Group of companies
"MINERAL"

The Hydroxyapatite 氫氧基磷灰石

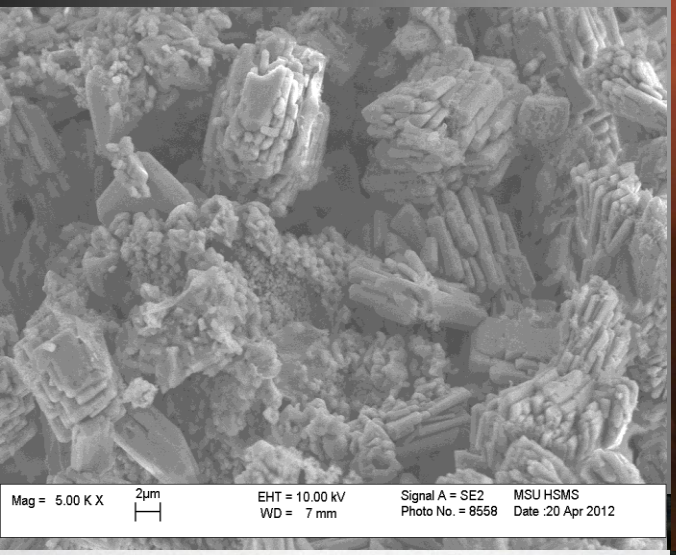
2017

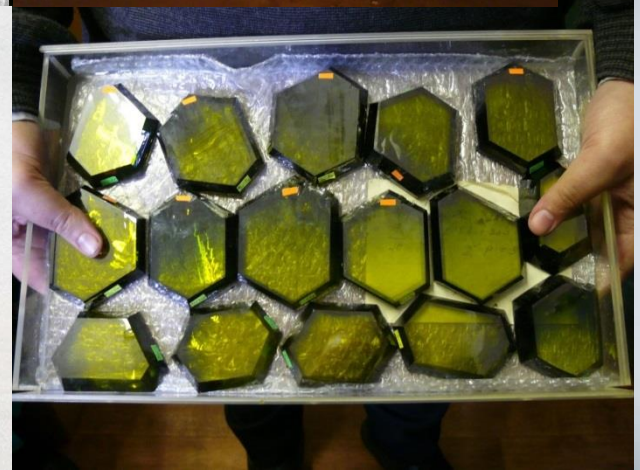
Mineral Ltd.

Address: 1, Institutskaya str., Alexandrov, Vladimir Region 601650 Russia.

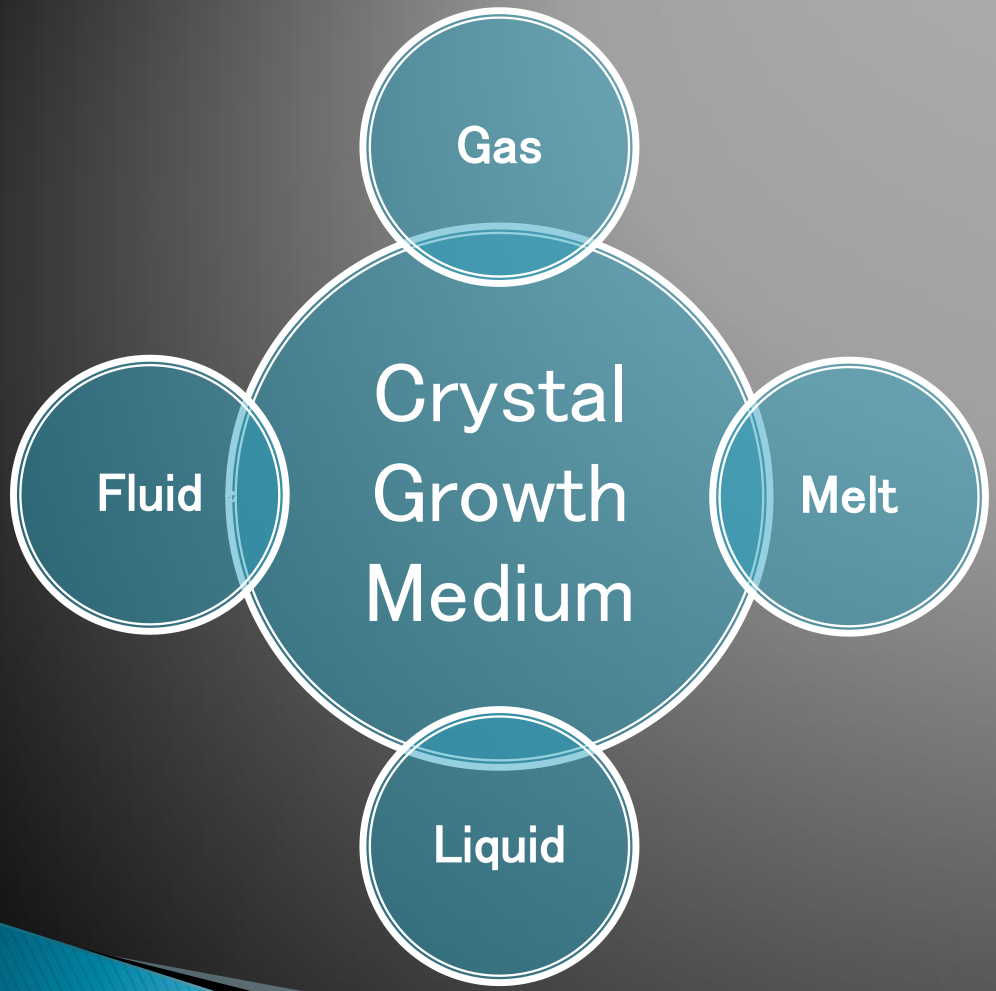
Employee: 125 including 19 Ph.D.

