Capabilities of the G.V. Kurdyumov Institute for Metals Physics of the N.A.S. of Ukraine

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PRESENTATION OVERVIEW

- General information on IMP
- Methodological and technological opportunities
- Examples of developments, possible application and targeted market segments
- Opportunity for joint work and contacts

DEPARTMENTS 27

LABORATORIES 10

EDITORIAL DEPARTMENT

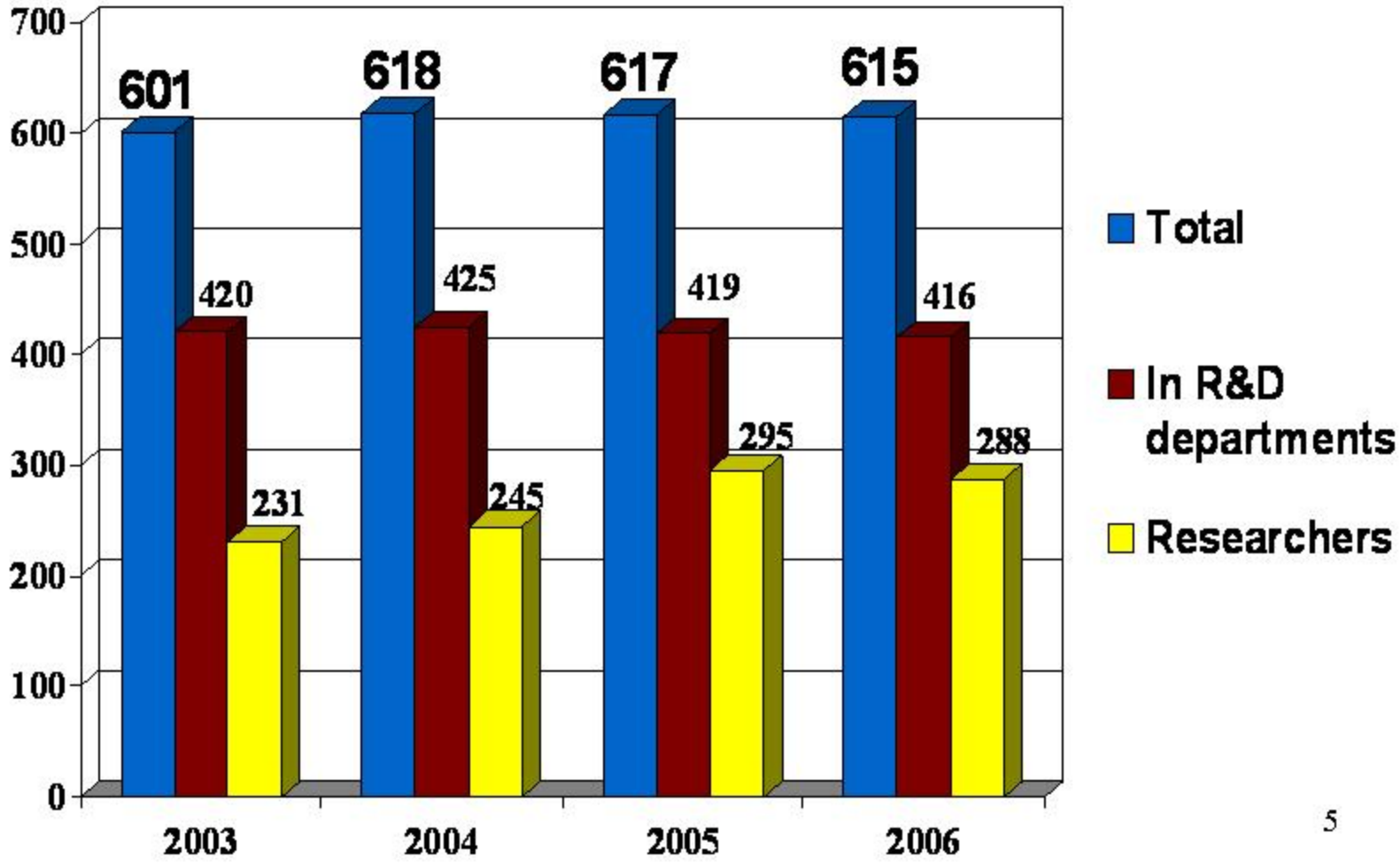
LIBRARY

SERVICE DEPARTMENTS 3

PRINCIPAL RESEARCH AREAS:

- ✓PHYSICS OF STRENGTH AND PLASTICITY OF METAL AND ALLOYS
- ✓ELECTRONIC STRUCTURE AND PROPERTIES OF METALS AND COMPOUNDS ON THEIR BASIS
- ✓NANOSCALE SYSTEMS
- ✓ATOMIC STRUCTURE OF METALS AND HETEROPHASE SYSTEMS ON THEIR BASIS

