Aerospace, Mechanical
and Materials Engineering Sciences
(A&M Department)

University of Liège, Belgium

The A&M departement is composed of 22 laboratories :

1. Aerodynamics (Prof. JA Essers)
2. Aeroelasticity and Experimental Aerodynamics (Prof. G Dimitriadis)
3. Applied Thermodynamics (Prof. V Lemort)
4. Automotive engineering (Prof. P Duysinx)
5. Computational Mechanics (Prof. JP Ponthot)
6. Computational & Multiscale Mechanics of Materials (Prof. L. Noels)
7. Computer Aided Geometric Design (Prof. E Béchet)
8. Continuum Mechanics and Thermomechanics (Prof. M Hogge)
9. Manufacturing (Prof. JF Debongnie)
10. Mathematical Modeling and Methods - (Prof. E Delhez)
11. Metallurgy and Materials Science (Prof. J Lecomte-Beckers)

The A&M departement is composed of 22 laboratories :

12. **Mechanical Production Systems and Dimensional Metrology (Prof. L Masalar)**
13. **Mechanical Vibrations (Prof. JC Golinval)**
14. **Multibody and Mechatronic Systems (Prof. O Brüls)**
15. **Multidisciplinary Optimisation (Prof. C Fleury)**
16. **Nuclear Engineering (Prof. P Mathieu)**
17. **Polymer and Composite Materials (Prof. JM Liégeois)**
18. **Space Structures and Systems (Prof. G Kerschen)**
19. **Structural Dynamics (Prof. M Géradin)**
20. **Thermotechnics (Prof. P Ngendakumana)**
21. **Tribology (Prof. JL Bozet)**
22. **Turbomachinery and Aerospace Propulsion (Prof. O Léonard)**

Science of metallic materials

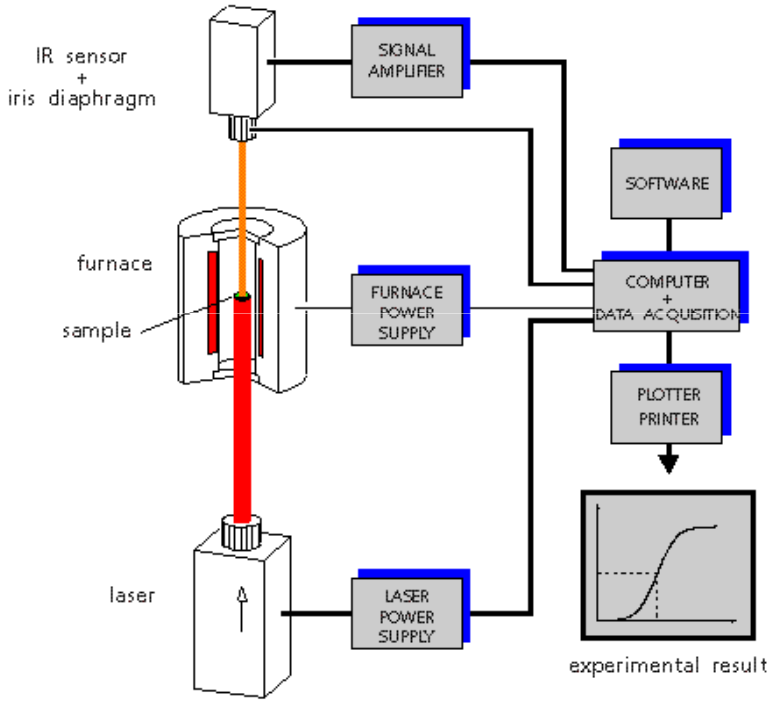
J. Lecomte-Beckers, Professeur
R. Pirson, Secrétaire
A. Rassili ,Chercheur qualifié

H.M. Montrieux, Assistant
J. Tchoufang, Ingénieur de recherche
Q. Contrepois, Ingénieur de recherche
H. Paydas, Ingénieur de recherche
J.C. Pierret, Ingénieur de recherche
S. Falzone, Ingénieur de recherche

S. Salieri, Technicienne de département
C. Zimbile,Technicien de recherche
J. Maire, Technicien de recherche

Research interests

1. **Metallic materials microstructural analysis**
2. **Study of phase transformations during solidification and thermal treatment**
3. **Measurements of materials thermal properties : thermal conductivity, thermal expansion, specific heat and specific mass**
4. **Damage phenomena analysis, corrosion and wear (metals, ceramics and biomaterials)**



Laser Flash Apparatus
LFA 427

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M/M.S. Matériaux Métalliques Spéciaux

Science of Metallic Materials

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Research topics

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- **Microstructural studies of metallic materials**
- **Study of microstructure - mechanical properties relations**
- **Development of taylored microstructure : powder metallurgy, thixoforming, vacuum deposition**

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Thermomechanical behaviour

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Controlled parameters

Process

- Chemical composition
- Material elaboration
- Thermomechanical Treatments of components