Total facilities area: 50 000 sq.m.





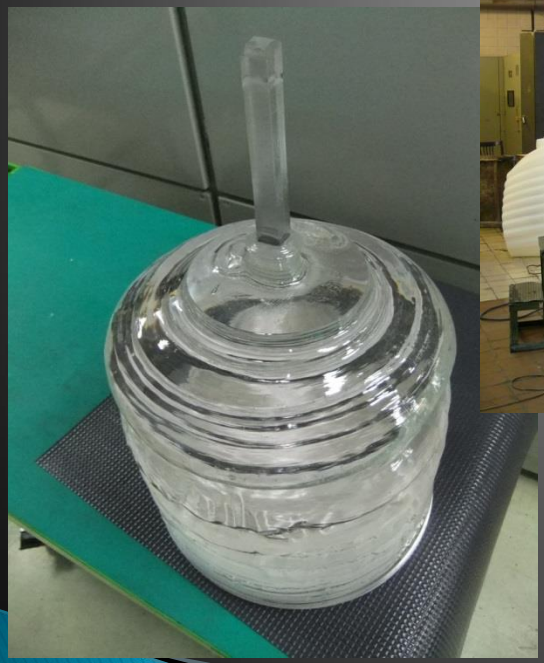
Methods of Mineral

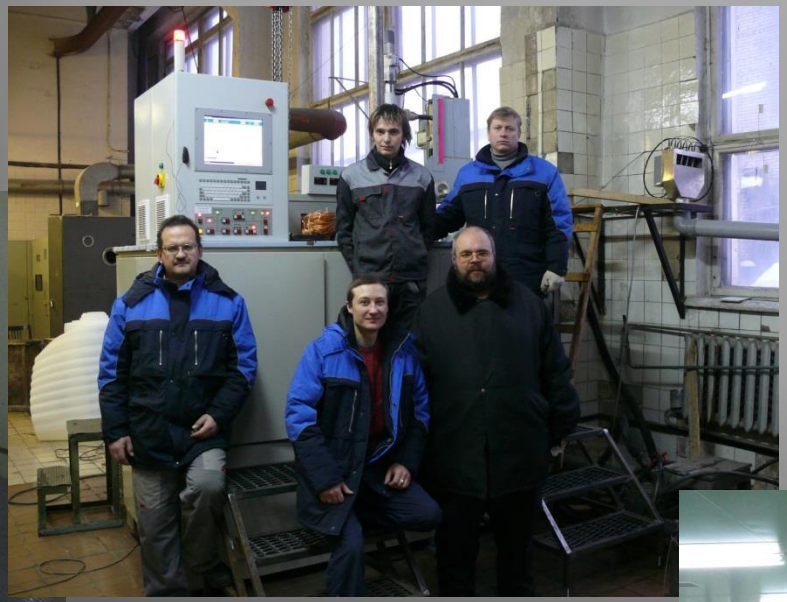


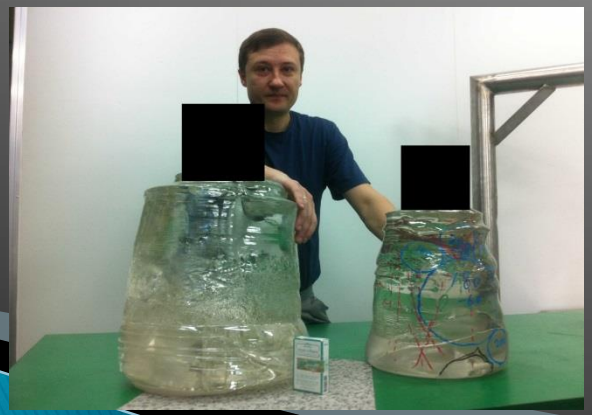
- Gas: SiC, Si, CNT.
- Melt: Sapphire, YAGs, Langasite, BGO, Lithium Aluminate.
- Liquid: Quartz, ZnO, LFP, **Hydroxyapatite.**
- Fluid: GaN, AlN.

Kyropoulos Grower 藍寶石長晶爐

1. DK Aztec Korea.
2. USIO Taiwan.







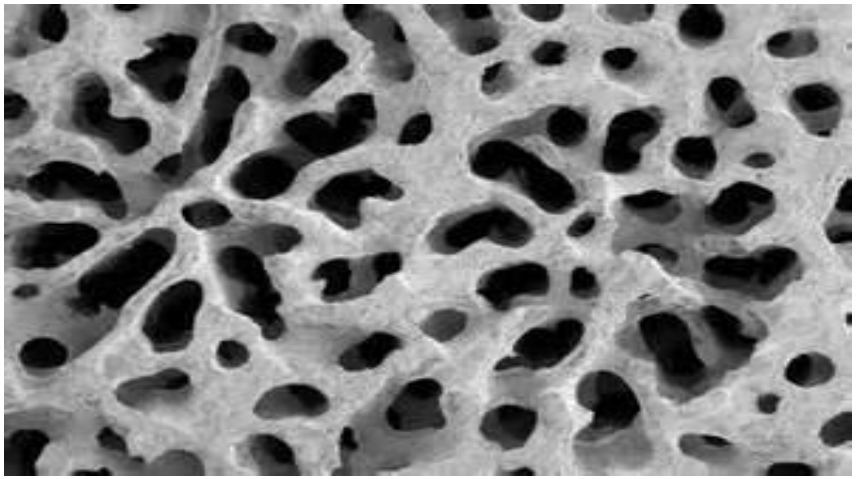
藍寶石長晶技術輸出專案

Astek Korea 2010

ACME/USIO Taiwan 2008

The Hydroxyapatite (HAP)