STAFF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500
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200
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0
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617
615
420
425
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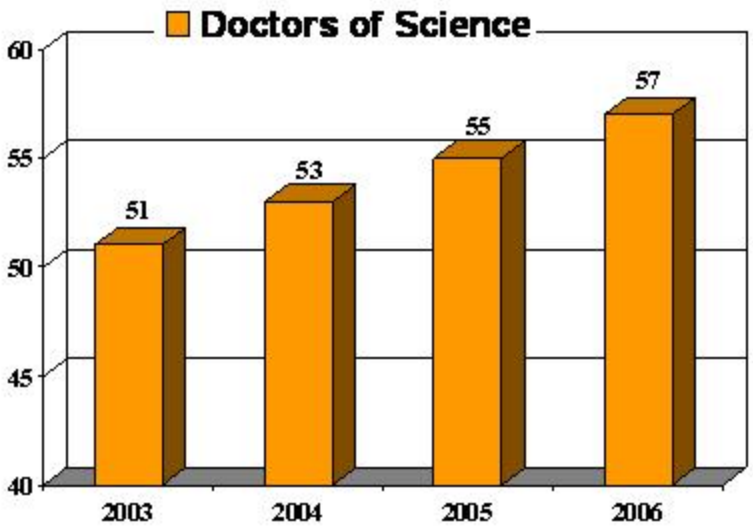
416
231
245
295
288
2003
2004
2005
2006
Total
In R&D departments
Researchers

R&D STAFF


Doctors of Science
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55
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53
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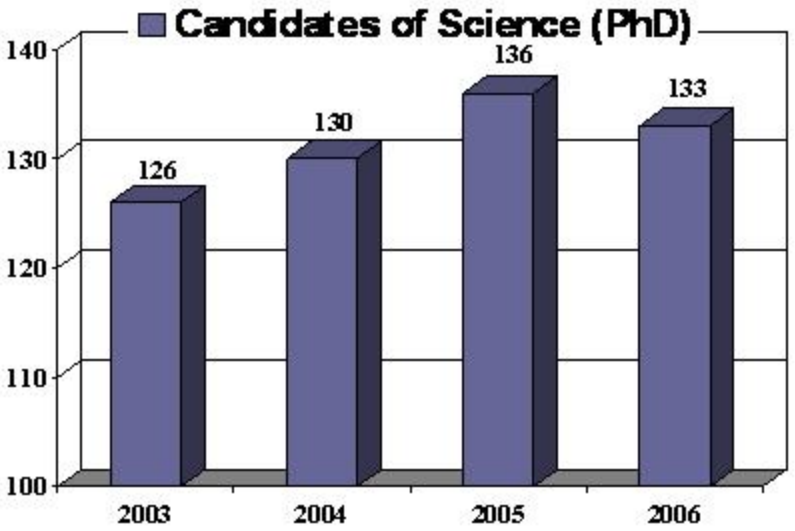
2003
2004
2005
2006


Candidates of Science (PhD)
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130
120
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126
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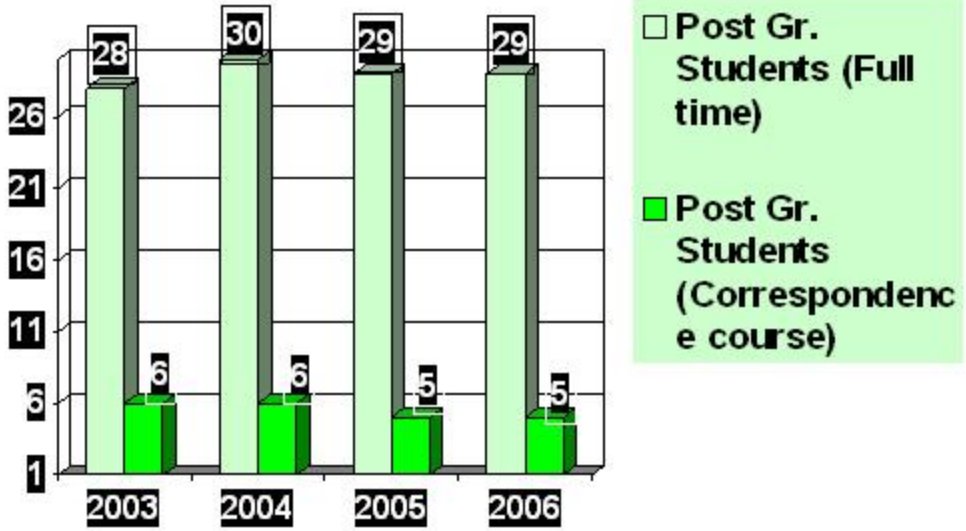
2003
2004
2005
2006


26
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16
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2003
2004
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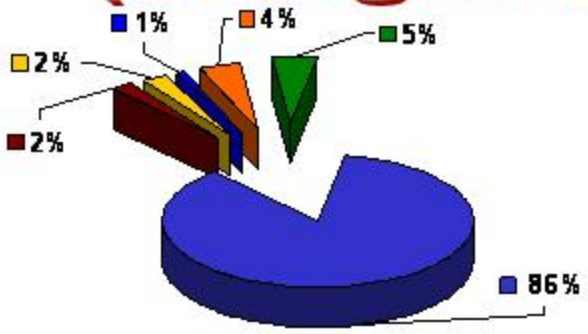
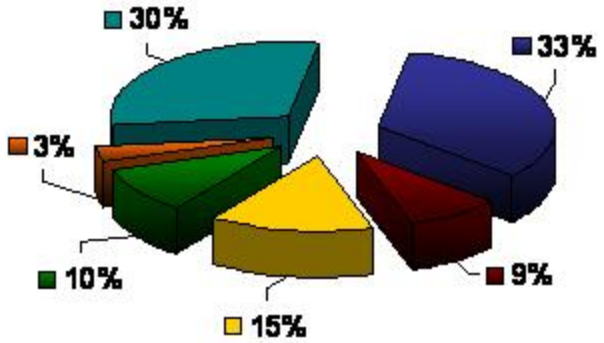
Post Gr. Students (Full time)
Post Gr. Students (Correspondence course)

