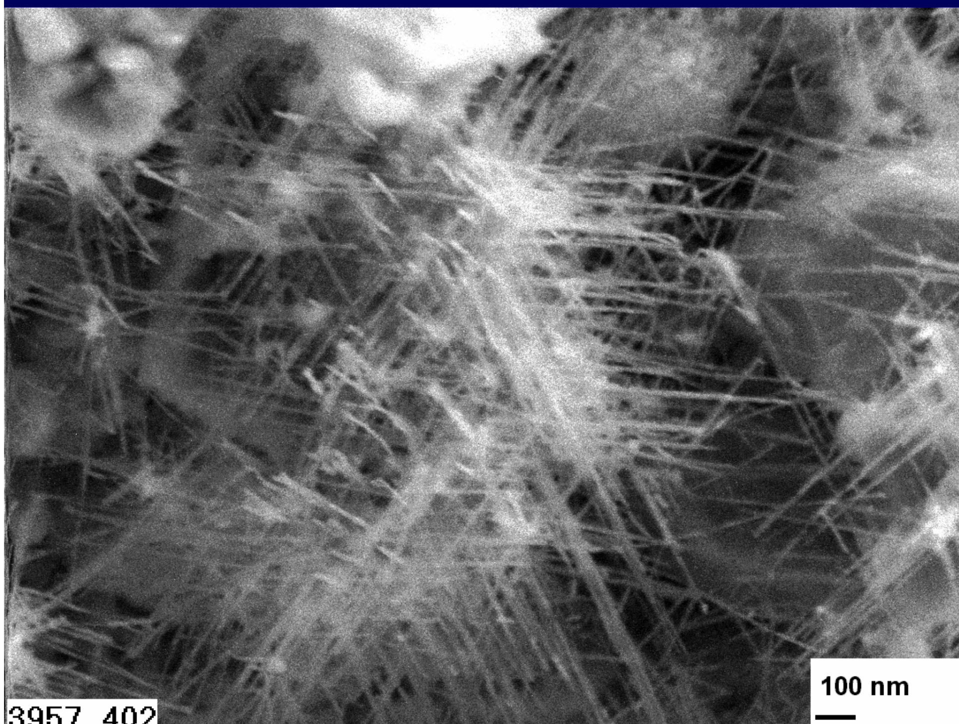


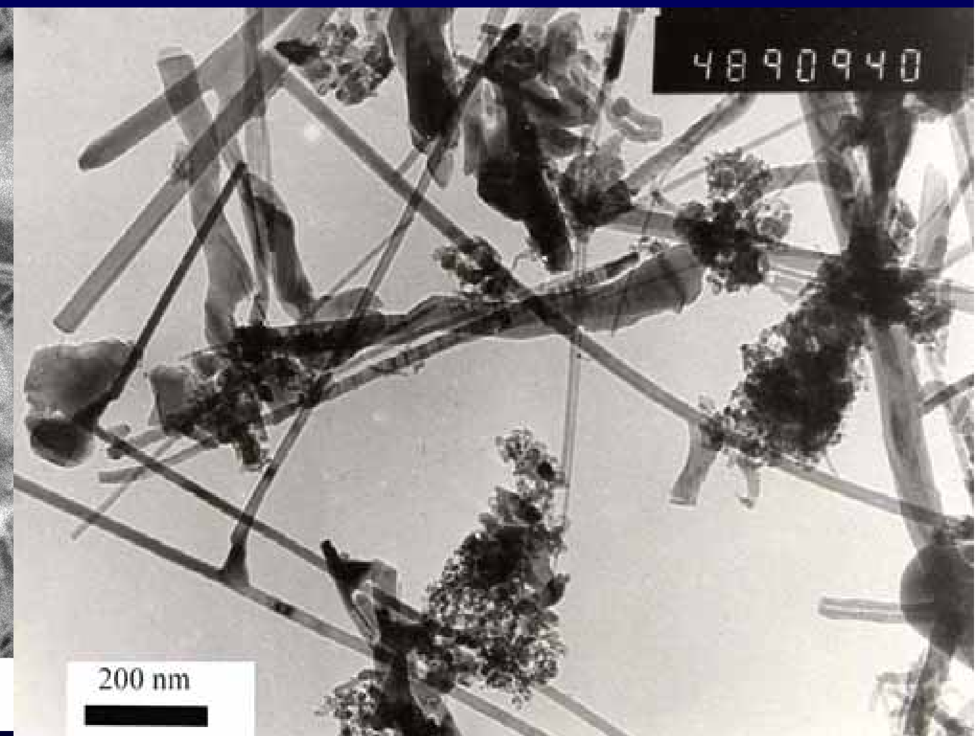
Co

Ni

Fe

Nanorods SiC, prepared by chemical synthesis using Fe – catalyst at 1000 °C for 60 min.