1. The Hydroxyapatite formula Ca10(PO4)6(OH)2. 氫氧基磷灰石
2. It Can be Produced by various methods
3. Biocompatibility because similar crystal structure as bone apatite



The Application Of Hydroxyapatite

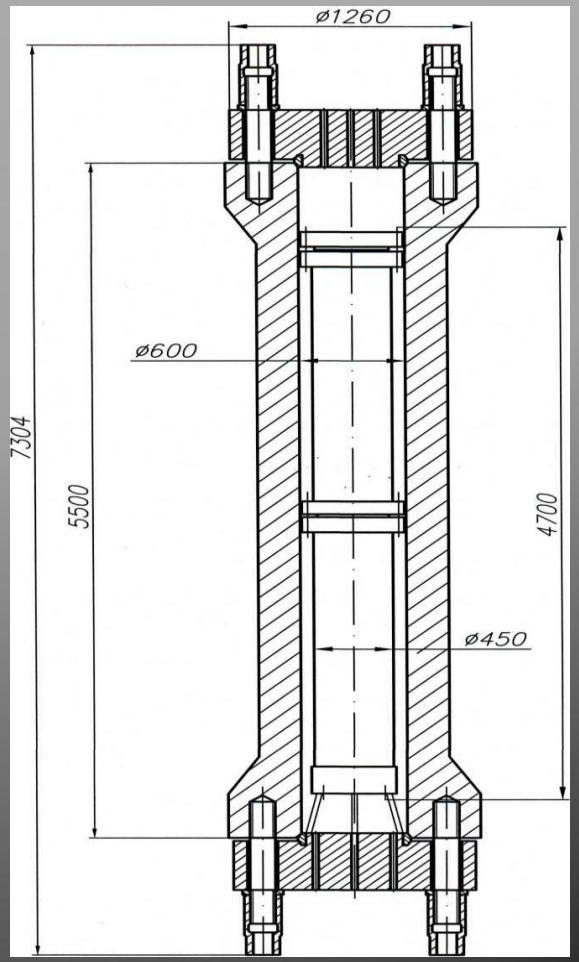
1. Material for Implants and Dental Cements
2. Granules for Dermal Fillers
3. Food supplement of human and animals.
4. Ion Exchanger and Sorbent of Radioactive Materials
5. Catalyst for Biobutanol Production
6. Antibacterial filter for liquid and air
7. Toothpaste component
8. Additive for sunscreen cremes and nail laquers

Methods of hydroxyapatite synthesis and challenges.

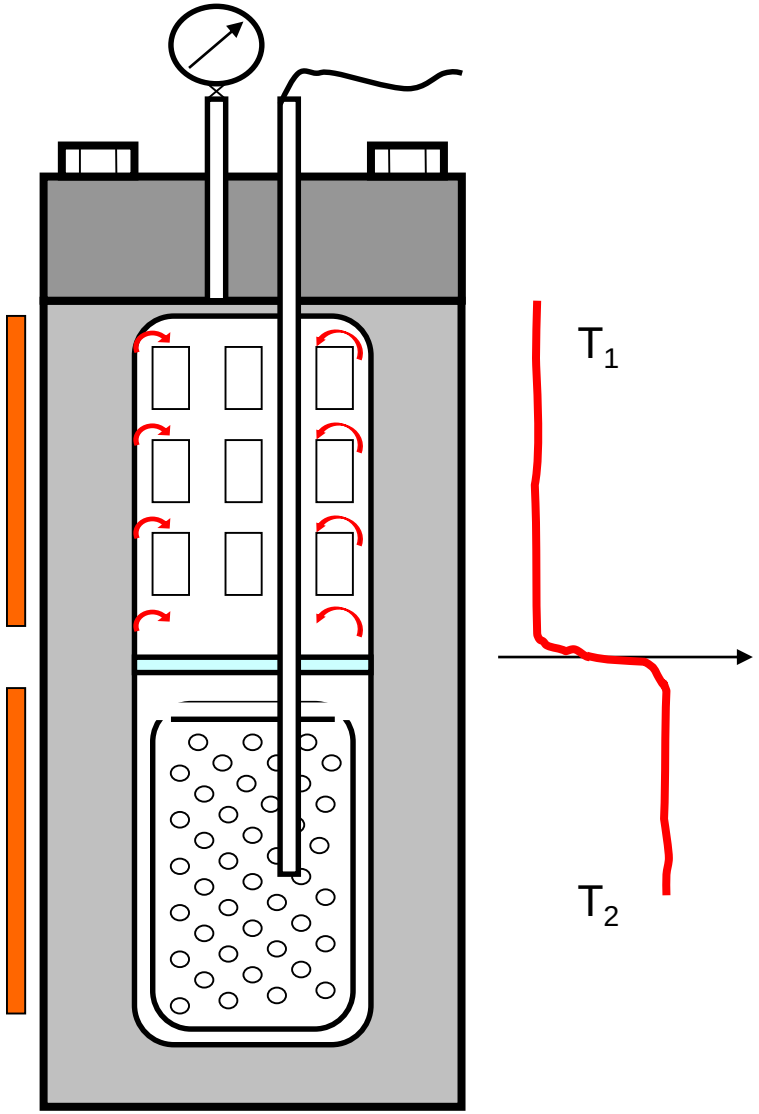
- **Solid state synthesis** 固相合成 –too big grains and not uniform properties of particles because of slow diffusion in solid state.
- **Aqueous precipitation** 水沉澱– low degree of crystallinity, other phosphate phases can appear.
- **Hydrothermal** 水熱合成– high degree of crystallinity, single phase of HAP, uniformity of shape and size of crystals, but require special autoclave equipment.
- **Sol–gel** 凝膠法 – same issues as in aqueous precipitation.
- **Self–propagation combustion** 自延燃燒法 – low crystallinity after calcination.