⇨

Tailoring

Microstructure
optimal

- Matrix: Solid solution hardening
- Strengthening precipitates
- Grains size
- Work hardening and recrystallisation ratios

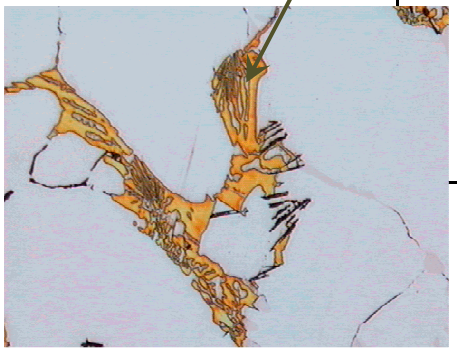
MICRO

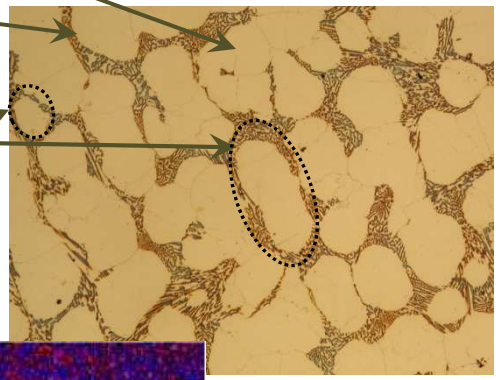
⇨

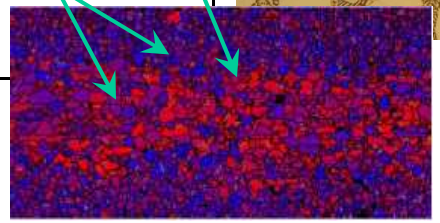
Improvements

Material properties

MACRO







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MICRO-MACRO modelling of thermomechanical behaviour

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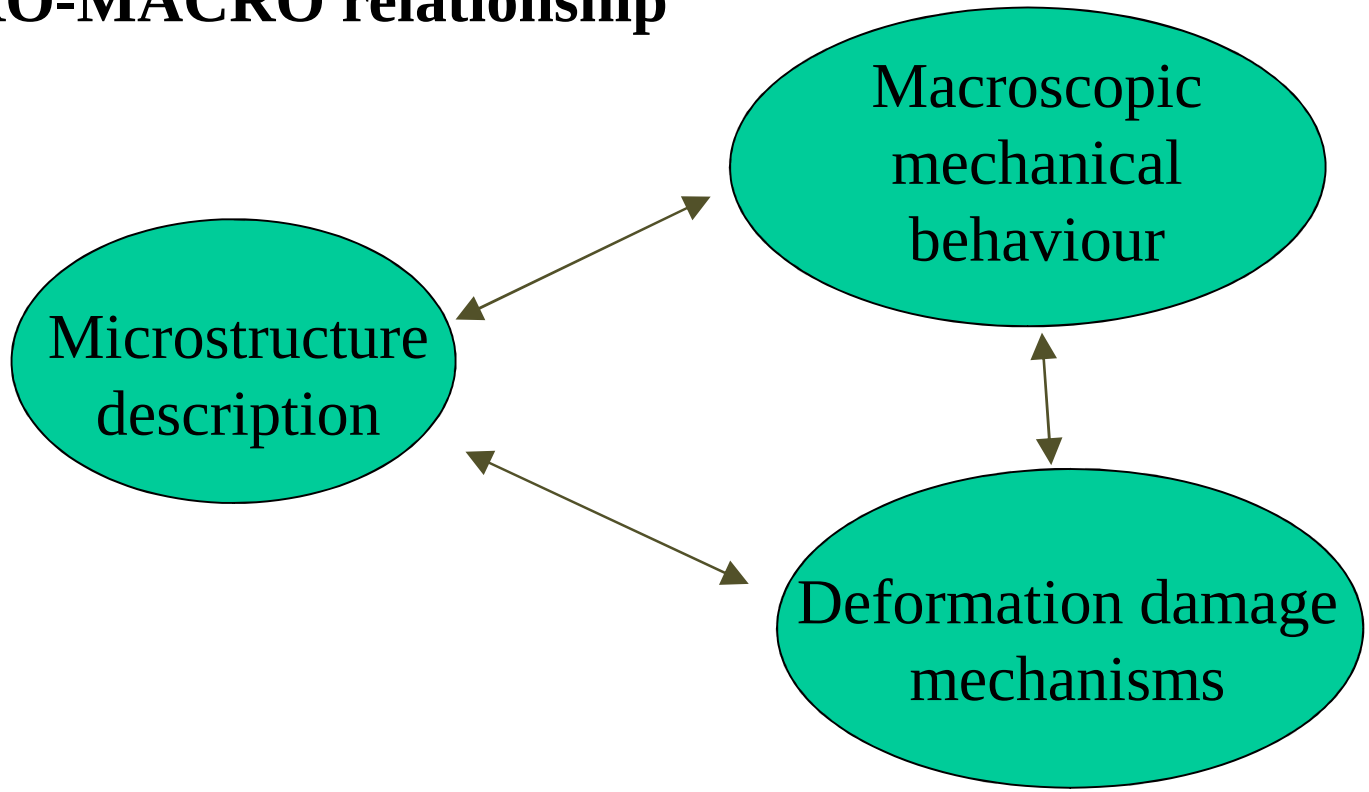
- **Mechanical behaviour prediction of structural components**
- **Current alloys improvement and new alloys development**
- **MICRO-MACRO relationship**



