PRODUCTION OF AMORPHOUS AND NANOCRYSTALLINE ALLOYS
PROBLEM DESCRIPTION

- Any electronic instrument and power equipment contain transformers. They need magnetic cores:
  - For measuring current transformers in electronic power meters (15 g, 30 g) and switch mode power suppliers (60 … 24000 g)
  - Miniature cores (2 - 3 g) for telecommunication transformers
PROBLEM DESCRIPTION

- The amorphous or nanocrystalline ribbons are advantages to manufacture of such cores because:
  - properties are higher
  - their stability is better
  - weight is lighter
  - size is smaller

  15 g core

- For 1.4 million of 15 g cores 20-22 t. of amorphous ribbon are needed $1.4 million.

  1 - 3 g miniature cores - more advantages

- The annual market requirement is several hundreds of millions from 20-22 t.

  $100-300 millions

  ~10% of miniature cores

- With high magnetic properties (for the most critical units of modern equipment and devices) are more expensive

  Demand for such magnetic cores is redoubled each year
BRIEF DESCRIPTION of the TECHNOLOGY

Stages of the production process of rapidly quenched ribbons

Amorphous ribbon thickness 18-30 μm

Melted alloy
T=1300-1500 °C

Rotating Cu wheel
T=50 °C

Ceramic nozzle

Amorphous ribbon
V=25 m/s

till 95% useable output of ribbon

~twice as higher comparing to competitive companies

Stable geometric and magnetic parameters
NANOCRYSTALLINE CORE PRODUCTION PROCESS

- Slitting of ribbons with high precision disc knives
- Winding process of tape wound cores
- Heat and/or heat-magnetic treatment
- Encapsulation of cores in plastic boxes with addition of silicon rubber or
- Applying of overall protective polymeric coating or
- Creation of high heat-conducting outer high voltage insulation
STAGE of DEVELOPMENT

Designed and manufactured: prototypes of technological equipment

Designed: documentation for manufacture of equipment for annual output of ~ 20 t. amorphous ribbons

Developed: new amorphous and nanocrystalline alloys

- \((FeSiB)_{96.6}(CuNb)_{3.4}\) - (MM-1N)
- \((FeSiB)_{96}(CuNb)_{4}\) - (MM-11N)

Developed: methods and equipment for manufacture of cores, their heat and heat-magnetic treatment, encapsulation and polymeric coating

The designed technology provides 50% production of small-sized cores with high magnetic properties

Patented

UA Patent No. 1304
“Method of continuous ribbon casting”

UA Patent No.19217
”Iron based amorphous alloy”
WIDE FREQUENCY RANGE:

- 10 Hz up to 1-3 MHz
- High stability of magnetic properties within – 60°C +180°C
- 10 times higher magnetic permeability
- 3 times higher saturation induction

SPECIAL IMPORTANT ADVANTAGES OF CORES:

- Magnetostriction is close to zero
- Extremely high initial magnetic permeability up to 160000
- Low and stable level of core losses
MARKET SEGMENT

High stable magnetic cores is guaranteed in the following branches of industry:

- electronics
- electrical engineering
- aircraft building
- space systems

In particular for manufacture of:

1. **High grade compact electromagnetic noise filters (CMC)**
   High magnetic permeability at high frequencies $10^4$-$10^6$Hz is required

2. **Matching small-sized HF transformers**
   High saturation induction $B_s$ and initial permeability is required

3. **Current measuring transformers with minimum overall dimensions**
   High level of temperature stability of magnetic characteristics is important
Miniature nanocrystalline and amorphous magnetic cores for transformers of telecommunication systems

PERFORMANCE:
✓ induction of saturation: 1.20 T;
✓ initial permeability \((f = 1\text{kHz})\): 30000 – 120000;
✓ Operating temperature: -60 – 180˚C.

The most important advantages - high permeability values, temperature and time stability characteristics.
Toroidal and rectangular cut amorphous and nanocrystalline tape wound magnetic cores for electromagnetic noise filters of switch-mode power supplies

Electromagnetic noise filters and chokes of power correctors

High magnetic permeability ($\mu=20000-90000$) in wide frequency range with high $B_S$ and low eddy current loss for magnetic cores made of nanocrystalline MM alloys ensure:

- possibility of less number of choke turns (interturn capacitance, respectively) at keeping of high inductance;
- low loss at direct current;
- especially high level of noise reduction (up to 50 dB) in the most critical (0.01 to 1 MHz) spectrum range;
- extremely small size of filters.