The Hydrothermal Method Of Making HAP Powder and Coating

- Example: 525 liter floating liner inside 1500 liter autoclave.
- **“Floating** “ mean that liner is not fixed to the inner wall autoclave but free stand on support; liner walls are under action of pressure created by water inside liner and outside liner.



The 24 liters Autoclave Settled



The Main Directions

1. Biocompatible doped nano HAP and TCP powder.

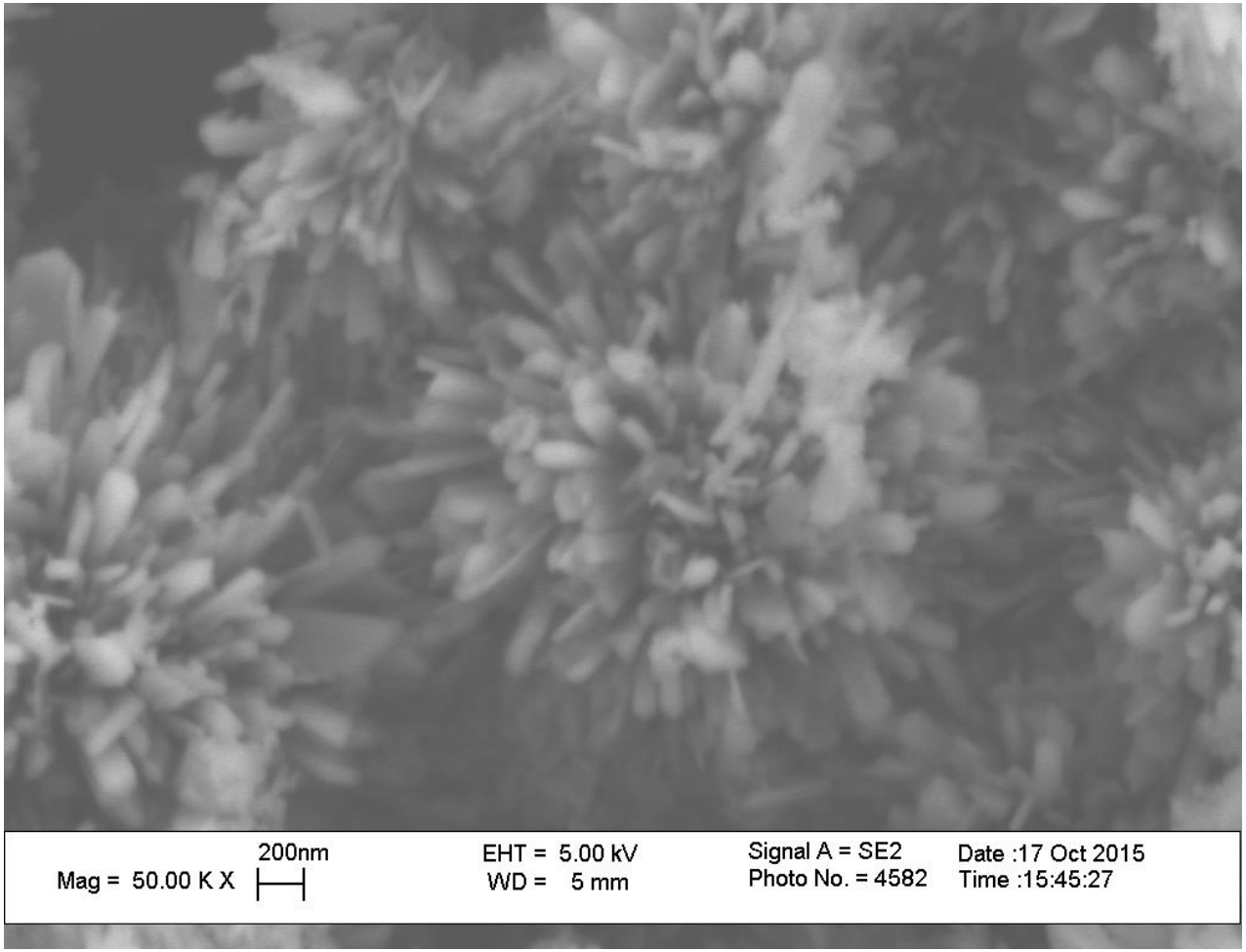
2. Manufacturing of spherical HAP and HAP/TCP granules