Studied materials

- **Metallic Matrix Composites Al-SiC - CMg**
- **Titanium alloys (Aerospace components)**
- **Aluminium alloys**
- **Fe–Cr–C-X Alloys (for mechanical applications)**
- **Zn-Al alloys (Cast components for Automobile)**
- **Thixo-Steels …**

Current researches (1/4)

• **Characterisation of mechanical and thermal hot properties**
→ Giving the data needed for the simulation

Applications: Non-oriented electrical steel grades, resistance spot welding…

• **Effect of carbides and inclusions in high alloyed irons and steels**
→ Establish the relationship between on the one hand, the cleanliness of the steel, the amount of carbides and the microstructure of materials, and then on the other hand their mechanical properties in service.

• **Development of new alloys for hot rolls**
→ Enhance the knowledge in this sector and particularly to study the kinetic of the precipitation and the formation of the carbides required for a good quality of the product.

• **Thixomoulding**
→ Write a new micro-macro constitutive equation that describes the semi-solid behavior

Current researches (2/4)

• **Development of Ti-LCB for turboreactors TITAERO**
→ **D**evelop a new material based on an existing alloy: Ti-LCB, but with better fatigue damaging properties and sufficient ductility.

• **Fabrication of metallic foils by vacuum deposition – First spin off**
→This technique would be able to realise foils with good surface quality in one step.

• **Micro-macro study of high temperature damage in steels**
→ Definition of rupture criteria coupled with a macroscopic damaging model.

• **Macrofoams, a new material for security in civil engineering**
→ Study and development of macro cellular foams obtained from cheap metallic components.

• **Virtual intelligent forging – coordinated action**
→ To gather and analyse this scattered knowledge in order to solve some of today's industrial problems and to incorporate into industrial practices the recent advances in virtual production, supply chain and life-cycle management.

Current researches (3/4)

- **Non – contact ultrasonic system for rail track inspection**

→ Proposes a non-contact ultrasonic system for periodic in-field inspections of rail tracks.

- **Open access to the belgian nuclear higher education network FP6-actions to promote and develop human resources and mobility**

→ To provide commonly accepted evaluation methodologies especially adapted for the assessment of education programmes.

- **Powder metallurgy**

→ Produces pieces with unique material properties that can not be obtained by any other process.

- **Definition of a thumb implant made of an intelligent biomaterial with gradual young's modulus**

→ Conception and the fabrication of a thumb prosthesis made of a gradual Young modulus and titanium based material and performed using the powder metallurgy technique.

Current researches (4/4)

• **Study of the influence of the physical chemistry in FE-CR-CX alloys on the solidification kinetics and nano properties ontained by thermo-mechanical treatments**

→ Establish a metallurgical predicting tool capable of optimising the microstructure and the subsequent mechanical behaviour of a HSS alloy towards a primary chemical composition setting.

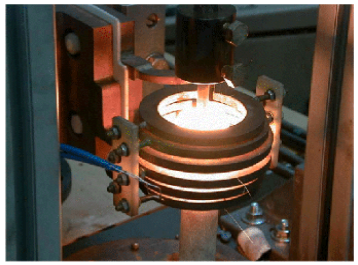
Presentation of the metallurgical laboratory

Microstructure et propriétés thermophysiques










Dépôt sous vide thixo four sous vide propriétés tribologiques

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Matériaux Métalliques Spéciaux

Metallic Material Science - J. Lecomte-Beckers
Measurement Facilities for Materials Characterization

Dilatometry

Dilatation measurement of materials
Determination of thermal expansion coefficient
Determination of density at high temperatures

Differential Scanning Calorimetry

Phase transformations analysis of materials
Determination of thermophysical parameters
(Cp, enthalpy, solid fraction, ...)