DISTRIBUTION OF EXPENCES (Budgetary financing)



Wages | Materials | Building service
Contractors | Equipment | Other

DISTRIBUTION OF EXPENCES (Extra-budgetary finansing)



Wages | Materials
Building maintenance | Contractors
Equipment | Other

Methodological and technological opportunities

Equipment

Scanning Probe Microscope JSPM-4610 (JEOL)

Resolution

Horisontal: 0.14nm

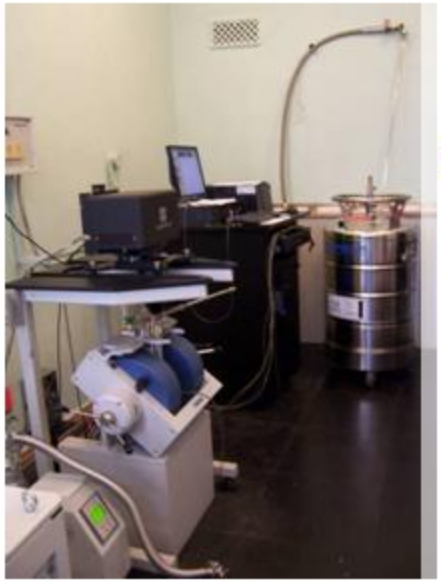
Vertical: 0.01nm

NMR Spectrometer BRUKER AVANCE 400

Frequency range: 20 ÷ 400 MHz (Δν = 20 MHz)

Temperature range: 20...77 ÷ 2000 K.

H = 9,6 T



Vibrating magnetometer 7404 VSM (Lake Shore Cryotronics, Inc., USA)

8-1273 K.

10^{-7}-10^{3} EMU

Axial Testing 20 t Machine

INSTRON 8802:
Tensile, suppression, cycles

250 kN

$-150^{0}C$… $+300^{0}C$

Frequency range: 10 ÷ 70 Hz

Technological bases

Vacuum laboratory furnaces with copper water-cooled crystallizers for induction and induction-arch melting of alloys (10-100 kg)

Cryogenic facility for production of liquid nitrogen and helium and scientific studies at low-temperatures

PVD-CAE technology ("BULAT" NNV-6,6 EQUIPMENT)

Facility for single crystal growing

Facility for heat and mechanical treatment of metals

Examples of developments and targeted market segments

HIGH-STRENGTH TITANIUM ALLOYS PRODUCTION TECHNOLOGY

Development:

Integrated technology of parts production from beta-titanium alloys was developed to obtain material characterized by extremely high strength (UTS ≥ 1600 MPa) keeping reasonable level of ductility (RE ≥ 8%)

High balance of mechanical properties is reached via forming fine-grained beta microstructure (average grain size of about 4 – 5 mkm) reinforced by dispersed alpha-phase precipitations

Patenting:

Ukrainian Patent #22693

Stage of development:

parts for critical application, for example – springs used in aircrafts

Application:

High-strength titanium springs developed for a new ANTONOV-148 aircraft

COST-EFFECTIVE PRODUCTION OF POWDER METALLURGY TITANIUM COMPONENTS

Development:

The technology was based on the blended elemental PM method in its simplest press-and-sinter approach without application of any pressure or deformation during or after sintering

The distinctive feature of technology is employment of hydrogenated titanium powder instead of traditional titanium powder.

Hydrogen has a major effect on synthesis improvement, providing production of alloys having 98.5-99.5% density, desired microstructure and chemical homogeneity, low impurity content and high mechanical properties.

Mechanical Properties (Ti-6Al-4V Composition)

Base powder	Alloying powder	YS, MPa	UTS, MPa	Elong. %	RA, %	Oxygen content, %
TiH_2	Al-V master alloy	850-930	960-990	10-12.5	23-29	0.11-0.25
ASTM standard		≥ 828	≥ 897	≥ 10	≥ 20	≤0.20

HIGH-STRENGTHENED AND HIGH-TECHNOLOGICAL ALUMINUM-BASED CAST AND WROUGHT ALLOYS

To create Al-based system, which is strengthened by particles of the second phase due to:

1. **optimization of composition by purposeful micro-alloying**

and

2. **using new schemes of heat treatment of the alloys**

in order to effect on particles nucleation, growth and their morphology

Systems of the alloys under study

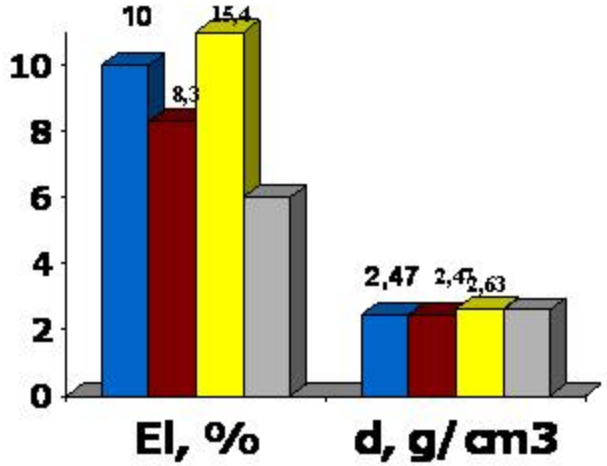
a) wrought alloys (d = 2,47- 2,65 kg/cm3)

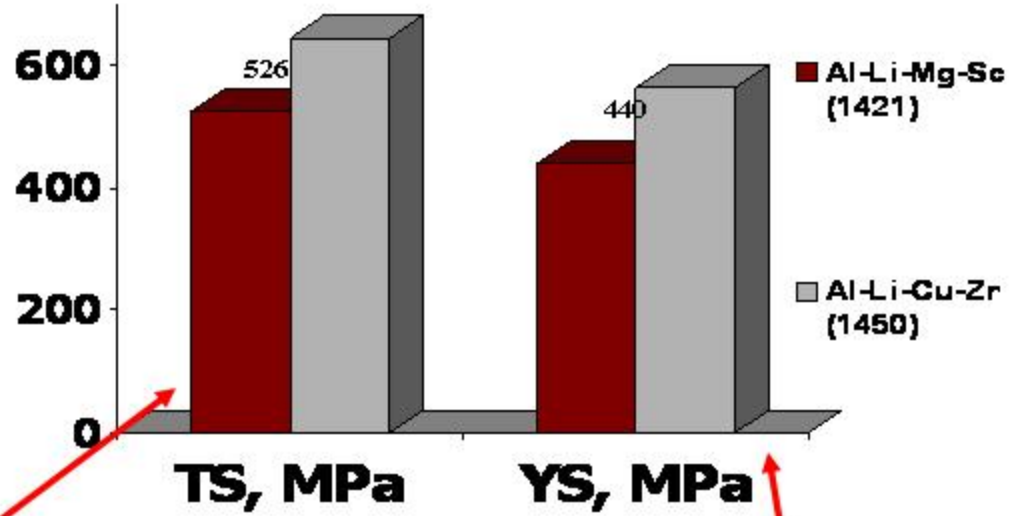
Al-Li-based alloys with the optimized Sc and Zr content
Al-Li-Mg, Al-Li-Cu, Al-Li-Cu-Mg
Al-Sc, Al-Mg-Sc, Al-Mg-Sc-Zr, Al-Mg-Zr-Hf
Al-Mg-Cu-Si Avial

b) cast alloys (d = 2,6-2,85 kg/cm3)

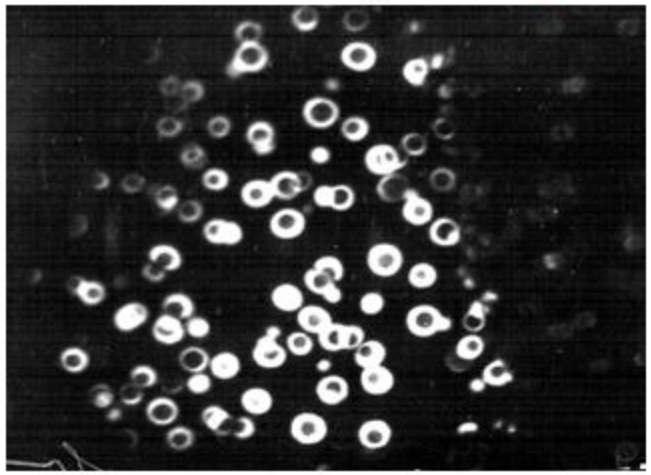
Al-Si-Sc
Al-Si-Mg (357, 356)
Al-Cu-Mg-Ag (201)
Al-Mg (520, 535)
Al-Zn-Mg (707, 710)

Composite Particles in Wrought Aluminum Alloys



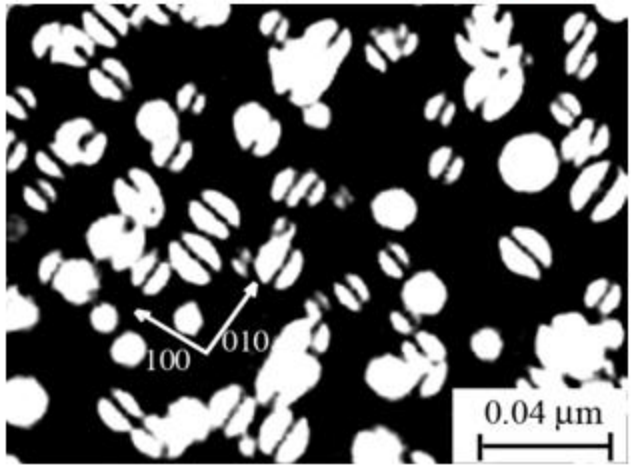


Al-Li-Mg-Sc



Al_3Li/Al_3Sc

Al-Li-Cu-Zr



Al_3Li/θ'' (Al_2Cu)

