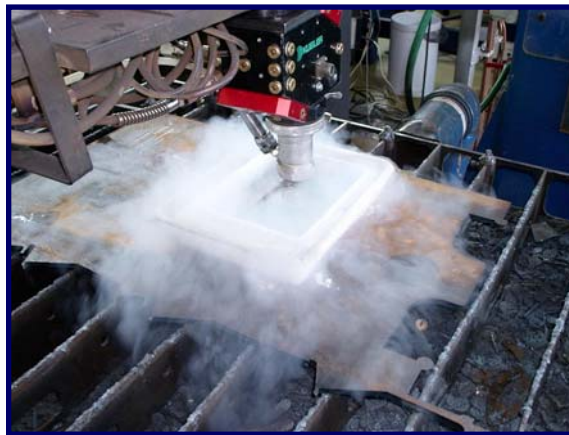


For submission to EU's 7<sup>th</sup> framework programme

## **Metallic materials for extreme environments with nanostructured surface layer (MENSUR)**

Programme objective: NMP-2007-4.2.5-1

**Novel materials tailored for extreme conditions and environments**



Laser melting of metallic material in liquid nitrogen

### **Main output**

- Metallic materials with improved resistance to corrosion, wear, tribocorrosion, high temperature oxidation
- New fabrication technologies
- New models of transformation of surface layer into nanocrystalline and amorphous structures
- Models of degradation of nanocrystalline surface layers of different materials by corrosion processes or by joint action of mechanical and chemical factors
- Computer tools for estimation of relations between structure of surface layers, their mechanical and physical properties and behaviour in conditions of varying stresses, strains and environments
- New and improved test methods

## ● Expert system for lifetime prediction

### Background

Nanometric structures possess usually better surface, optic, electronic, magnetic, chemical and mechanical properties than conventional metallic materials. The improved strength is obtained following an appearance of very short Coble slip instead of classical dislocation slip. There is still no knowledge on a source of better corrosion resistance; the decreasing grain size should result in worse corrosion resistance and an adverse effect may be related to creation of completely new thermodynamically unstable homogenous structure.

Nanomaterials can be obtained by three groups of methods: transformation of whole bulk materials into nanocrystals; deposition of nanostructures on surfaces of conventional materials; transformation of surface layers into nanolayers. The classical techniques include: heavy plastic deformation by twinning, compression or extrusion; pressing and milling; infiltration; electrocrystallization and nanocrystallization of glasses; chemical decomposition; cathodic sputtering; hypersonic plasma deposition; annealing; sol-gel methods; condensation with an use of microwaves; sonochemistry et al.

The transformation of surface layer into nanostructures needs incubation of new grains in conditions opposing their growth. In this project two different approaches are proposed, based on previous experience. The first approach includes melting of surface layer with its subsequent quick cooling or freezing. The second approach implies hydrogenation of surface layer of some refractory metals in which hydrides may form and decompose, leaving very small grains.

The melting of surface layer will be reached by a number of unconventional techniques. The first technique is application of laser beam. The creation of nanocrystalline surface layer, well adjacent to

the base, no-cracked, of sufficient thickness, is difficult and needs developing the model of melting and crystallization in conditions of fast heating and cooling. It must take into account the properties of material and input and output conditions. So far attempts have included an application of high power laser with subsequent cooling in liquid nitrogen or an use of short pulse excimer laser with cooling in air. Another method relies on surface treatment by simultaneous wear and fast cooling (pulse – mechanical technique). Both techniques have been developed for steels and only recently applied for Al, Cu and Ti alloys.

The hydrogenation of Ti and its alloys at temperature 400–900°C followed by plastic deformation has been shown to create nanometric grains. Because the presence of hydrogen and hydrides seems to decide on such transformation, the surface electrochemical hydrogen charging could result in formation of nanostructural surface layer, the effect never investigated.

Developed surface layer may possess excessive waviness and roughness. There is unknown which procedures, mechanical, chemical and electrochemical polishing, may be used to decrease such undesirable and expected effects.

The choice of the materials, especially structural ones, is very important. Among such materials one may consider: light weight materials, such as Al alloys for car engines, Ti alloys for implants, Mg alloys; Cu alloys subjected to cavitation and erosion for e.g. propellers of high speed boats; Co alloys for permanent magnets; intermetallics Fe–Al and Ti–Al for high temperature applications.

