Head of the Center
Professor Elguja Kutelia

Past, Present and Future of the Republic Center for Structure Researches of Georgian Technical University

Outlook

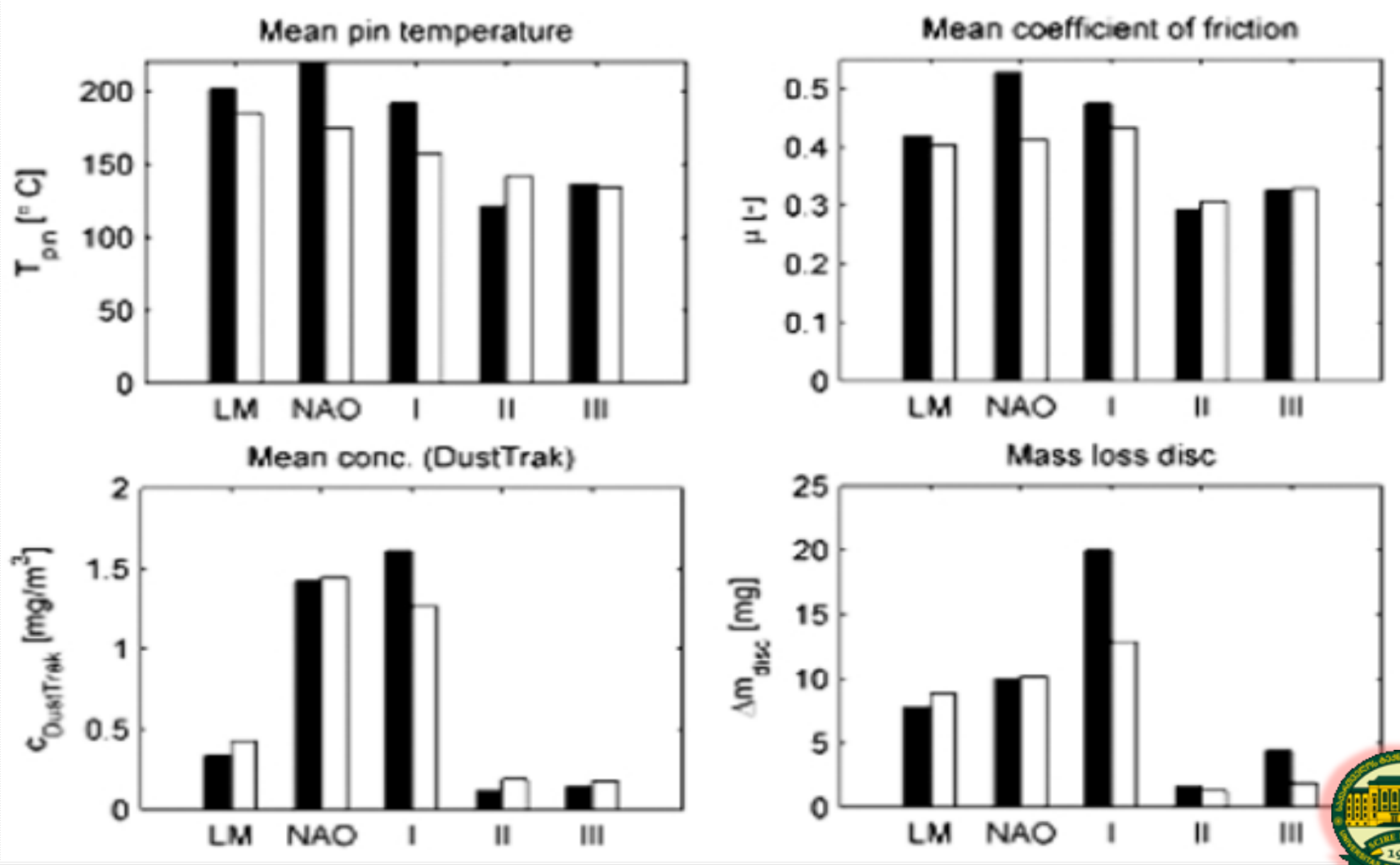
- New generation nano-porous brake pads
- New ADI class deformable high strength cast iron (DADI)
- Relatively simple and low cost technique of new metal-ceramic medical implants based on Fe-Cr-Al-RE alloy
- Nano-crystalline compositional materials