STAGE OF DEVELOPMENT

Wrought alloys:

(ii) 1421, 1423, A1 -Li-Mg -Zr – Sc (Airframe)

(i) 1430, A1 - Li - Mg - Cu – Zr (Airframe) (Patent of USSR № 1417487, 1987)

New modes of heat treatment:

(i) Al–Li–Mg-based alloy (1420) for improving the corrosion properties (Airframe). (Patent of USSR № 994112, 1983)

(ii) Al–Li–Cu-based alloys (1450, 1451) for increasing mechanical properties (Airframe), (Patent of USSR №1527939, 1989)

Cast alloy: Al–Mg–Sc-based alloy
(Patent of USSR №297820, 1989), Patent of Ukraine (№18538, 2006)

Collaboration

"Antonov" NTK (Kiev)

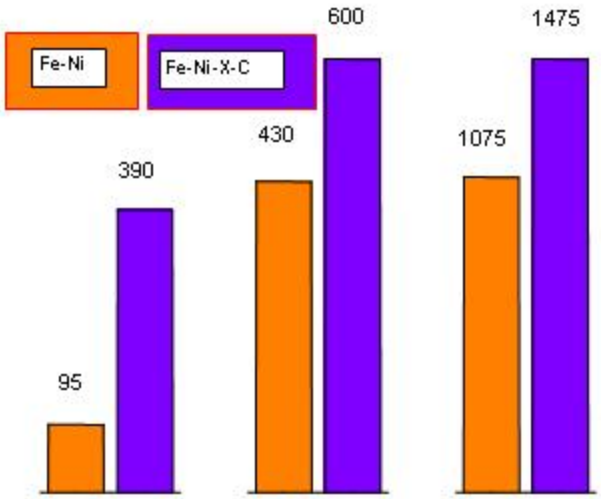
All-Russian Institute for Aero Industry VIAM (Moscow)

AIRBUS Company EC

Martin Luter University in Halle (Germany)

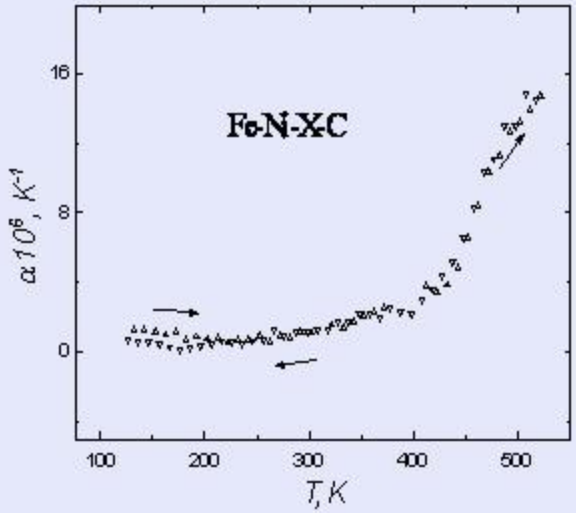
Physical Technological Institute for Metal and Alloys of N.A.S. of Ukraine

HARDENED INVAR ALLOY



Development:

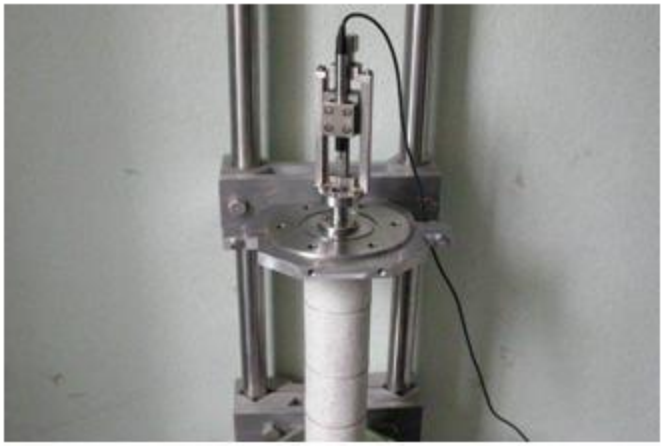
the Invar Fe-Ni-X-C-based alloys which for low and stability of thermal expansion in the temperature range of 100 – 400 K do not yield to the traditional Fe-Ni Invar and additionally demonstrate edvantagous combination of mechanical, fatigue and elinvar properties



Advantages

low thermal expansion coefficient α (TEC)
elinvar properties
advantage combination of strength and plasticity
resistance to cyclic loads
possibility to change and renew TEC on products

HARDENED INVAR ALLOY



Low temperature dilatometer with the main parts manufactured from developed Invar alloy

Metallic sound guide manufactured from Invar alloy in equipment for measurements of ultrasonic velocity

