Zirconia nanopowders
and technology of their production

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named after O.O. Galkin of NAS of Ukraine

Donetsk, Ukraine
Nanopowders for ceramic production

- R&D ceramic oxide powders - 48%
- R&D in the energy sector - 22%
- Development or commercialization for power devices - 44%

Electronics and photonics - $1.5 billion (2012)
Bioceramics - $2.3 billion (2011)
World market of zirconia nanopowders

The market segments of zirconia nanopowder production

- China: 18%
- USA, Great Britain: 18%
- Japan: 18%
- Australia: 12%
- France: 6%
- Russia: 28%

<table>
<thead>
<tr>
<th>COUNTRIES</th>
<th>PRODUCTION (in metric tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>481</td>
</tr>
<tr>
<td>South Africa</td>
<td>380</td>
</tr>
<tr>
<td>China</td>
<td>140</td>
</tr>
<tr>
<td>Indonesia</td>
<td>60</td>
</tr>
<tr>
<td>Ukraine</td>
<td>35</td>
</tr>
<tr>
<td>India</td>
<td>31</td>
</tr>
<tr>
<td>Brazil</td>
<td>18</td>
</tr>
<tr>
<td>Other countries</td>
<td>30</td>
</tr>
</tbody>
</table>

SOURCE: USGS; Mineral Commodity Summary 2011

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Product - zirconia nanopowders.
Economic advantages

<table>
<thead>
<tr>
<th>Product</th>
<th>Price per kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nano-oxide Inc. (6nm)</td>
<td>$3760</td>
</tr>
<tr>
<td>Xuancheng Jinguri MNCo (5 - 10 nm)</td>
<td>$700</td>
</tr>
<tr>
<td>DonIPhE (6, 10,..., 40 nm)</td>
<td>$80</td>
</tr>
<tr>
<td>Tosoh (40 nm)</td>
<td>$125 in Japan, $200 in Ukraine</td>
</tr>
</tbody>
</table>

Quotations of world manufacturers of zirconium oxide nanopowder (FOB)
New technology for nanopowders production

Traditional method:
- Coprecipitation
- Drying
- Calcination
- Grinding

Special processing:
- Drying

New method:
- Without grinding
- Calcination

Intellectual property:
- Technology is patented in Ukraine and contains know-how
Peculiarities of DonIPhE technology

- specified particle size (7 ... 50 nm)
- a narrow particle size distribution
- specific surface area (200 ... 10 m²/g)
- soft agglomerates

\[ \text{ZrO}_2 + 3 \text{ mol.}\% \text{ Y}_2\text{O}_3 \]

- controlled chemical composition
- specified phase composition
- high properties stability
- surface modification

DonIPhE technology
Ukraine's first pilot line for the production of oxide nanopowders and the development of new technologies

Productivity - 10 kg per month

catalysts
pigments
composites
LEDs
markers in medicine

ZrO₂, TiO₂, LaMnO₃, Al₂O₃, mullite
Matrix of comparison of the powders characteristics

<table>
<thead>
<tr>
<th>Important product or technology characteristics</th>
<th>DonIPhE NASU, Ukraine</th>
<th>NexTech, USA</th>
<th>Tosoh, Japan</th>
<th>NANO-Oxides inc, USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size, nm</td>
<td>5;10;15;20;30;40</td>
<td>30 - 40</td>
<td>40</td>
<td>3 - 5</td>
</tr>
<tr>
<td>BET, m²/g</td>
<td>200 - 15</td>
<td>10 - 15</td>
<td>16</td>
<td>200</td>
</tr>
<tr>
<td>Agglomeration</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>Process type</td>
<td>Precipitation</td>
<td>-</td>
<td>Hydrolysis</td>
<td>Molecular decomposition</td>
</tr>
<tr>
<td>Price, $/kg</td>
<td>80 – 100*</td>
<td>300</td>
<td>200</td>
<td>3760</td>
</tr>
</tbody>
</table>

* cost price in laboratory conditions
Application: catalysts based on zirconia nanoparticles

For oxidation CO

better catalytic properties

In collaboration:
Institute of Surface Chemistry, NASU, Kiev

For oxidation of organic substances

New composite nanocatalysts with high catalytic properties

In collaboration:
Institute of Organic Chemistry and Coal Chemistry, NASU, Donetsk
**Application:** thermal barrier coatings for turbine blades

Problem of coating stability:

Use of nanopowders increases the stability of coating and the service time of aircraft engine

In collaboration:
MC of Electron Beam Technologies of EWI of NASU, Kiev
**Application: fillers for composites**

Zirconia nanoparticles of DonIPhT NASU lead to improvement of the properties composite materials.

For fluoroplast F4CN20

For reactor dispersion strengthened steels

For metal electrochemical coatings

**In collaboration:**

KhNU, Khmelnitsky

NSC KIPT, Kharkov

USUCT, Dnipropetrovsk
Application: ceramic with pre-determined structure

Nanoparticles based on ZrO₂ with modified surface

Ceramics for air and water purification filters, bone implants

150 nm
Porosity > 60 %

Needle-like nanoparticles
Application: markers for diagnosis of "core-shell" tumor types of cancer

- Biocompatibility
- High levels of fluorescence

ZrO$_2$ nanoparticles

The fluorescence of ZrO$_2$: Eu$^{3+}$ nanoparticles

ZrO$_2$:Eu$^{3+}$ core

In collaboration with the Institute of Cell Biology NASU, NU "Lviv Polytechnic"
Application: XRD contrasted osteoplastic composite material based on zirconia nanopowders with the effect of regeneration of bone defects

Initial state with defect

Visualization of filled defect after 8 days

In collaboration with NU "Lviv Polytechnic« and Lviv National Medical University
Our proposals

Nanopowders based on zirconia and their production technology

Sale of oxide nanopowders of various purpose

Transfer of production technology of oxide nanopowders (licensing)

Organization of industrial production of oxide nanopowders (investment)

Organization of the company for target development of new technologies, production and characterization of nanopowders based on DonIPhT
Technology approbation and prospects of production

We tested the use of ZrO₂ nanoparticles:

- pigments - diagnostic markers
- catalysts - growth promoters
- ionistory - fillers for composites
- sensors - film (tape casting)
- heat-resistant coating - ceramics
- composites - components of fuel cells

How much money do we need for the organization of the enterprise for the production of oxide nanopowders and ceramics?

<table>
<thead>
<tr>
<th>The volume of production</th>
<th>- 1 ton/month, after 3 years to 2 tons/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>The total cost</td>
<td>- 37 400 000 UAH</td>
</tr>
<tr>
<td>Project payback period</td>
<td>- 4 years and 7 months</td>
</tr>
<tr>
<td>(from the start of production capacity)</td>
<td></td>
</tr>
<tr>
<td>Discounted payback period</td>
<td>- 7 years and 9 months</td>
</tr>
<tr>
<td>The average net income for 5 years</td>
<td>- 13 546 800 UAH per year.</td>
</tr>
<tr>
<td>Profitability of production</td>
<td>- 84%.</td>
</tr>
</tbody>
</table>
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