Nanocrystalline magnetic cores in noise-suppressing chokes allow decreasing their overall dimensions by 3-4 times in comparison with conventional chokes with ferrite cores.
High-stable monolithic nanocrystalline tape wound magnetic cores for output power transformers of switch-mode power supplies

Magnetic cores for commercial production of power supplies of electric locomotives

Cut magnetic cores of pulse high-voltage (up to 60 kV) transformers of power supplies for commercial electron-beam melting of titanium

MAIN ADVANTAGES OF NANOCRYSTALLINE MAGNETIC CORES:

- Low specific loss at frequencies up to 200 kHz (50-60 mW/g at 100 kHz, 0.2T and 25°C, compared to 180 mW/g for ferrites)
- High working induction (up to 1.1T) at elevated (up to 120°C) temperatures decreases by 10% only (compared to 30% and more for ferrites)
- High (not less than 25-10 thousand) pulse permeability at induction 0.1-1.0T
- Considerably

Mass and overall dimensions of output transformer with nanocrystalline magnetic core can be decreased by 2-10 times compared to Mn-Zn-ferrite transformer
Output power transformers of switch-mode power supplies (inverters) of various power and purpose

Transformers of commercial switch-mode high-frequency (100-kHz) 3 and 6 kW power supplies

Transformers for frequency converters of HF melting and quenching plants of 125 kVA and 250 kVA power

Transformers of commercial switch-mode medium-frequency (10-15 kHz) 2,5 - 3 kW power supplies
Nanocrystalline magnetic cores for commercial and standard current measuring transformers 200/5A - 3000/5 A

On the base of new temperature and mechanically resistant nanocrystalline magnetic cores weighing 0.7-2.4 kg it were designed current measuring transformers of accuracy class from 0.5S (commercial counting) to 0.01 (standard) which are used for receiving an objective information to control regimes and to account electric power in industry.

Implementation:
JSC EPK „KHELNITSKOBLENERGO”, Khmelnitsk high voltage networks, JE MIKROKOD Ltd (Lviv), OLTEST Ltd (Kyiv), JSC “BIT” (Zaporizhzhia), NPE UKRTRANSENERGO Ltd (Dnipropetrovsk).
OUR PRODUCTS ARE USED
Lviv Centre of Institute of Space Research
Highly sensitive probes of magnetic field induction magnetometers new generation (LEMI-120)

SPECIFICATIONS:
- Lowest noise in class. Only 1340 mm long. Low power consumption, twice the battery life of other commercially available coils.
- Wide frequency range (0.0001 – 1,000 Hz)
- Wide range of power supply voltage ±6 V to ±15 V
- Low power consumption. More than twice the battery life of MFS-06
- Wide bandwidth 0.0001 Hz to 1000 Hz
- Weights only 5.7 kg

The LEMI-120 features extremely low noise as well as frequency and dynamic ranges making it the perfect choice for a major variety of geophysical applications. A state of the art modulator-demodulator, preamplifier with low power consumption, and a differential output ensures that the sensor may be used with any acquisition station providing the distance is less than 200 meters.

Monolithic Linear magnetic cores

Used in 7 countries
MEASURING EQUIPMENT
"Comparator SA507"

Designed for use as a comparison device during calibration of the current transformers and voltage transformers

Exported to 50 countries worldwide

CURRENT TRANSFORMERS
Current transformers Tolu-10-4 are intended to signal measurement equipment, protection and control device

OUR PRODUCTS ARE USED
OLTEST Ltd., Kyiv, Ukraine
Company “Beontop”, Ukraine
COMPETITION

1. Magnetics (USA)
2. Arnold corporation (USA)
3. Hitachi metals corporation (Japan)
4. VAC (Germany)
OPPORTUNITY FOR JOINT WORK

Type of cooperation
Credit provision for Science park or establishment of joint venture

The material technology is available for:
licensing of products
joint developments