Area of Applications

dilatometry

parts for ultrasonic delay line
laser optics

telescope body

parts for tanks for transportation of liquid gases

clock and watches

radio frequency resonant cavity

electronics

HIGH TEMPERATURE AND WEAR RESISTENT ALLOYS FOR STRAGSENING BANDAGE SHELFS OF GAS TURBINE ENGINES

The problem:
low wear abrasive protection and strength of bandage shelf of gas turbine engines under high temperature and combusted fuel

Development:
the Co-based eutectic alloys alloyed with Cr, W, Mo, Al and containing ~20 vol.% niobium refractory monocarbides (XTH-61 and XTH-62)

Patenting:
Patent Ukraine №8240A,
Patent Ukraine №394550

Properties:
· high wear-resistant at temperatures up to 1000° - 1100°C

· the melting temperature is no low then 1300°C

· structural and phase stability up to 1300°C

· heat-resistant in aggressive environment of combusted fuel

Competitive data:
The developed alloys are applied under most higher temperature and have wear-resistant characteristics in 5-10 times higher then commonly used ВЖЛ-2, ЖС6У alloys

HIGHTEMPERATURE AND WEAR RESISTENT MATERIALS FOR STRAGSENING BANDAGE SHELFS OF GAS TURBINE MOTORS

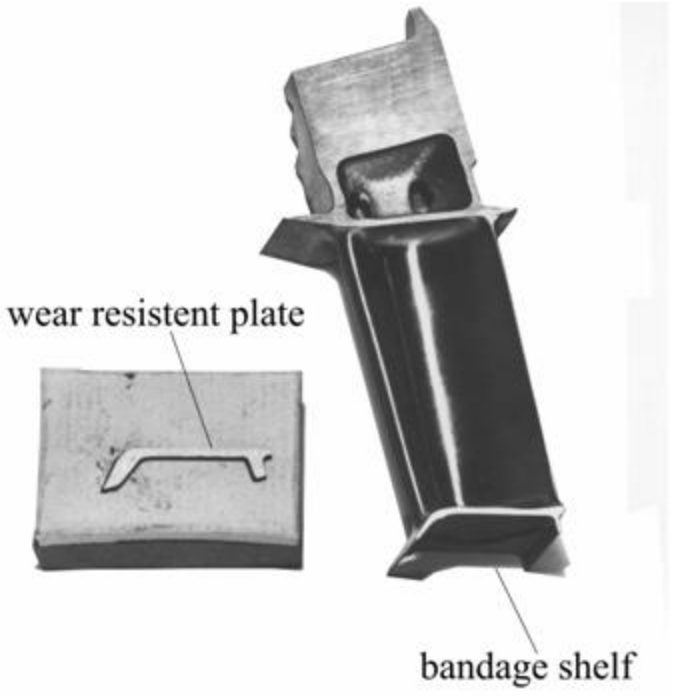
Stage of development:

the XTH-61 alloy shows longevity of ~6000 hrs in AH-124 "RUSLAN" cargo jet engines
the XTH-62 alloy is industrial tested in gas turbine engines

Further step of development:

· alloying of eutectic alloys in order to increase working temperature and heat-resistant

· to use powder metallurgy (liquid-phase sintering) to increase carbide volume fraction up to 70-80 vol.% in order to increase wire resistance



Area of Application:

Aerospace industry

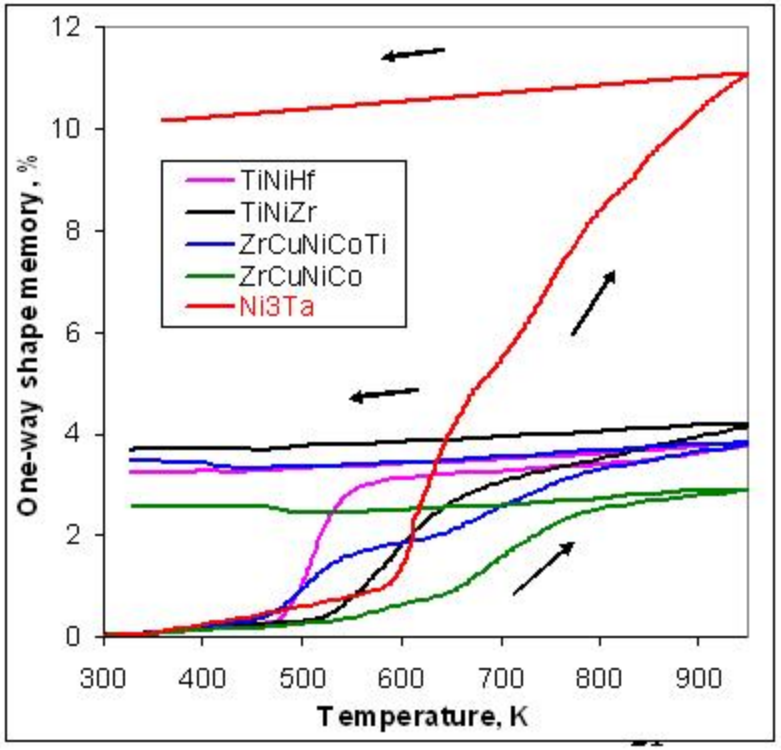
HIGH TEMPERATURE SHAPE MEMORY ALLOYS – POTENTIAL AEROSPACE MATERIALS

Already known **New**

Alloy system	Highest T	Alloy system	Highest T
Fe-Mn-Si + Co,Ni,Cr;	470 K	**Zr-based intermetallics** Zr(Cu-X) X- Ni, Co, Ti; ZrRh, ZrIr, Zr(RuPd)	1200 K
Co + Si,Ge,Al	800 K		
Cu-Al-Ni + Mn, Ti, B, Zn	470 K		
(Ni-X)Ti, X- Pt,Pd,Au,Rh	1300 K	**Ta-Ru, Nb-Ru**	1400 K 1170 K
Ni(Ti-X), X-Hf, Zr	620 K	**Ni-Mn-Ga**	550 K
Ni-Al + Fe, B, Cu, Co, Ag	1170 K	**Co-Ni-Al**	440 K
Ni-Mn + Al, Ti, Cu, Co, Cr	1020 K	**Ni-Ta**	580 K

Ni_3Ta SMA, Patent of Ukraine №20378, 2007

Martensitic deformation 7-10% → complete shape recovery



HTSMA under developments

- Ni- and Zr-based intermetallics – high temperature shape memory
- Co-based alloys – high temperature damping

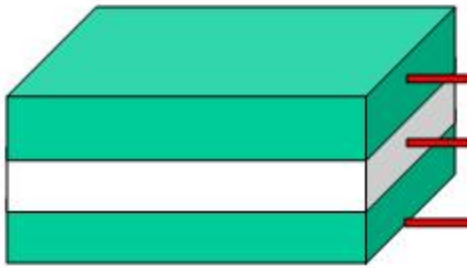
Desirable HTSMA properties

- ❑ Shape recovery above 390 K
- ❑ Narrow temperature interval of shape recovery
- ❑ High thermal cycling stability
- ❑ Good ductility
- ❑ High oxidation resistance

Some examples of possible aerospace applications

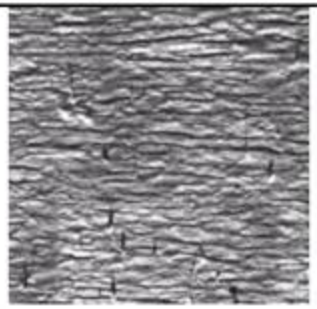
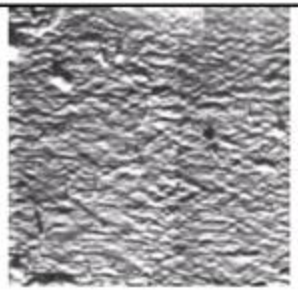
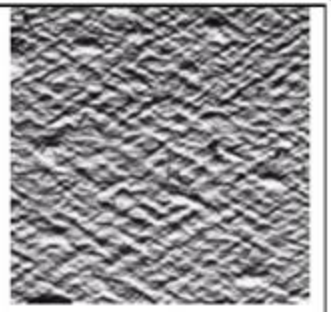
- ✓ Components of turbine engines
- ✓ Sensors
- ✓ Locking-unlocking applications
- ✓ Inlet flow control for supersonic jet

SMART MULTILAYER SENSOR FOR DIAGNOSTICS OF DAMAGE



Principal design

- High sensitive soft single crystalline film (Al)
- Polymer layer sensitive to surface form changes
- Multiscale grid of contacts for data acquisition by standard interface

			
a) flat bands 56 000 cycles	b) hills 96 000 cycles	c) ridges 270 000 cycles	d) highlands 970 000 cycles

Areas of Application:

Diagnostics of constructive elements which failure could lead to catastrophe damage

Aerospace and automotive industry: for measurements of actual accumulated fatigue stresses

Heat and power engineering: installed pipelines, high-pressure vessels and reactor materials under the loading conditions

Civil engineering: high-rise buildings, towers, cranes, bridges, passages

COMPETITIVE MATRIX

	SMLS (IMP NASU)	**Radiography**	**Ultrasonic diagnostics**
Inspection time	**Real time/minutes**	Days/hours	Hours
Periodicity of inspection	**Continuous, unlimited, with accumulated information**	Discrete, limited, schedule-dependent	Discrete, limited, schedule-dependent
Sensitivity	**0.01-0.1 mm**	0.1-1 mm	3-10 mm
Specific diagnostic equipment	**No**	Radiation source and receiver	Ultrasonic source and receiver
Cost of system unit, €	**€2 000–6 000**	€8 000–40 000	€2 000–20 000

COMPETITIVE MATRIX

Important product or technology characteristics	IMP NANU and MELTA Ltd's product MM-11N	Ferrite T-38	Permalloy 4-79
Initial permeability (10kHz) (25/130^{0}C)	70.000 / 65.000 40.000 / 38.000	10.000 / 20.000	30.000 / 18.000
Saturation Induction, B_S, T (25/130^{0}C)	1.20 / 1.15	0.38 / 0.1	0.7 / 0.6
Continuous service temperature, ^{0}C	up to 180	95	95
Prices for MT cores €/kg	€ 20-90	€ 6-20	€ 30-60