New generation nano-porous brake pads (based on the domestic row material)

Why "new generation"? – because it meets all the modern requirements as follows:

1. **No asbestos content**
2. **No squeal while braking at low speeds**
3. **Stability of the tribological parameters up to 500^{o}C**
4. **The minimal level of the environment pollution by the wear products**
5. **Low wear of the brake disk**
6. **The same efficiency while wet and dry friction**
7. **Aesthetic wear products**
8. **Low price**

The tests results obtained in the royal technological institute (Stockholm, Sweden)



Product / Parameters	LM –EU	NAO –USA	I,II,III –GE
The number of components	9	7	5
The limit of the paramaetes stability	450^{O}C	450^{O}C	600^{O}C
The number of elements in the wear product	9 Fe, Mn, Cu, Sn, Al, Cr, Ti, Zr, Ba	7 Fe, Cr, Cu, Ti, Ba, Zr, Zn	5 Fe, Cu, Si, Al, Ba

New ADI class deformable high strength cast iron (DADI)

Our know-how:

1. The energy saving technology for the obtaining of DADI
2. The composition of DADI
3. The regimes of thermal and thermal-mechanical treatment for the mechanical properties of DADI

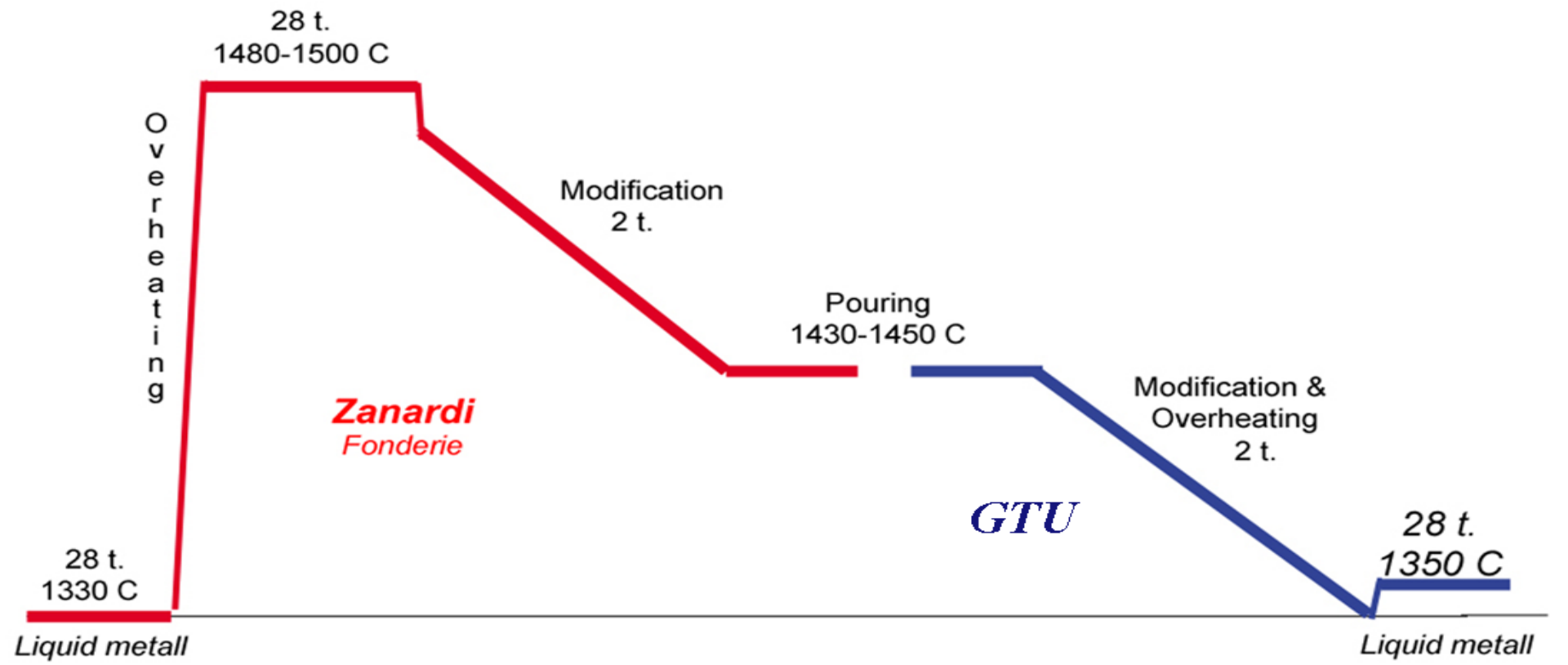
Our experience:

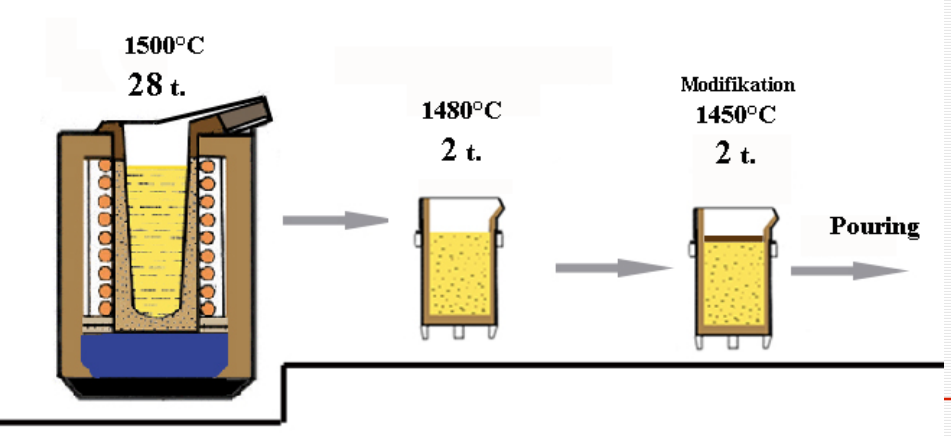
DADI is the effective substitute for the expensive steels:

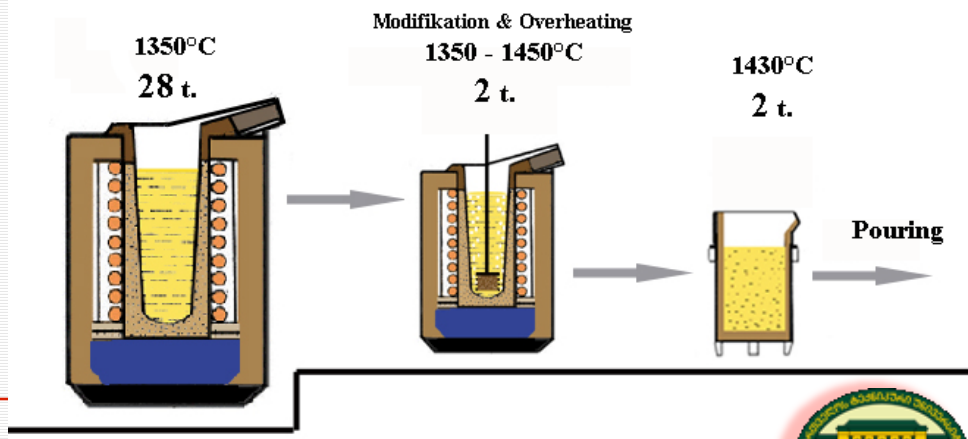
1. The down hole oil pumps *(grant CRDF-2006)*
2. High pressure multi-step gas pumping compressors *(grant CRDF- 2010)*

The perspective:

Automotive industry, railway transport, mechanical engineering, oil industry


28 t.
1480-1500 C
Overheating
Modification
2 t.
Pouring
1430-1450 C
Zanardi
Fonderie
Modification &
Overheating
2 t.
GTU
28 t.
1350 C
28 t.
1330 C
Liquid metall
Liquid metall

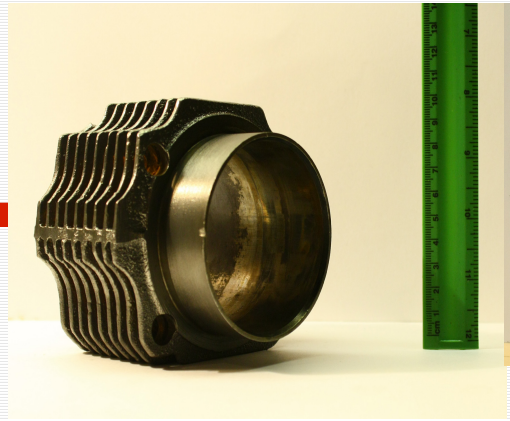

1500°C
28 t.
1480°C
2 t.
Modifikation
1450°C
2 t.
Pouring

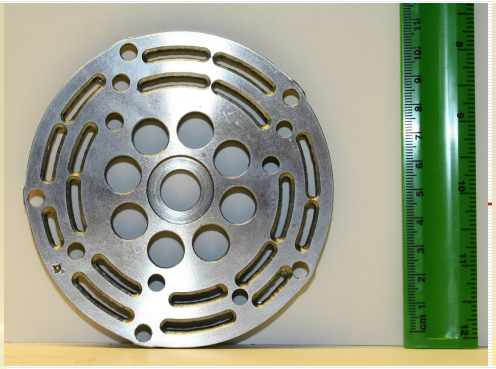

1350°C
28 t.
Modifikation & Overheating
1350 - 1450°C
2 t.
1430°C
2 t.
Pouring

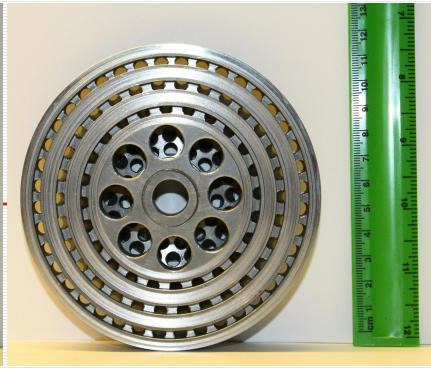
Results of the experiments confirming an excellent castability of the developed DADI