Investment
Project cost: € 3,34 million
Own funds: € 0,34 million
Investment: € 3 million
Project realization period: 3.5 years
Project pay-back period: ~ 5 years
## COMPETITIVE MATRIX

<table>
<thead>
<tr>
<th>Important product or technology characteristics</th>
<th>IMP NANU and MELTA Ltd’s product MM-11N</th>
<th>Ferrite T-38</th>
<th>Permalloy 4-79</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial permeability (10kHz)</strong>&lt;br&gt;(25/130°C)</td>
<td>70.000 / 65.000&lt;br&gt;40.000 / 38.000</td>
<td>10.000 / 20.000</td>
<td>30.000 / 18.000</td>
</tr>
<tr>
<td><strong>Saturation Induction, B_s, T</strong>&lt;br&gt;(25/130°C)</td>
<td>1.20 / 1.15</td>
<td>0.38 / 0.1</td>
<td>0.7 / 0.6</td>
</tr>
<tr>
<td><strong>Continuous service temperature, °C</strong></td>
<td>up to 180</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td><strong>Prices for MT cores €/kg</strong></td>
<td>€ 40-90</td>
<td>€ 6-20</td>
<td>€ 30-60</td>
</tr>
</tbody>
</table>
Comparison of nanocrystalline MT cores with ferrite cores

The dependence of core losses on the temperature

![Graph showing the dependence of core losses on temperature.]

@ 0.1T, 100 kHz

The dependence of output power of transformers on their mass

![Graph showing the dependence of output power on mass.]

Mass and overall dimensions of output transformer with the tape wound magnetic core can be decreased by 2 up to 10 times in comparison with the Mn-Zn-ferrite-based transformer.
AMORPHOUS AND NANOCRYSTALLINE ALLOYS WITH A MARGINAL LEVEL HARDENING AND HIGH CORROSION RESISTANCE
FEATURES AND ADVANTAGES

Technology allows to receive directly from the melt are newer extremely durable, corrosion-resistant ribbon (50 mm) and bulk (the plate thickness of 5 mm) and amorphous-nanocrystalline and 100% nanocrystalline alloys based on iron (nano-steel).

The nanocrystalline alloy plate HBRM-4 (Fe-Cr-Mo-Nb-Cu-Si-C-B) cross section 2×10 mm²

Technology of bulk amorphization
The microhardness of alloys Fe-(Cr,W,Mo,(Nb,Cu,Al,Y))-C-Si-B

<table>
<thead>
<tr>
<th>Alloy</th>
<th>In the initial an amorphous state, GPa</th>
<th>After the heat treatment condition in the nanocomposite, GPa</th>
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</thead>
<tbody>
<tr>
<td>HB-2</td>
<td>10.1 ± 0.08</td>
<td>15.5 ± 0.1</td>
</tr>
<tr>
<td>HBRM-4</td>
<td>10.3 ± 0.1</td>
<td>17.7 ± 0.1</td>
</tr>
<tr>
<td>HBCY-1</td>
<td>10.9 ± 0.1</td>
<td>17.1 ± 0.1</td>
</tr>
</tbody>
</table>

Can be used for coatings for wear resistance is almost three times surpass bearing steel
APPLICATIONS

- The elements of the heaters
- Extra durable compact membrane
- The elements of structures with high strength and corrosion resistance

RIBBON AMORPHOUS MATERIALS

- The electrodes for applying nanostructured coatings with high strength, hardness and corrosion resistance
- Elements of constructions with increased parameters wear and corrosion resistance

BULK AMORPHOUS AND NANOCRYSTALLINE MATERIALS
EXAMPLE OF USING THERMAL PANELS ON THE BASIS OF AMORPHOUS RIBBON

Experimental drying for loose materials

ADVANTAGES:

• Lower energy costs at an equivalent thermal recoil
• Improved mechanical and corrosion characteristics
• Lower the final cost of the heater
CONTACTS

CORPORATION “SCIENCE PARK TARAS SHEVCHENKO UNIVERSITY OF KYIV”
Vitalii Cherniuk
CEO
Telephone +380 44 239 3468
E-mail: spark_corporation@ukr.net

G. V. Kurdyumov Institute for Metal Physics of N.A.S. of Ukraine
36 Academician Vernadskii Blvd., 03680 Kyiv, UKRAINE

Thanks you for your attention !