3. HAP 3D printer of scaffolds for bone tissue engineering. 3D列印支架骨骼組織工程.

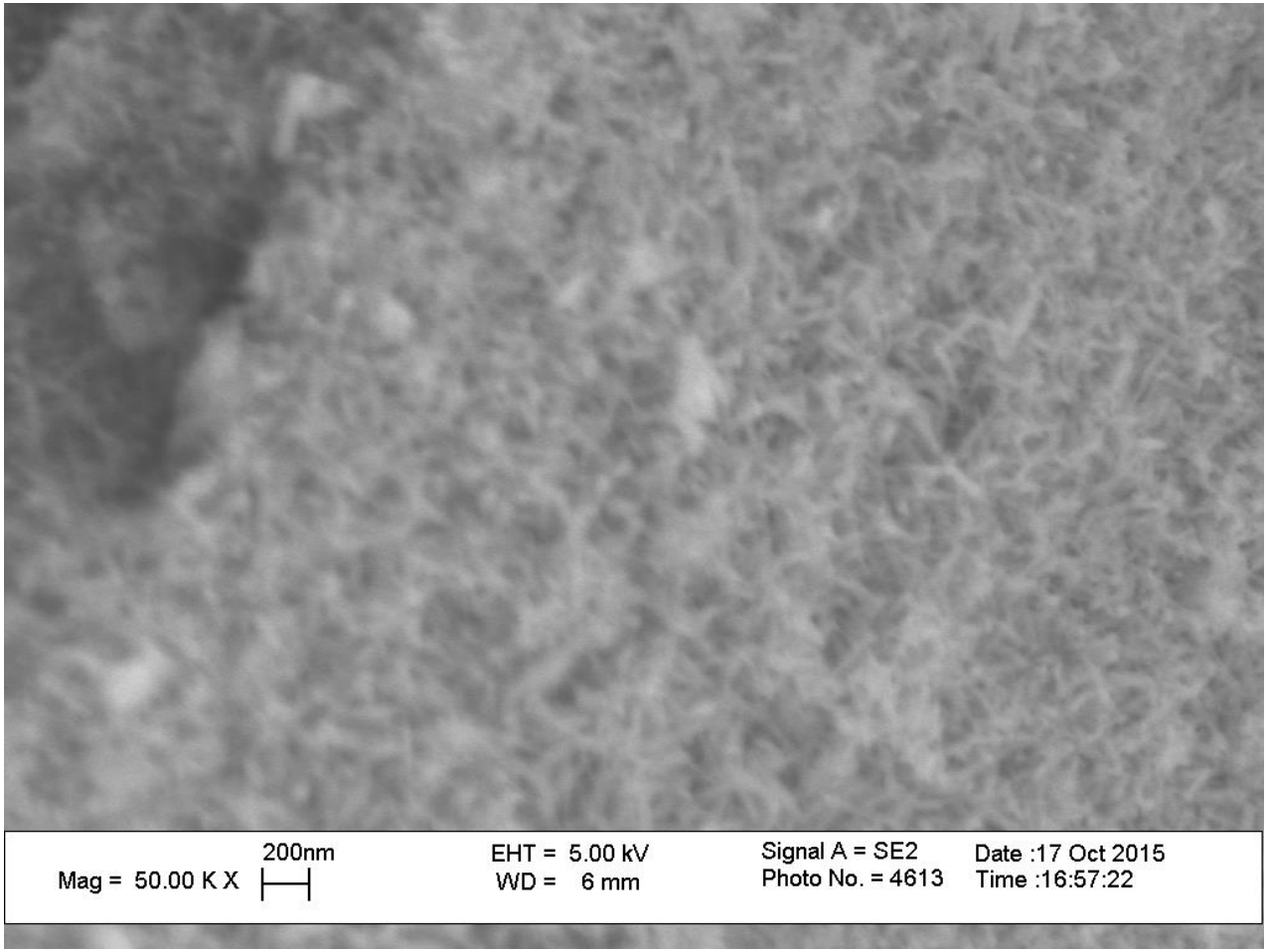
Crystallinity degree is controled by temperature regime in autoclave

- **High crystallinity degree** is important for HAP particles or coating with low resorption applications where long time mechanical reliability of particle or coating is needed
- **Low and Medium crystallinity degree** is important for HAP particles and coatings with high resorption (raw material for new bone growth near implant, food supplement)
- **Off-stoichiometric hydroxyapatite** can be used for manufacturing **HAP/TCP composites**

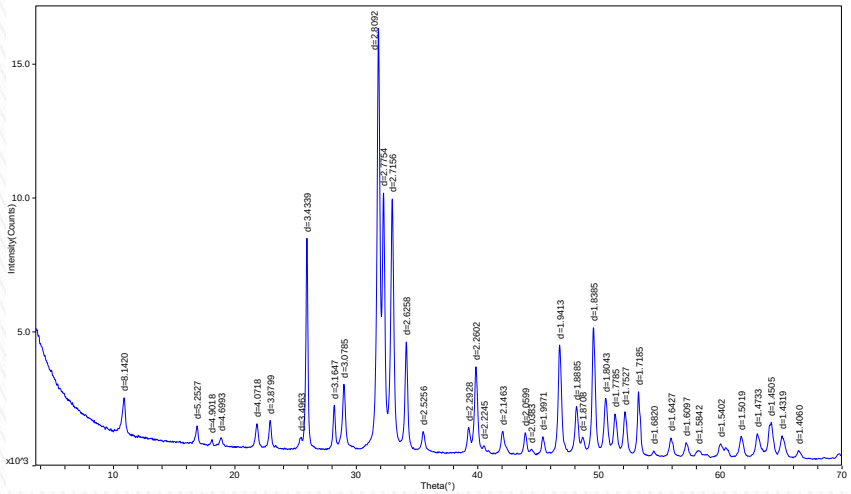
SEM of High Crystallinity Degree HAP T=280 centigrade , Duration= 10 hours.