Demonstration of deformability of the DADI

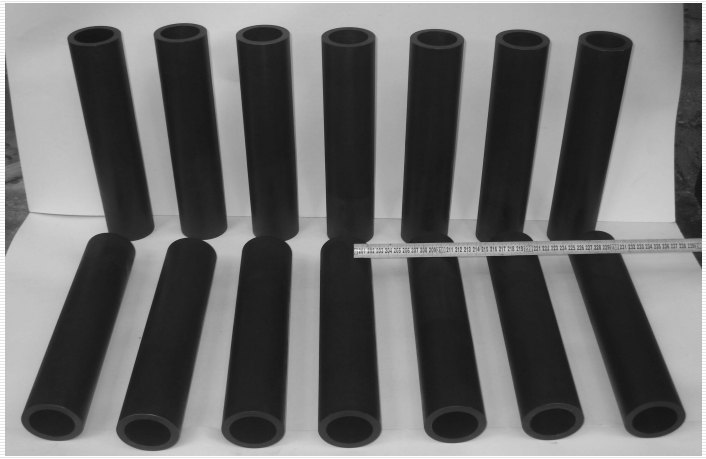
The Critical Parts of the Compressors

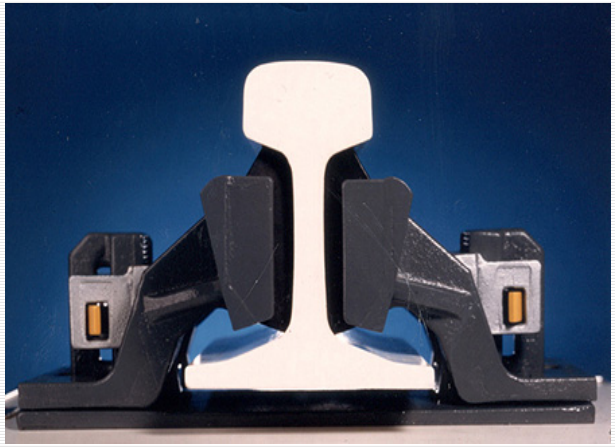






The Critical Parts of the Deep-well oil pumps and railway





COMPETITION

The Critical Parts of the Compressors

THE PART	MATERIAL FOR THE PART	RETAIL PRICE $/TON	WEIGHT, KG			MECHANICAL TREATMENT		THERMAL TREATMENT	
			DEVICE	THE PART	COEFFICIENT OF THE METAL APPLICATION	THE NUMBER OF OPERATIONS	DURATION OF THE OPERATIONS, H	STEP NUMBERS	DURATION OF THE STEPS, H
Cylinder	Ст 45	700	30,11	9,60	31,89	12	3	-	-
	ШХ 15	1400	12,16	2,23	18,34	12	8	10	26
	ADI	300	13,16	11,1	84,12	3	2	3	4

Compressors

MANUFACTURER	THE PARAMETERS FOR THE GAS PUMPING COMPRESSORS					
	Weight, kg	Pumping up speed, number of cycles	Outcome, m^3/h	Comparative price, %	Price of the sphere parts, %	Noise
Tinvo Co, China	6000	400	500	100	-	High
Exergia, GEORGIA	600	1500	500	80	100	Med.
Exergia-New, GEORGIA	540	1500	500	60	50	Low

Deep-well oil pumps

Pump barrel material	Actual Production Rate *(m^3/24 h)*		Decrease in pump productivity $(Q_i-Q_f)/Q_i$	Duration of pump test before the first borehole technical shutdown, *days* t	Increase in the coefficient of leaking rate ή	Ratio of plunger wear to barrel wear
	Initial Q_i	Final Q_f				
Steel-20	152	126.4	0.168	56	0.46	0.382
DADI	162.6	136.2	0.162	55	0.48	0.241

Relatively simple and low cost technique of new metal-ceramic medical implants based on Fe-Cr-Al-RE alloy

A majority of implantation technologies utilizes metals due to their advantageous mechanical properties. Metals possess high strength, high elastic modulus, and their manufacturing is quite easy. However, even high corrosive resistant metallic based implant materials (e.g., Ti_6Al_4V) have low in-vivo biocompatibility and bioresorbability

Metallic Implants: future

- Due to the high cost of the ceramic biomedical implants, metal-ceramic implants still will be dominant implant material.
- Therefore, it will be necessary to create novel metal-ceramic composite systems with improved bio-compatibility, low cost and improved mechanical and manufacturing properties.
- Coating durable metal surfaces with biocompatible glasses, ceramics or bio-active material such as hydroxyapatite (HA) is one of the promising methods to achieve natural bonding. However, HA can’t satisfy the required mechanical strength and adhesion ability (Kaya et al., Advanced Engineering Materials, 10, 2008)

Novel Implant Material

We proposed a novel Fe-Cr-Al-RE based metal-ceramic low cost implant material which would allow to produce a new class Thermal-Barrier-Coating (TBC) +HA composite with improved bio-medical properties and prolonged stability

Novel implant Material (advantages)

- No need for the vacuum during manufacturing process.
- No need for complicated and expensive coating techniques such as thermal stimulated deposition (TSD), EB-PVD, EPD, laser stimulated deposition (LSD), etc.).
- Metal-ceramic composite will be produced as a result of the corrosion resistant TGO-TBC formation at the metallic product's surface.
- High corrosion resistance, High adherence, Prolonged stability
- High shear strength at implant/coating interface
- High biocompatibility for the fixation period
- Modulated microstructure of the formed TBC surface will prevent a peeling of bioactive HA layer