TECHNOLOGY AND EQUIPMENT FOR ULTRASONIC IMPACT TREATMENT OF METALS

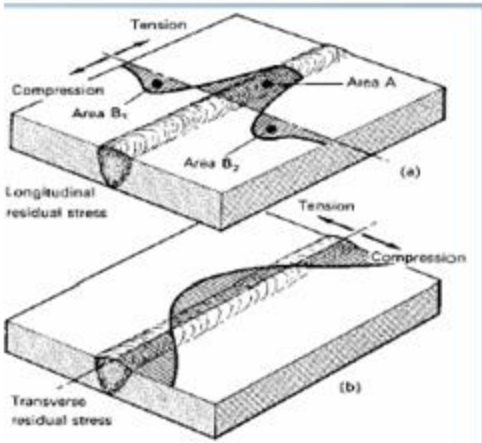
Welded joints are in large constructions:

bridges, oil platforms, pipelines, ships and tankers, agricultural machines

One of the main problems in large constructions working under loads and vibration loads is

FATIGUE FRACTURE

of welded joints resulting in catastrophic sequences



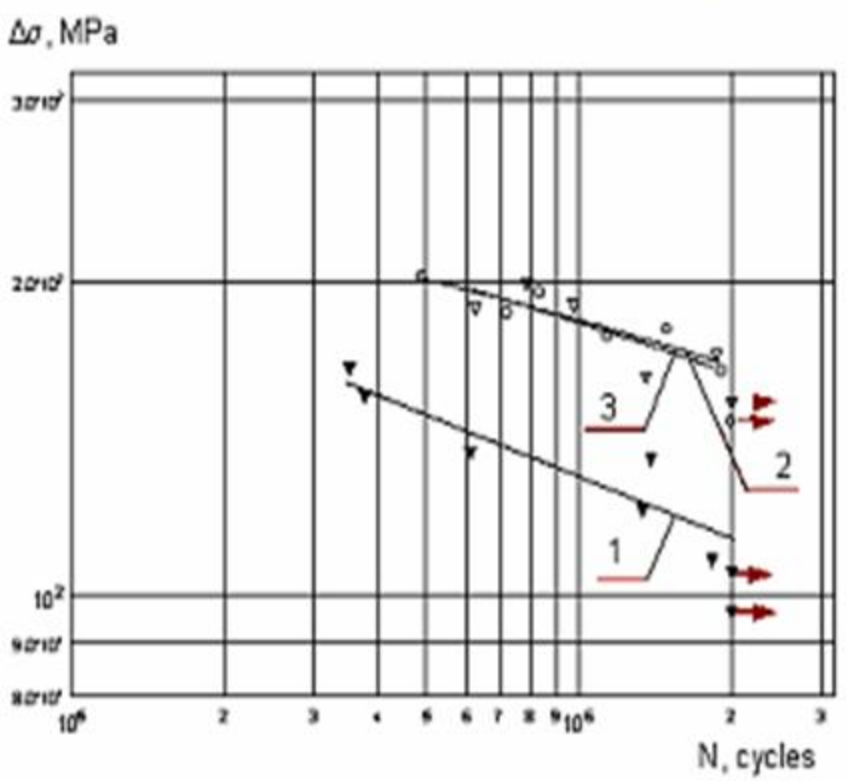
Fatigue strength of welded joints is much lower than of non-welded metal components due to the high residual tensile welding stresses nearby a joint resulting in early crack initiation

TECHNOLOGY AND EQUIPMENT FOR ULTRASONIC IMPACT TREATMENT OF METALS

SOLUTION

Ultrasonic Peening (UP)

UP improves FATIGUE LIFE



1 - as-welded

2 and 3 - after UP with magnetostrictive transducer (P = 1 kW) and piezoelectric transducer (P = 0,25 kW)

TECHNOLOGY ADVANTAGES

As compared to shot peening and hammer peening

Important key technology characteristics	Our technology	Applied Ultrasonics USA+Rusia	Ultrasonic Ltd China
Weight	5.5 kg	8 kg	13 kg
Transducer and cooling system	Piezoceramic Air cooling	Magnetostrictive Water cooling	Piezoceramic Air cooling
Power output and Energy consumption	Optimized 300 W Lower < 1 kW	- Higher 1.2 kW	200 - 350 W Lower < 1 kW
Price	€7,000-10,000	$30,000	$15,000-20,000

- Ukrainian Patent # 8366. (29.03.1996)
- USA's Patent # 6467321. (23.10.2002)
- Ukrainian Patent # 60390 (15.10.2003)

TARGETED MARKET SEGMENT and POSSIBLE APPLICATION of UP

Estimated demand in UP technology in one branch of an industry ~ 100 units/ year

aircraft building

UP "cure" of fatigue cracks in Kyiv bridge

UP improvement of WJ in automotive industry, pipelines constructions, **ships and tankers, agricultural machines**

POSSIBLE OPPORTUNITIES

- **Cooperation** in joint development and manufacturing of alloys, units and equipment, in **certification and standardization**, in **commercialisation and market determination**, in providing scientific services

- **Investment is required**

CONTACTS

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- **Deputy Director Prof., Academician IVASYSHYN Orest**

- **Deputy Director Prof., Corresponding member of NAS UVAROV Viktor**

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Thank you for your attention !