Université de Liège

Metallic Materials Science

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Study of Carbon Fibre-Reinforced Magnesium Composites

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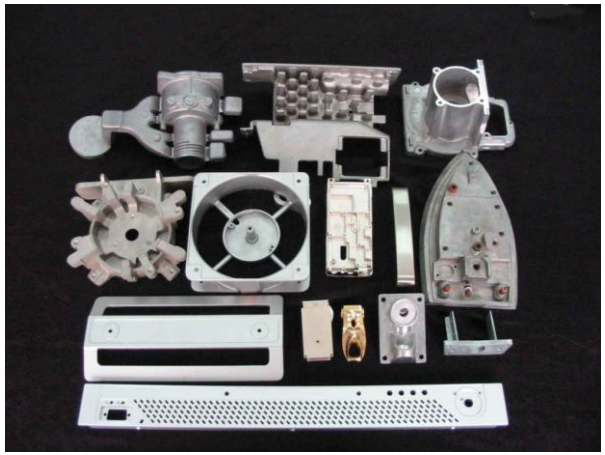
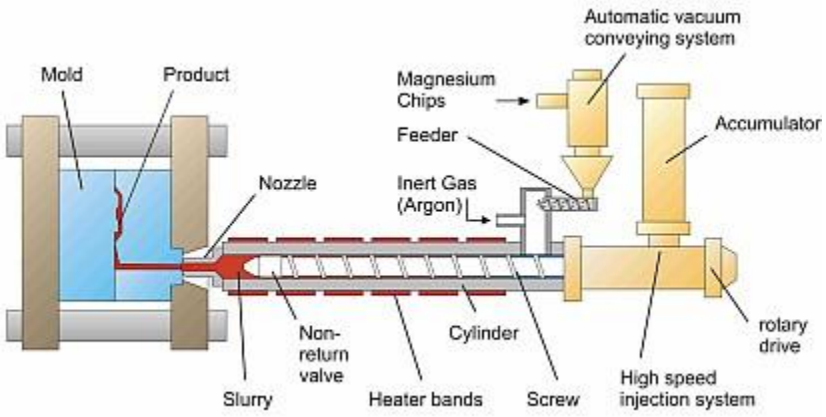
Introduction

- What is CMg MMC related to ?
  - Acronym for **C**arbon **Mag**nesium **M**etal **M**atrix **C**omposite
  - Project financed by RW (Marshall Plan)
  - Aim : Develop the manufacturing of CMg MMC by the squeeze casting process
  - Partners : UCL (Pr F. Delannay), Sirris (J. Halleux)





Source : http://www.nmfgmbh.de/

INTRODUCTION

- What are the interests of (CMg) MMC ?
  - Low density
  - High tensile strength & Young modulus

$$\delta = \frac{\sigma_{max}}{\rho} \qquad \theta = \frac{E}{\rho}$$

  - <u>But</u> pretty high manufacturing costs & need to increase % of fiber content

→ Material designed for high performance applications

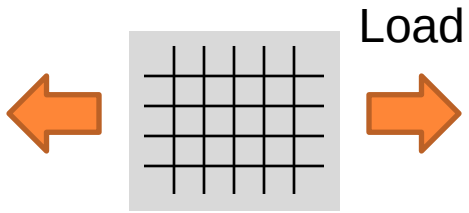
Material	σ_y(MPa)	ρ (kg/m³)	E (GPa)	δ (10^{-3} MPa.m³/kg)	θ (10^{-3} GPa.m³/kg)
AISI 314 (annealed)	320-360	7800-8000	195-200	40-46	24-26
TA6V	780-910	4430-4510	110-119	170-210	24-27
BFR-Al (**50%**)	910-925	2700-2710	208-215	330-340	**77-80**
CFR-Mg (**70%**)	650-660	1790-1860	91-93	**350-370**	**49-52**

Cheaper

Better perf.

Source : CES EduPack 2008

INTRODUCTION



- From macroscopic to microscopic need
  - Need of the best performance index (δ or θ) — **Macroscopic**
  - Need to increase fibres content – choose particular weaves
  - Need to transfer stress from matrix to fibres
  - Need to ensure good interfacial properties — **Microscopic**

Avoid porosity | Improve wettability | Protect fibres

Avoid porosity	Improve wettability	Protect fibres
Casting Strategy Alloy rheology Fibres content …	Casting Strategy Interaction betw. fibres/liq. metal Treatment of fibres …	Casting Strategy Alloy reactivity Treatment of fibres …

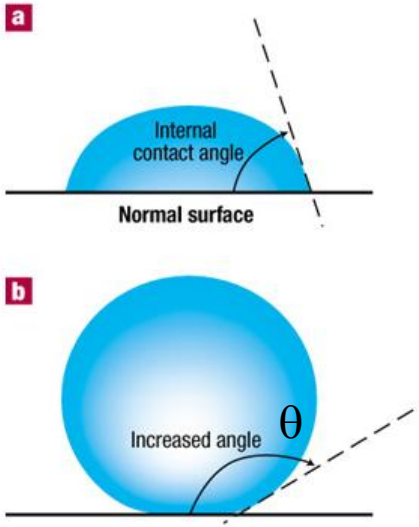
Introduction

- Because…
  - Poor wettability leads potentialy to bad mechanical properties
  - Interaction between C fibres & Mg is weak
- Strategy to improve wettability
  - Create new interfaces (Carbon-XX'-Mg alloy)
  - Take advantage of heat treatments

$$\sigma_{SV} = \sigma_{SL} + \sigma_{LV} \cos\theta$$

Carbide Formers
(ex : Ti, Zr)

Oxides
(ex : SiO_2, Al_2O_3)