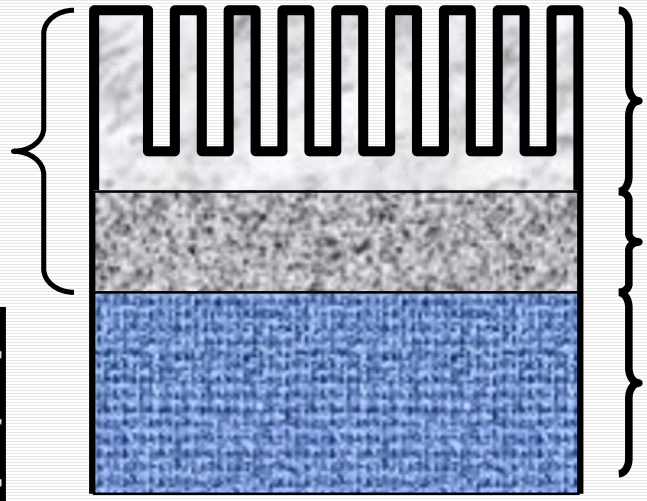
Manufacturing implant product using new material (stage 1)

Manufacturing a final form of the implant product from metallic alloy Fe-Cr-Al-RE using any available mechanical treatment technique ((stamping, polishing, cutting, drilling, extrusion, etc.).

Manufacturing implant product using new material (stage 2)

Self-organizing ceramic TBC with modulated micro-wrinkled structure is formed at the product surface (internal and external) via cold thermal treatment