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Matériaux Métalliques Spéciaux

Metallic Material Science - J. Lecomte-Beckers
Measurement Facilities for Materials Characterization

Thermal diffusivity:

Overheated sample using a pulse laser

Determination of thermal conductivity via density, specific heat and thermal diffusivity

High resolution Microscope

Brinell, Rockwell or Vickers hardness:
mapping of the microstructure hardness by coupling with an optical microscope

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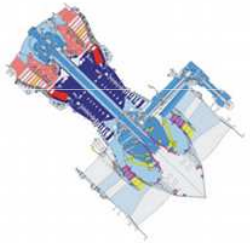
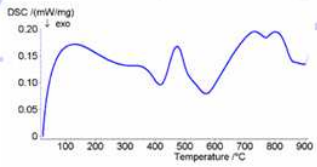
Metallic Material Science - J. Lecomte-Beckers

Microstructures, thermophysical properties and "micro-macro" relationships of advanced metallic materials



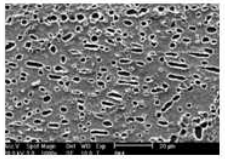
Titanium alloys in the low pressure compressor of turbojets

Characterization of thermophysical properties



DSC curve of Ti-LCB

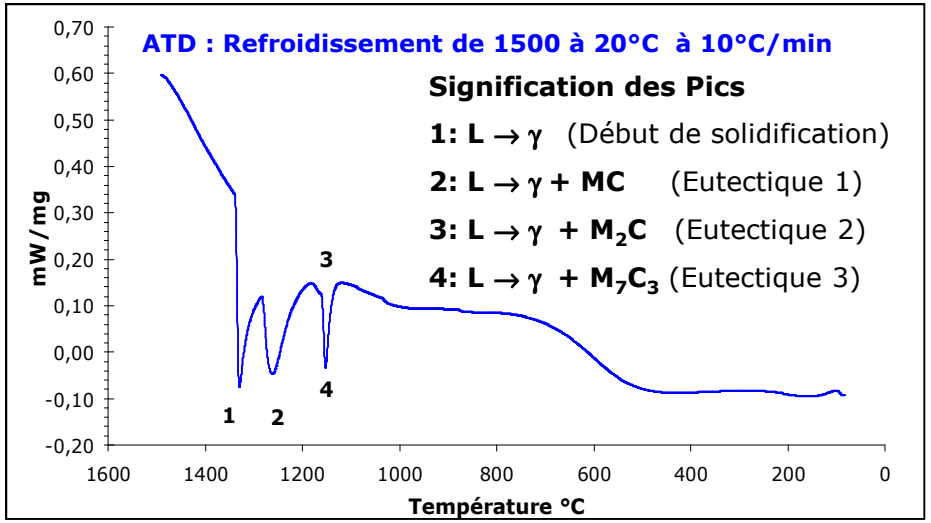
Microstructural characterization



Electronic Microscope view of Ti-555

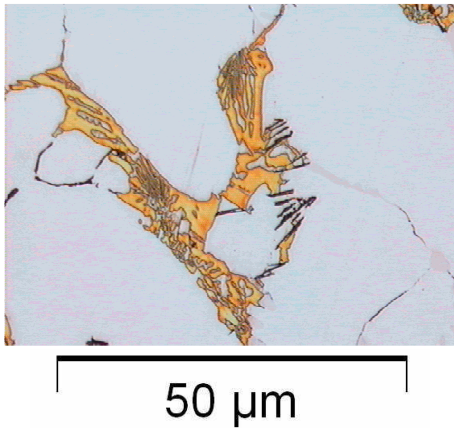
Chemin de cristallisation et Caractérisation de phases à l'état solide (Acier Type HSS)

Étude par ATD/DSC pour détermination du chemin de cristallisation



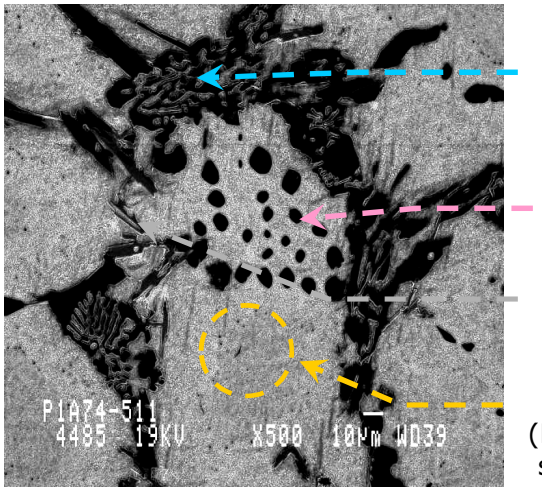
Métallographie après essai ATD

(Attaque chimique au réactif de Groesbeck)



M_7C_3 (Agrégats Massifs Jaune orangé), M_2C (Aiguilles Noires) et MC (Lobules Rose pâle)

Examen métallographique pour détermination nature des phases: Analyse chimique complexe → carbures ≠