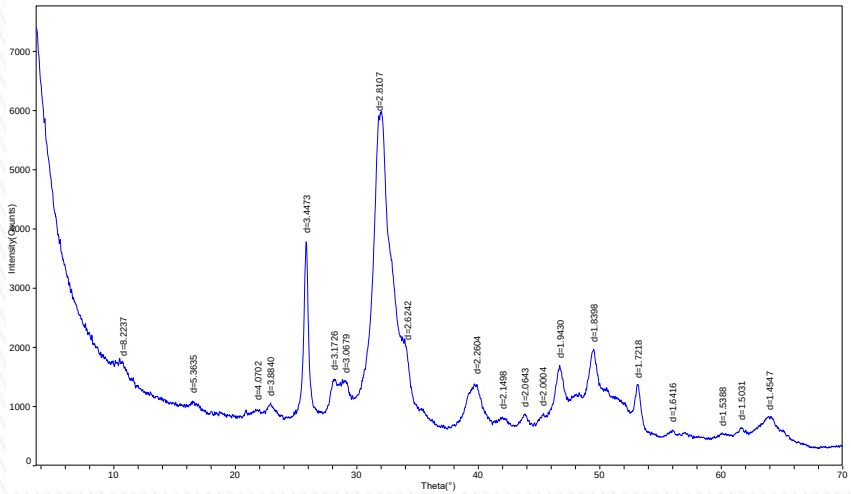


SEM of Low Crystallinity Degree HAP T=30 centigrade , Duration= 1 day.



Crystallinity
hydrothermal vs. precipitation





High crystallinity

Low crystallinity

3D Printed Scaffolds (Bone grafts)

- **Availability** of two types of the HAP powder (resorbable and non-resorbable) and HAP/TCP powder will permit to build bone scaffolds ideal for osteoblasts cells proliferation with stable HAP areas for osteoblast cells living and easy soluble TCP areas as raw material for new bone growth.

- **Availability** of hydrothermal treatment for printed scaffolds open prospective of scaffold improvement after printing.