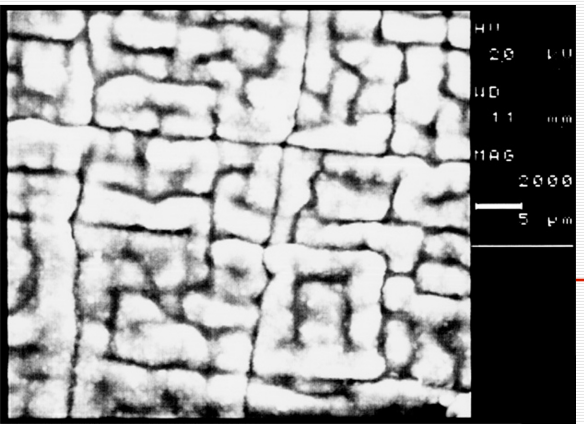
Self-organizing TBC
~10 μm



Complex oxide
Fe $(Cr, Al)_2O_4$

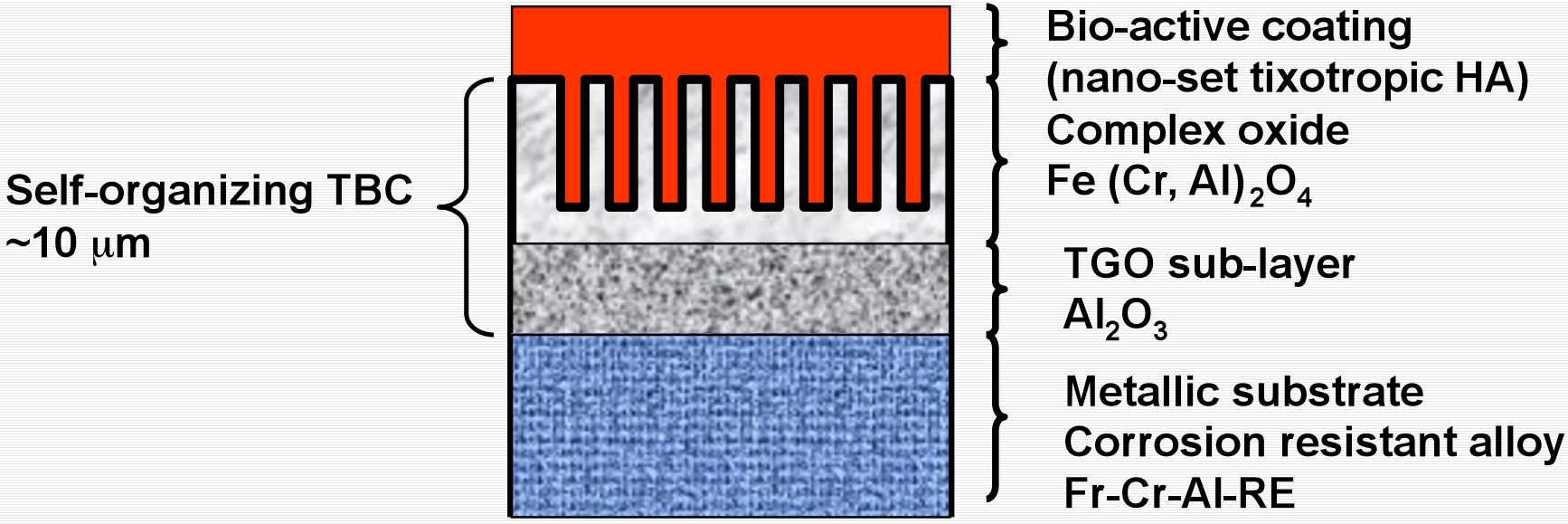
TGO sub-layer
Al_2O_3

Metallic substrate
Corrosion resistant alloy
Fr-Cr-Al-RE



Manufacturing implant product using new material (stage 3)

Bioactive HA (hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$) coating is applied at the product surface (Fe-Cr-Al-RE alloy) with self-organizing TBC.

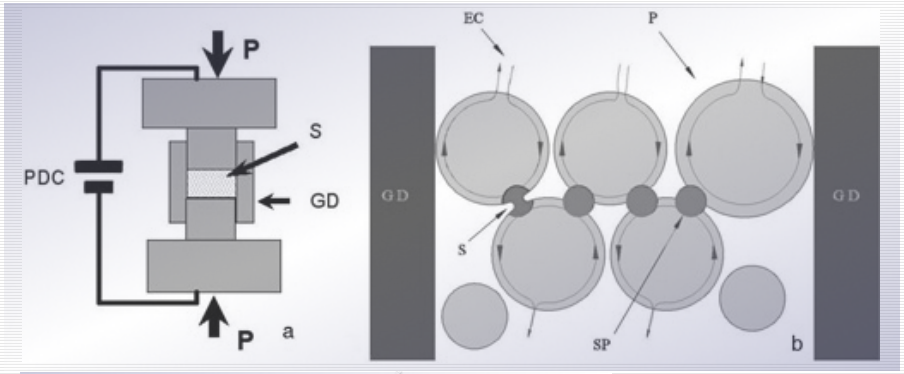


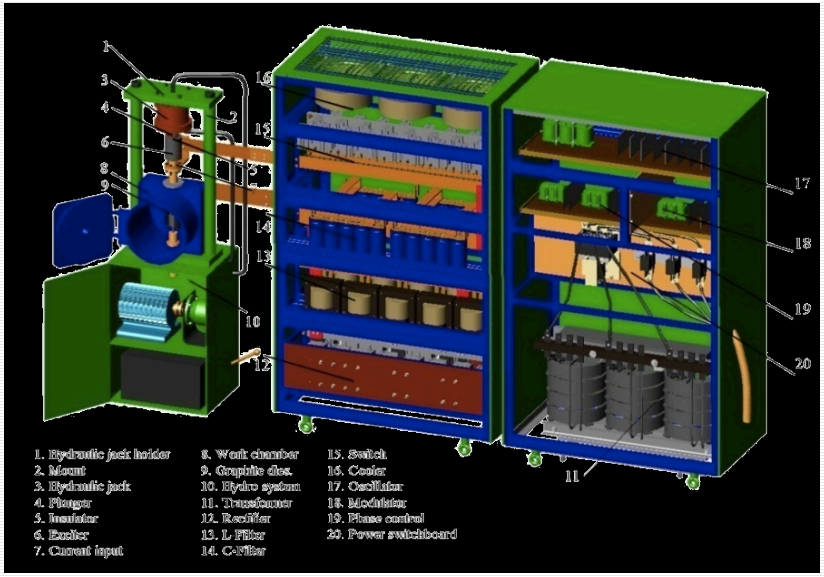
The materials of nano-crystal compositions