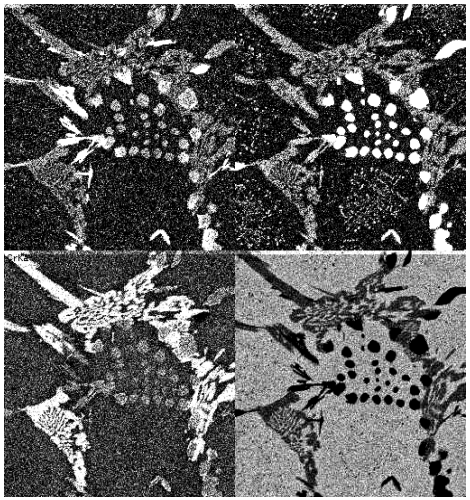
M_7C_3 (en arêtes de Poisson)

MC (Lobules)

M_2C (Aiguilles)

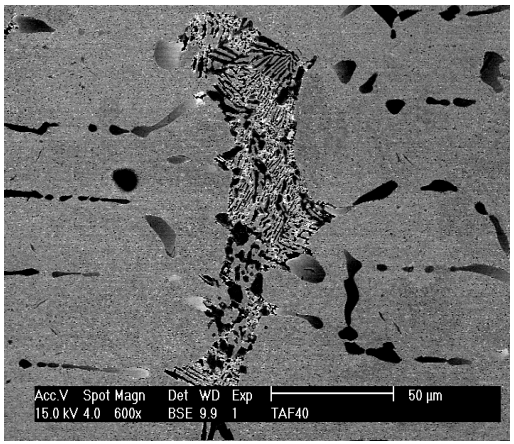
$M_{23}C_6$ (Fins carbures secondaires)

Mo (Lα) ***V (Kα)***



Cr (K α) ***Fe (K α)***

Cartographie EDX associée



Carbure mixte M_7C_3/M_6C et Agrégat de MC en ligne - Variations contraste carbures MC (Noir à Gris) en relation avec variations composition chimique liquide résiduel et avancement front de solidification

Composition complexe → ≠ types de carbures, aux joints de grains (M_7C_3, MC, $M_{23}C_6$)

Contact: Jacqueline.Lecomte@ulg.ac.be – website: www.ulg.ac.be/metaux

Corrélations Inclusions et Propriétés mécaniques sur des Aciers pour Cylindres de laminoir

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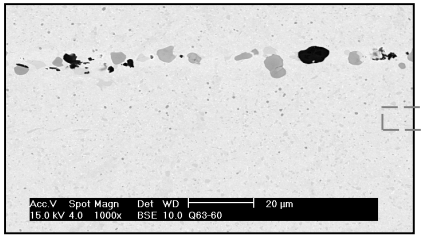
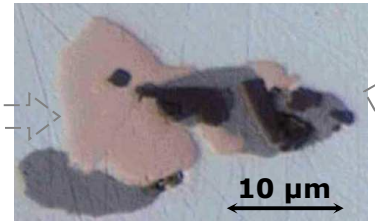
Matériaux Métalliques Spéciaux

Inclusions et carbures

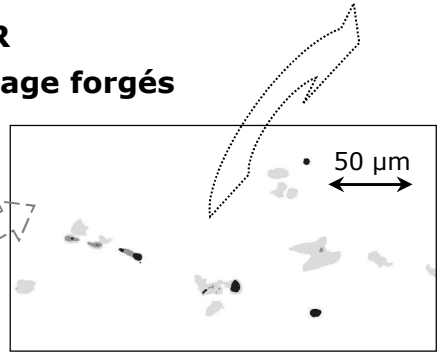
- **Provenance: Coulées EAF ou ESR**
- **Applications: Cylindres de laminage forgés**
- **Analyse et caractérisation**



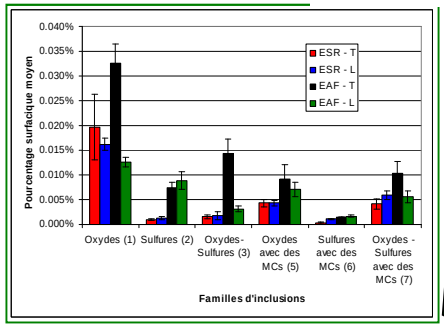
Détermination de la nature des phases (MEB/EDX): Relief (SE) et Composition chimique (BSE)



Caractérisation des phases en Optique (Sulfures Gris, Oxydes Noirs Nitrure Rose)

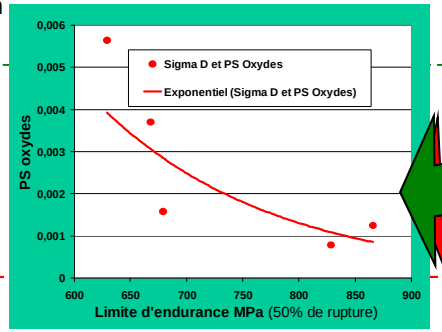


Traitement d'une image source en poli miroir par **Analyse Spectrale, Seuillage, Erosion et Reconstruction**