The Bone Grafting

- 3D Printed

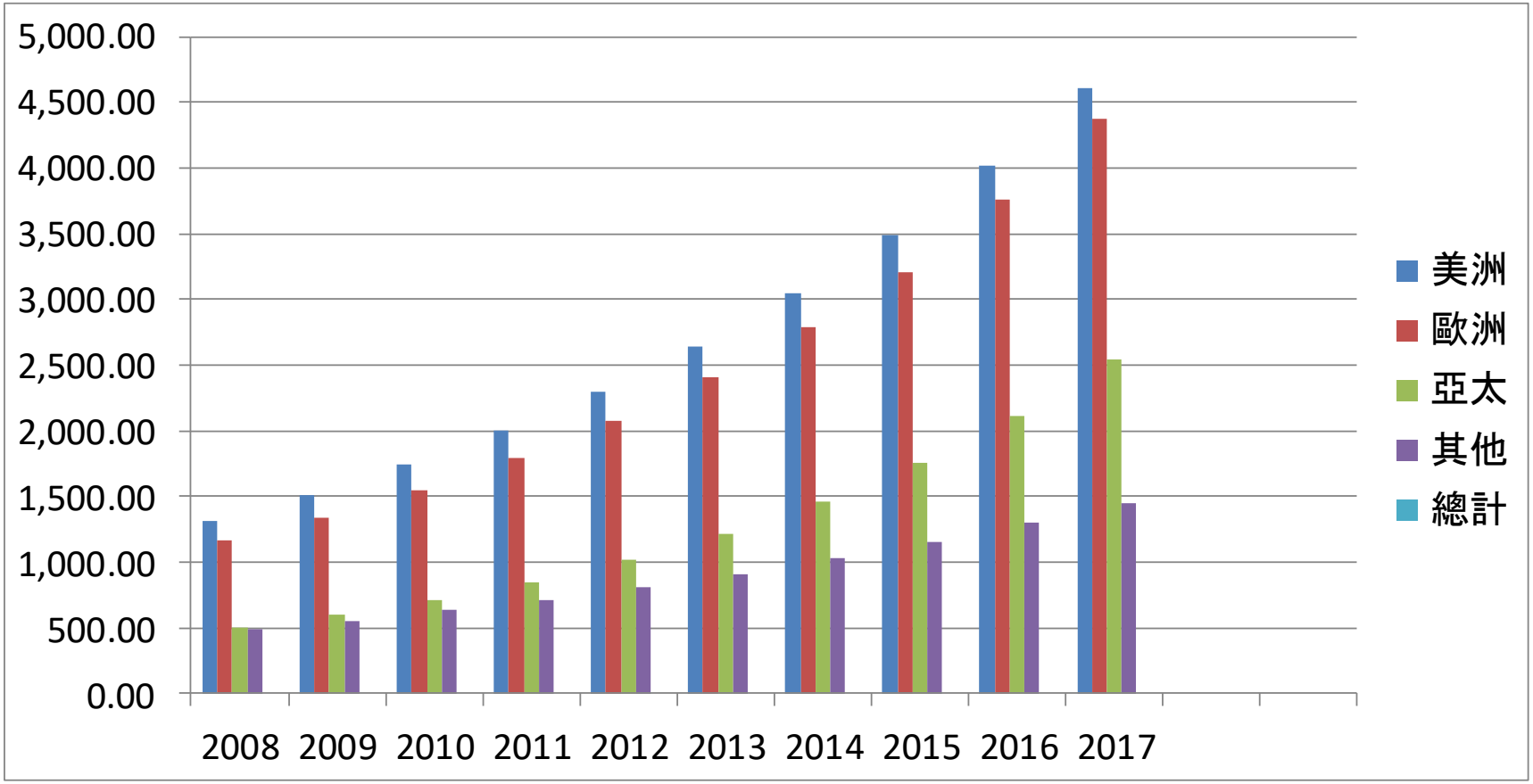
- 3D Printed

Evaluation Methods

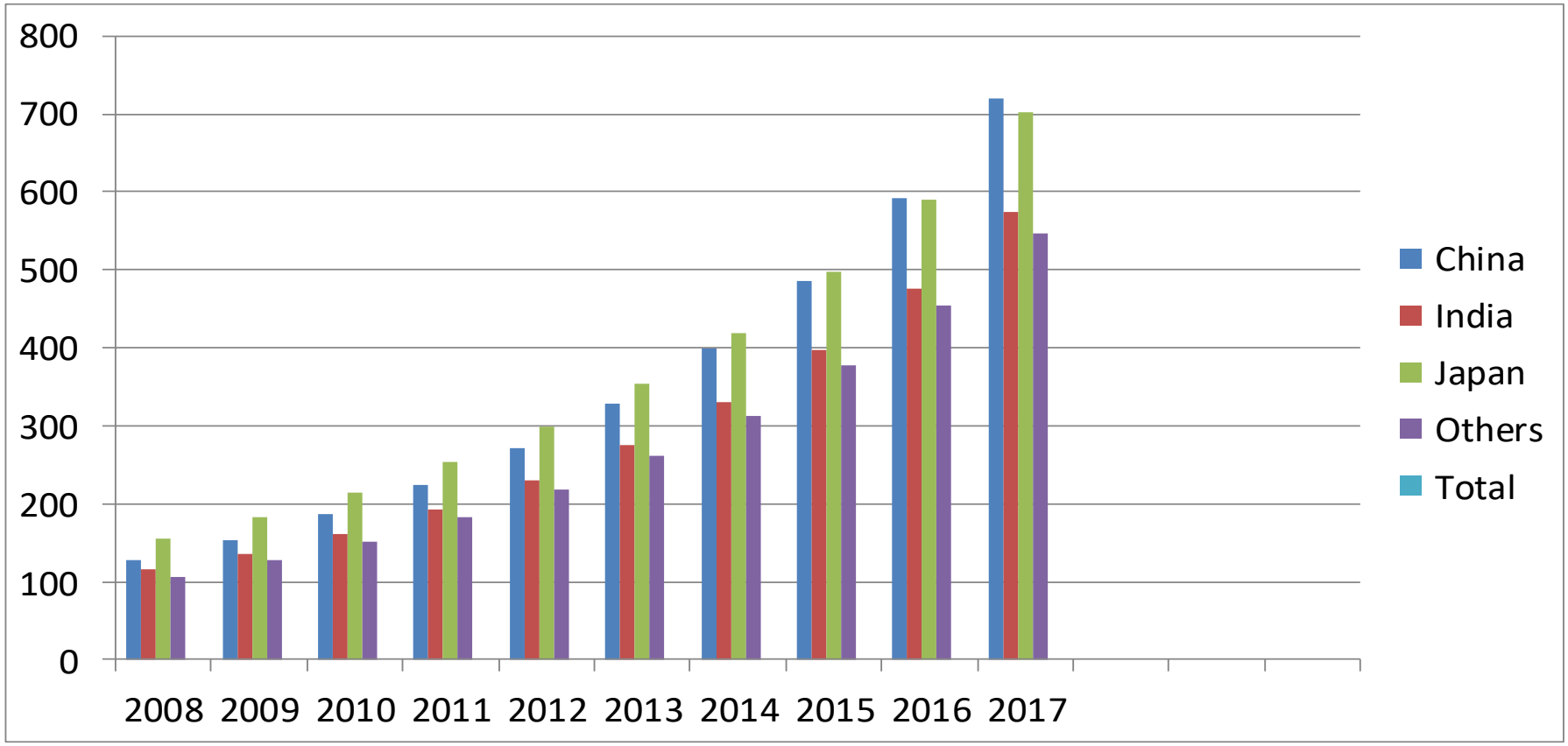
- SEM, Scanning Electron Microscope.
- XRD, X Ray Diffraction.
- ICP-AES
- TGA, Thermogravimetric Analysis.

- Material characterization was done by leading labs in Russian State Universities: Moscow State University, National University of Science and Technology