Drs. P. Sylenko, A. Ragulya

Dr. Kharlamov

Patents of Ukraine

Nanowires of TiB_2, synthesized from Ti-C-O-B system at temperature 1100 °C.

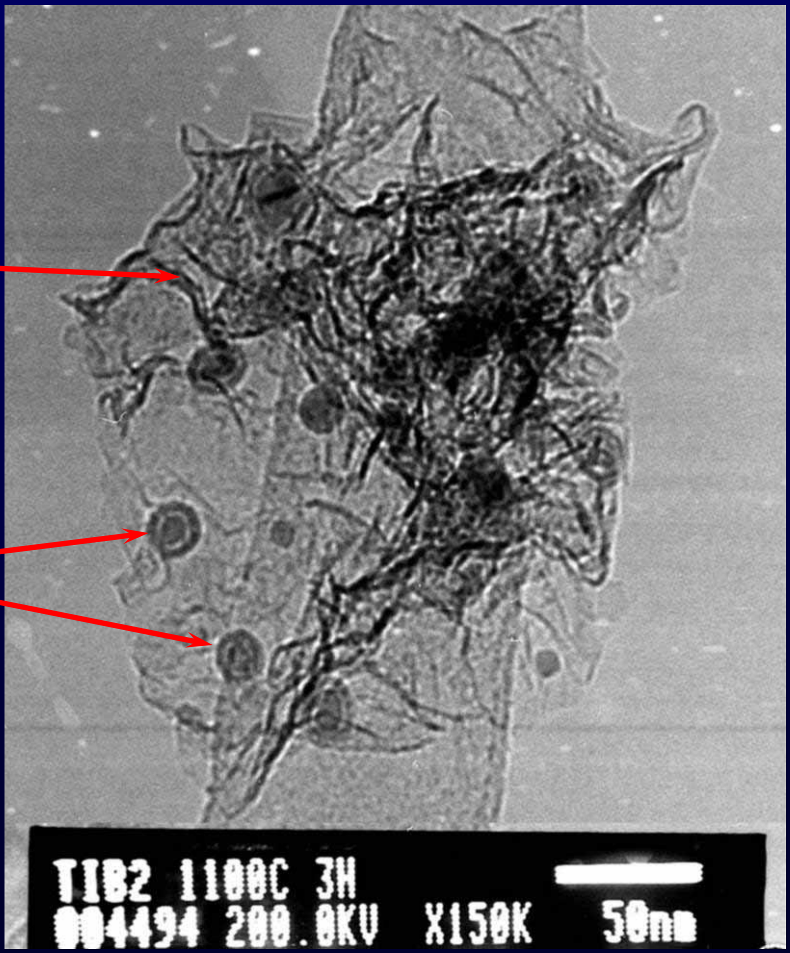
Nanowires TiB_2

6-8 nm in diameter

and 50-100 nm length

Nano-onions TiB_2

10-25 nm in diameter



Drs. E. Prilutski, E. Smuk

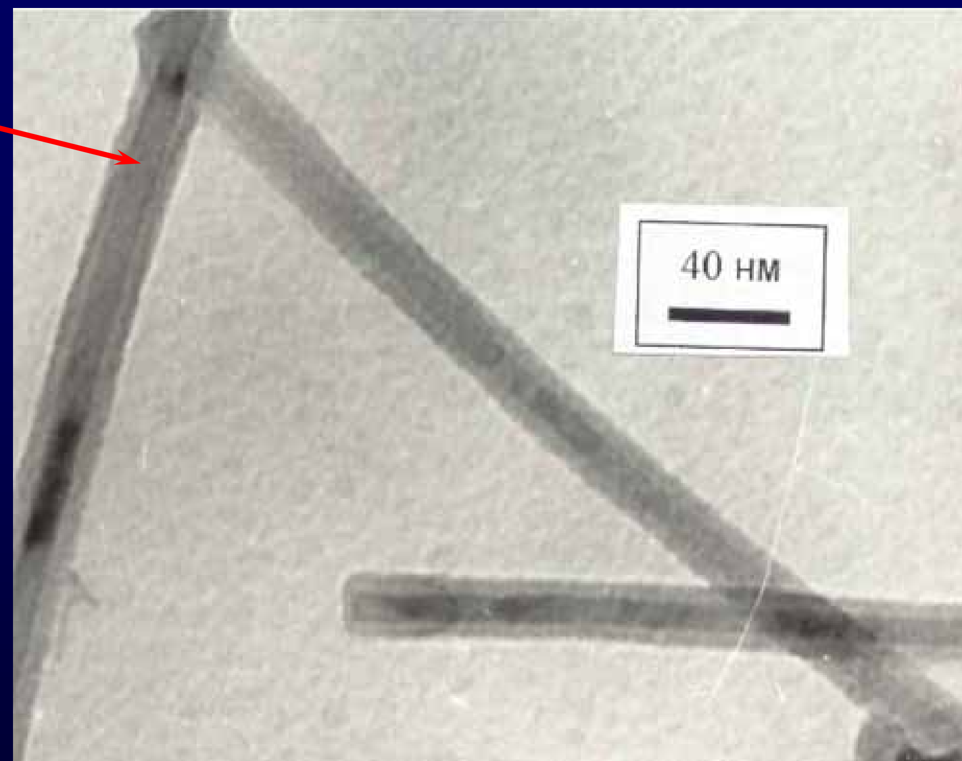
Patent of Ukraine

Developed the technology of synthesis of Si_3N_4 nanorods and nanotubes by CVD technology

Nanotubes of Si_3N_4

15-25 nm in diameter

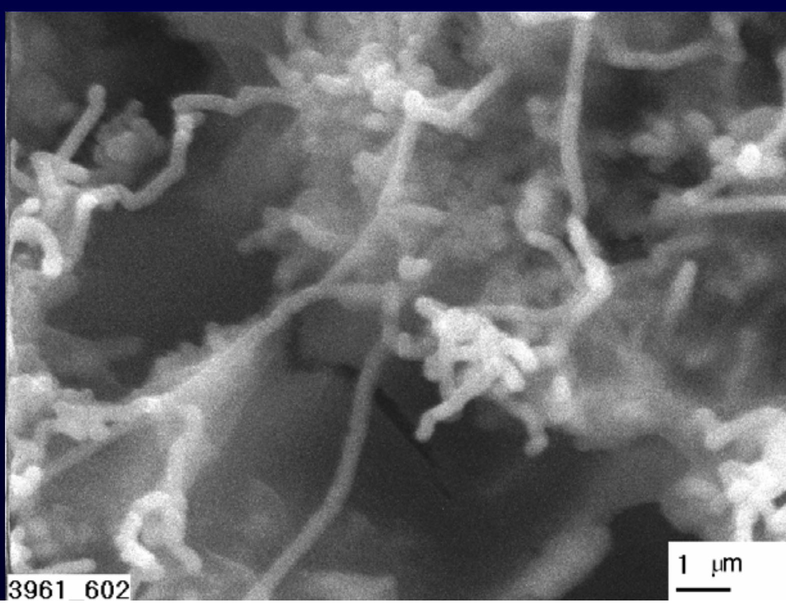
and up to 1 μm length



Nanorods of Si_3N_4 of

50-75 nm in diameter

and up to 100 μm length



Conclusions

- Tens of particulate substances and compounds had been obtained on laboratory, pilot and industry scales;
- Developed new concept of nanoparticle synthesis in nanoreactor considering wide number of possible reactors;
- Developed rate-controlled synthesis method appropriate for flexible control of nanoparticle size distribution;
- Developed new combined method for synthesis of nano-cubic boron nitride under shock–wave conditions in diffusion-controlled area of transformation from graphite-like BN;
- Developed pilot-scale manufacturing of carbon SWNT and MWNT by carbon oxide conversion reaction
- Developed laboratory synthesis of nanorods, nanowires and other elongated nanostructures based on SiC, Si_3N_4, TiB_2, BN…


THANK YOU