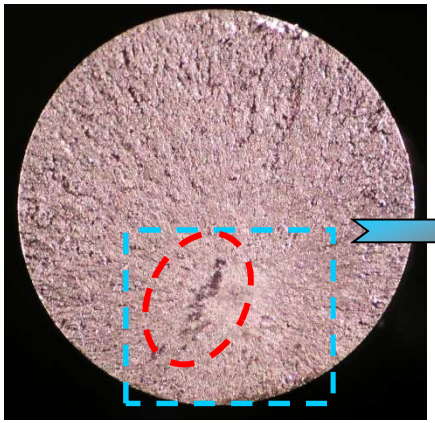
Résultats de la Quantification par Analyse d'Images

Pourcentage surfacique moyen par famille d'inclusions

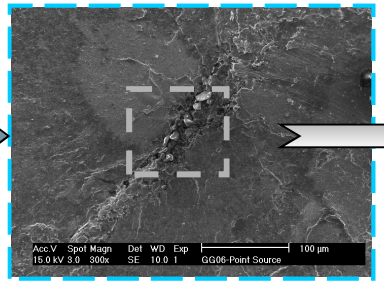


Corrélations Inclusions/Propriétés Mécaniques :
Influence néfaste des Oxydes d'Aluminium
(σ_D (50%) ↘ quand PS Oxydes ↗)

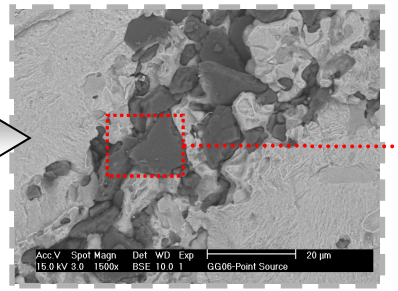
Analyse section de rupture



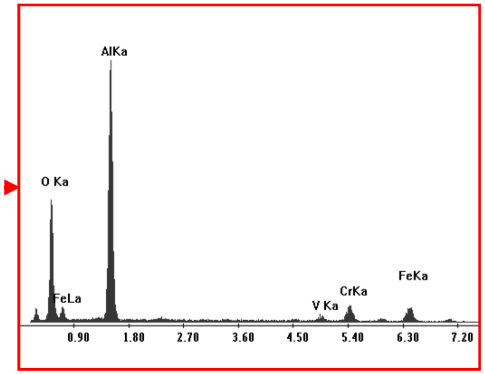
Faciès de rupture en fatigue Auréole d'initiation et stries de propagations



Agrégat d'inclusions en ligne (Centre Auréole d'initiation - MEB)



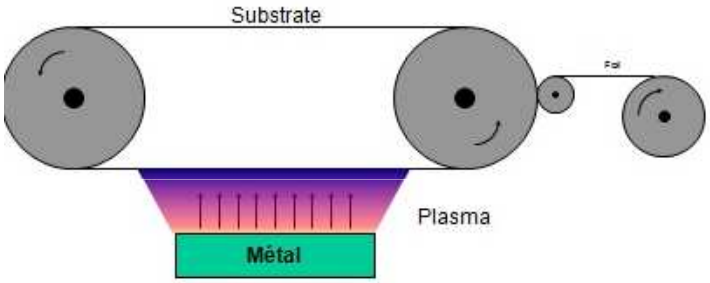
Zoom (MEB) sur Point source pour Analyse EDX



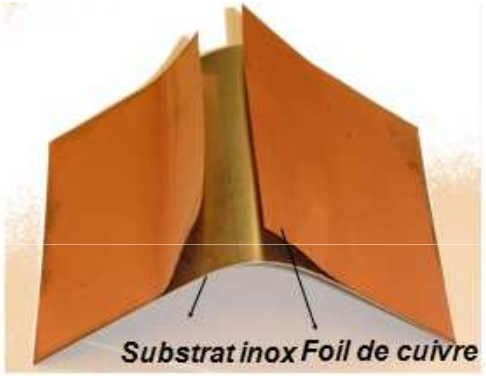
Détermination Nature Point Source (Spectre EDX) : *Agrégat d'Inclusions de type Oxydes d'Aluminium*

Contact: Jacqueline.Lecomte@ulg.ac.be – website: www.ulg.ac.be/metaux

Process (foil)