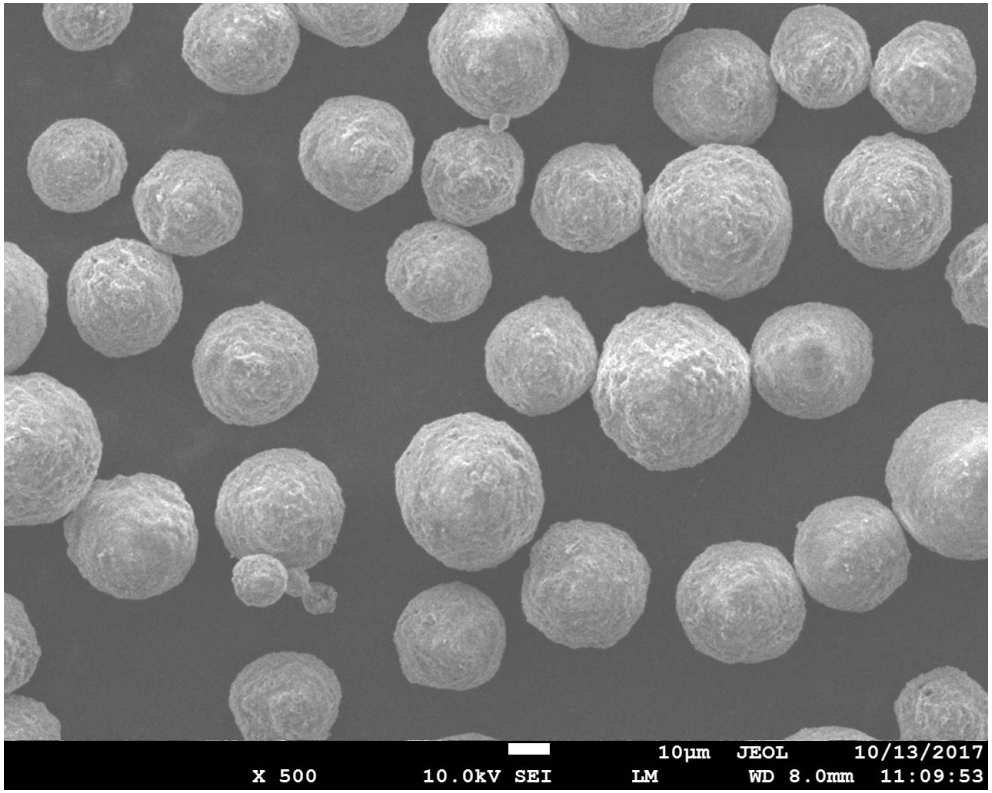
The Global Ceramic Biomaterial Market Analysis 2008-2017 (CAGR 15.9% in USD Million)



The Ceramic Biomaterials Market in Asia-Pacific 2008-2017 (CAGR 21.1% USD Million)



Spherical HAP powder (dermal filler and powder for spray coating and powder for 3DP)



Spherical form importance

- Spherical shape is needed to provide ideal flowability through syringe for face lifters, injector of plasma spray or nozzle of 3D printer
- The particle size uniformity is important to obtain dense packing of spheres at final destination
- Particle size control is provided by sieving or air classifier

Spherical particles production stages

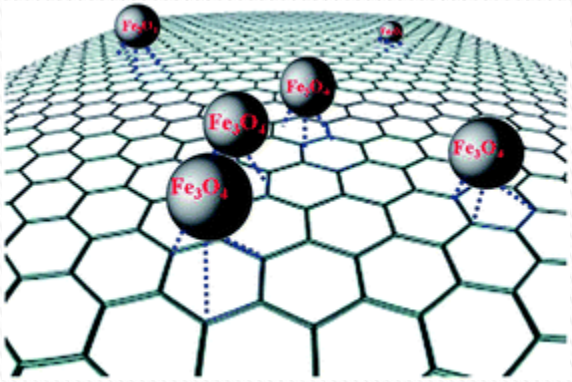
- Ultasonic Dispergation of nanocrystals
- Spherical particles granulation
- Sintering
- Sieving or air classification

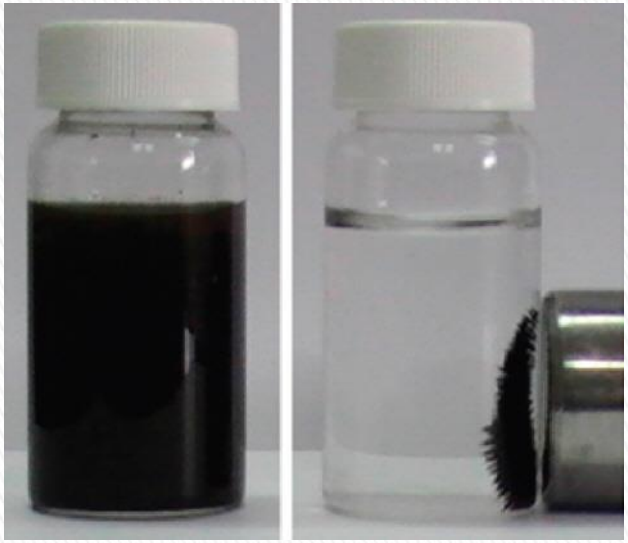
Composite materials

- 3D printing can be used for creation composite implants
- Hydroxyapatite bring biocompatibility
- Other materials like ZrO2 can improve mechanical properties of ceramics
- 3D printed ZrO2 skeleton (frame) inside HAP implant body can improve characteristics

Magnetic HAP-Fe_3O_4 composite for drug delivery systems and hyperthermia

Other biomaterials could be effectively produced in autoclave





- Graphene oxide-Fe3O4 composite for anti-cancer drug delivery system could be produced in autoclave
- Graphene oxide could be used for many applications including graphene scaffolds for medicine, conductive graphene ink for flexible electronics, radioactive water sorbent and others

HAP Conclusion

- 自然骨骼中約有65%左右的氫氧基磷灰石.
- 骨骼移植在醫院是僅次於輸血的醫療行為.
- 人工骨骼目前可以大量製造及使用最廣.
- HAP為基礎的生物活性陶瓷是目前最好的.
- 奈米骨骼100nm size,可加強成骨細胞的功能.
- 如何做好骨骼組織工程的核心目標.