### **Societal/environmental objectives**

- New knowledge permitting designing and fabrication of new nanomaterials
- New products, concurrent on the world market

- New fabrication technologies, concurrent on the world market
- Longer lifetime of a number of products
- Improved security and reliability of offered products

## Principal Objectives and Sub-Goals

- Development of laser technologies permitting to obtain structural materials with improved surface properties
- Development of pulse-mechanical technologies permitting to obtain improved structural materials
- Development of hydrogen-related technologies permitting to obtain improved structural materials
- Elaboration of new generations of Al, Ti, Cu, Co, Fe-Al and Ti-Al alloys
- Elaboration of a model of creation of nanocrystalline structure in conditions of surface melting and fast cooling
- Elaboration of a model of creation of nanocrystalline structure in hydrogen charged Ti alloys
- Development of mathematical tools of optimisation of properties of surface layers
- Development of mathematical tools for complex analysis of interrelations between factors influencing the implant corrosion and lifetime in conditions of joint action of mechanical loads and human fluids` environment

## Work packages; the Scientific Parts

**WP 1** – Elaboration of methods of surface treatment:

- 1.1. Choice of materials
- 1.2. Surface treatment with excimer laser
- 1.3. Surface treatment with CO<sub>2</sub> laser
- 1.4. Surface treatment with electrolytic hydrogen
- 1.5. Surface treatment by pulse-mechanical method
- 1.6. Testing of microstructure and properties
- 1.7. Analysis of results and choice of the experimental details

**WP 2** – Optimisation of properties of the surface treated materials and choice of the best technologies:

- 2.1. Electrochemical general and local corrosion tests
- 2.2. SCC, hydrogen embrittlement and corrosion fatigue tests
- 2.3. Tribological wear tests
- 2.4. Tribocorrosion tests
- 2.5. High temperature corrosion tests
- 2.6. Analysis of results and choice of the experimental details

**WP 3** – Elaboration of methods of final surface treatment:

- 3.1. Chemical polishing
- 3.2. Electrochemical polishing
- 3.3. Mechanical polishing
- 3.4. Heat treatment
- 3.5. Assessment of grain size and internal stresses
- 3.6. Assessment of roughness, waviness, hardness and microstructure
- 3.7. Analysis of results and choice of technology

**WP 4** – Elaboration of mathematical tools and models

- 4.1. Elaboration of methods for optimisation of properties
- 4.2. Development of physical and mathematical models describing constitution of surface layer

**WP 5** – Elaboration of industrial technologies and demonstration

- 5.1. Elaboration of technologies for chosen surface treatment methods
- 5.2. Fabrication of chosen details
- 5.3. Preparation of tests in industrial scale
- 5.4. Testing of layer structure and properties
- 5.5. Tests in full scale
- 5.6. Analysis of results and elaboration of complete technologies

**WP 6** – Project management and coordination

**NMP-2007** 2.5-1 Novel materials tailored for extreme conditions and environments (citation)

Technical content/scope: Materials especially tailored for extreme conditions and environments, which are resistant to very high or very low temperatures, radiation, high pressures, high electromagnetic fields, damaging chemical reactions such as corrosive or oxidizing environments, biodegradation, or several of these conditions at the same time, are becoming increasingly important in a variety of industrial fields. Research should focus on radical innovations in the properties and processing of bulk or surface treated materials designed for extreme environments, based on an enhanced understanding of materials degradation. Composite materials, metallic materials, and engineering ceramics need further development, but also new alternatives are sought for wide industrial applications (e.g. turbines, engines, aerospace and maritime applications, machinery, sensors and the chemical industry).

Funding scheme: Large scale integrating collaborative projects.

Special features: In line with the objectives of this topic, adequate industrial participation is recommended.

Expected impact – Novel materials for extreme environments can offer increased durability of surfaces and products (e.g. in energy production, chemical or petrochemical industry and aerospace applications), contributing to a decrease in the risk of industrial hazards and an increase in safety. Step changes in the understanding of materials degradation mechanisms in extreme environments are expected.

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### Searched partners

- Industrial partners of the considered industrial sectors: Energy Production, Chemical, Petrochemical, Aerospace
- Small or medium enterprise (SMEs)