Plasma



Zinc foil

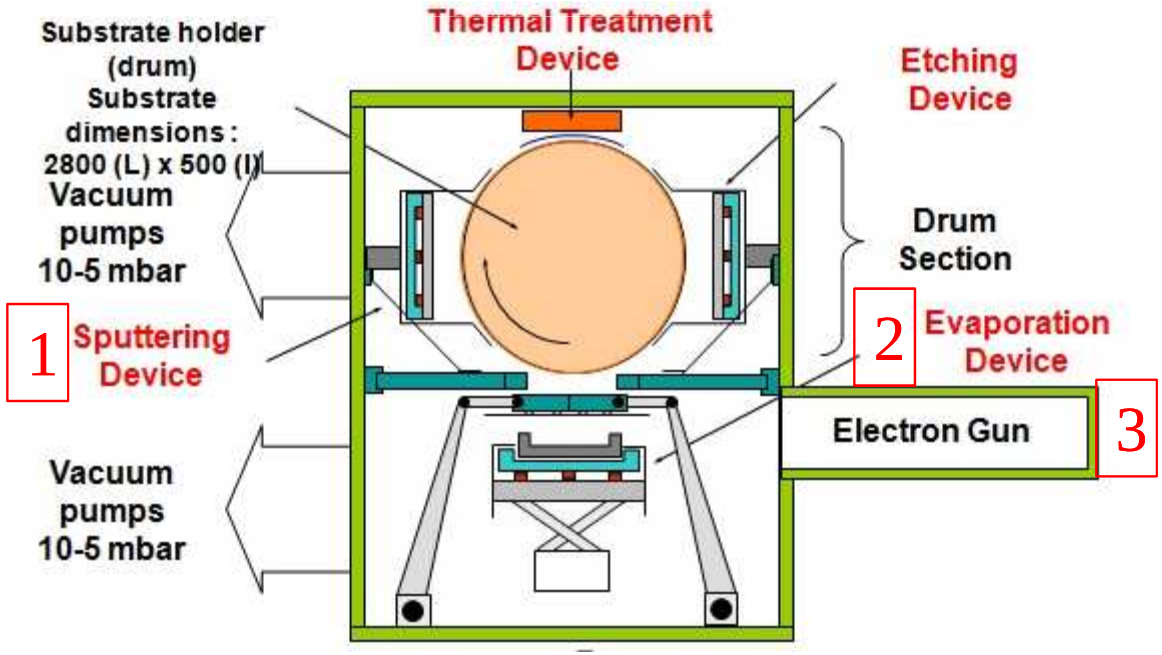
Pure metals (Zn, Cu, Ti…) or *multilayers* are deposited by PVD:

- *self induced ion plating* → *EVAFOIL*
- *electron beam* → *EBEAMFOIL*

onto a substrate and peeled off to form a self standing foil. Thickness is from a few microns to hundreds of microns.

EVA (vacuum deposition) (2/2)

Physical vapour deposition (PVD) covers a broad class of vacuum coating processes in which material is physically removed from a source by evaporation or sputtering, transported through a vacuum or partial vacuum by the energy of the vapour particles, and condensed as a film on the surfaces of appropriately placed parts or substrates.

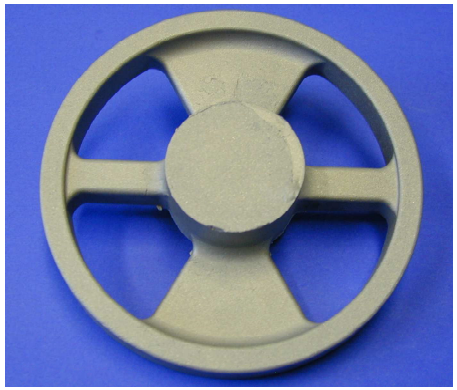


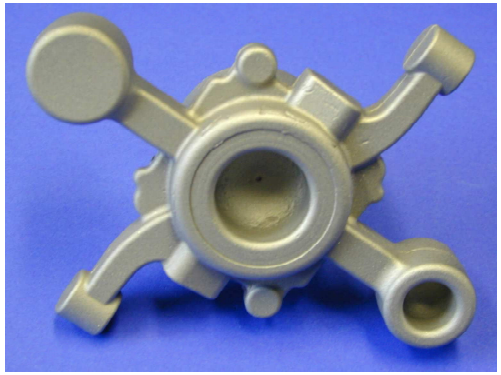
EVA : Possibilities

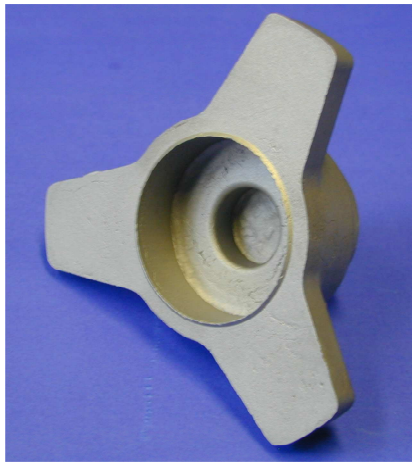
EVA : Vacuum Coater

Thixoforming device (1/2) (APT 500T)

Thixoforming is a semi-solid forming process carried out in the melting-interval, where a defined fraction of globular solid particles are surrounded by the liquid phase. It can therefore be classified as intermediate between casting and massive metal forming. Since a thixotropic material behaves like a viscous liquid, the process enables the manufacture of complex shaped parts with very small forces in a single step operation.