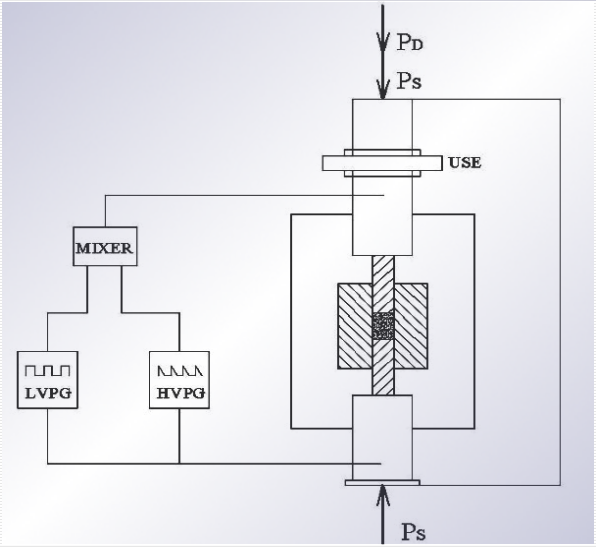
It is elaborated:

1. **The energetically efficient technology of the obtaining of Nano- crystalline composition materials and SPS device**
2. **There are obtained Ti carbide, B carbide, Ti boride, Ti-Al Ti-Si carbide base new type nano-crystalline powders of hard alloys as well as their bulk specimens**
3. **There are obtained the new type nano-crystalline scintillation materials powders and bulks for the Hf-ates, titanides and phosphates**
4. **The works are still going on the elaboration of the technology for compositional materials obtaining**

SPS equipment







The temperature of the synthesis (max 2500°C)

current (max 5000 A)

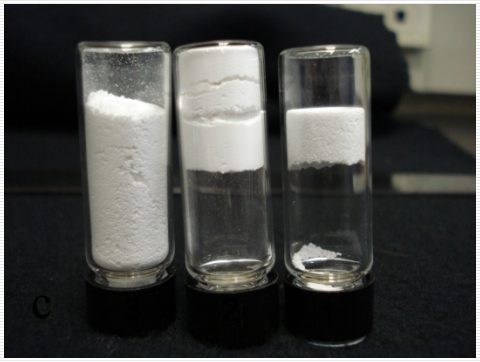
pressure (max 200MPa)

the SPS modernized equipment for the compacting of insulator materials

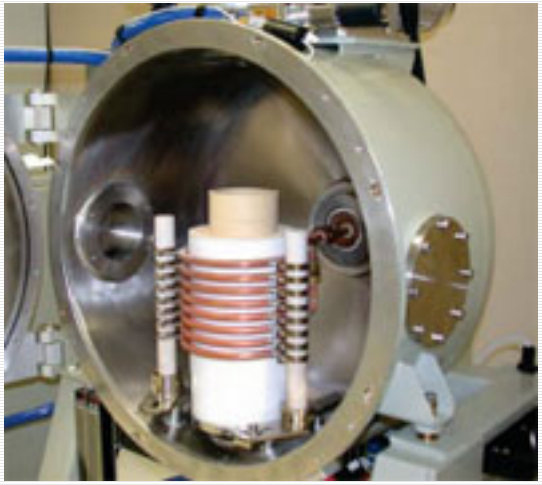
a - the nano powder after the cold mounting Y_2SiO_5

b - the volume comparison
1- compressed Y_2SiO_5, 2-standard Y_2SiO_5 ,
3- nano-powder Y_2SiO_5

c - the comparison of powder charging
1- compressed Y_2SiO_5, 2- standard Y_2SiO_5
3- nano-powder Y_2SiO_5



YSO:Ce 0.005% monocrystal



The system of Czochralski for the crystal growth

Thank you!

Questions?