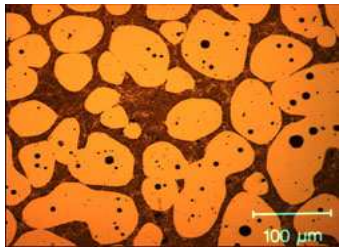


Thixoforming device (2/2) (APT 500T)

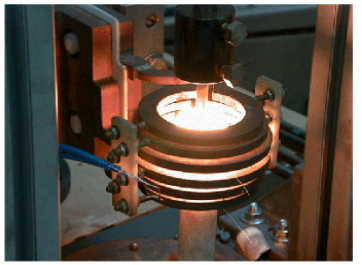
Thixoforming is a multidisciplinary research topic and involves many themes. At the department of Aerospace & Mechanical Engineering, specific attention is paid to the following issues :

- Routes to thixoformable starting materials and identification of suitable materials (External partners : CRM, MK, SIRRIS and ASCOMETAL)

- Modelling of die fill and rheological property measurement (External partners : RWTH Aachen, University of Cyprus, University of Leicester)



- Technology and industrialisation (External partners: ICE (ULg), ASCOMETAL, MRC)



Vacuum furnace (or controlled atmosphere)

The equipment makes it possible to carry out cycles of heat treatments under :
- primary vacuum
- secondary vacuum
- partial pressure (neutral gas or reducing gas)
- controlled atmospheres.

Vertical furnace with internal heating (Type : standard CRYSTAL 40 X 40X) operating automatically

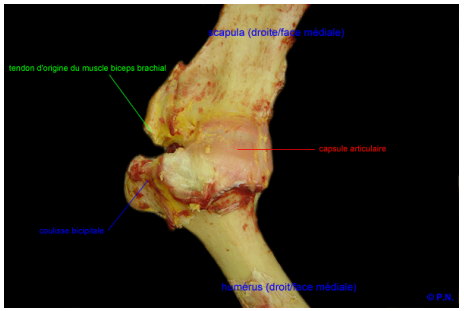
→ Powder metallurgy

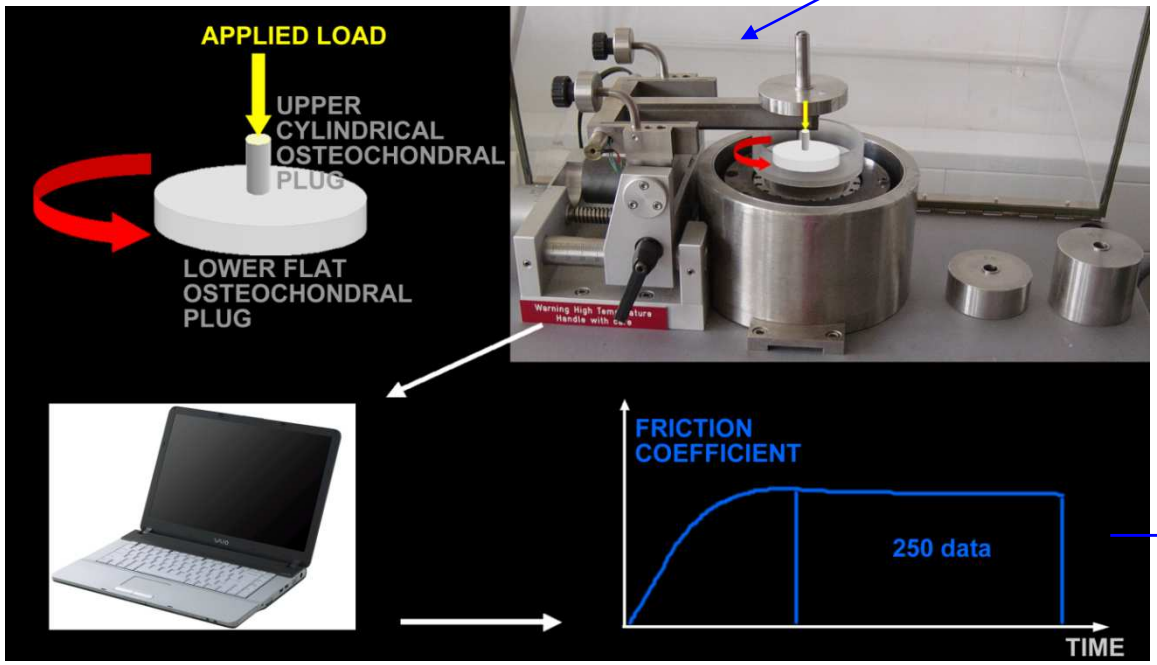
Pin-on-disc tribometer (friction wear measurement)

Exemple d'application en collaboration avec la Faculté de Médecine Vétérinaire de Liège :

An equine joint friction test model using a cartilage on cartilage arrangement

(Noble, P., Collin, B., Lecomte-Beckers, J., Magnée, A., Denoix, J.M., Serteyn, D)





Macroscopical examinations

Statistical tests