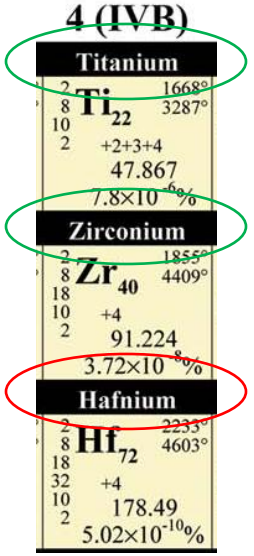


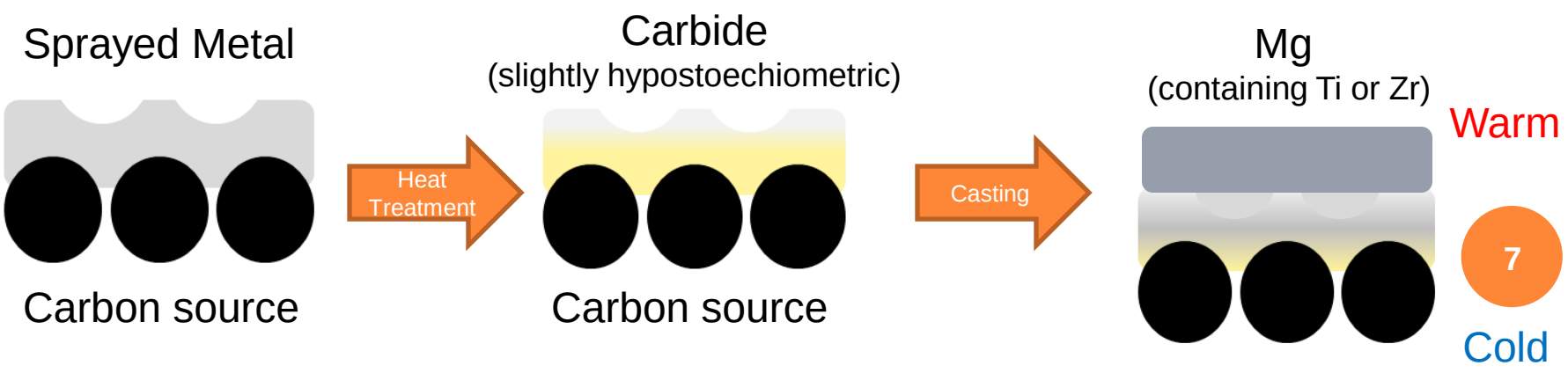
Source : nature.com

Strategy to improve wettability

Use of Carbide Formers & Refractory Metals
(ex : Ti or Zr)

1) Spraying of such metals on C fibres weaves
2) Heat to form hypostoechiometric carbides
3) Cast Mg alloy (containing Ti or Zr)

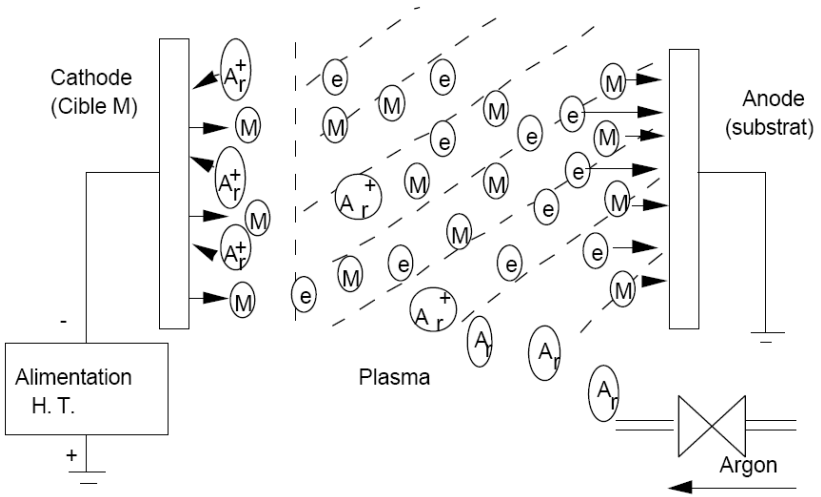




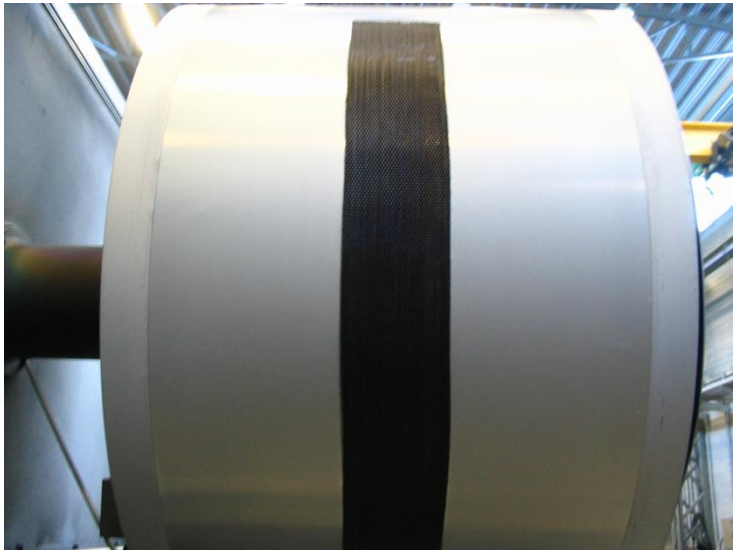
Experimental

- Sputtering Layers (PVD)
  - Metal Spraying
  - Ti, Zr

Ti coated CF weave



Sputtering principle

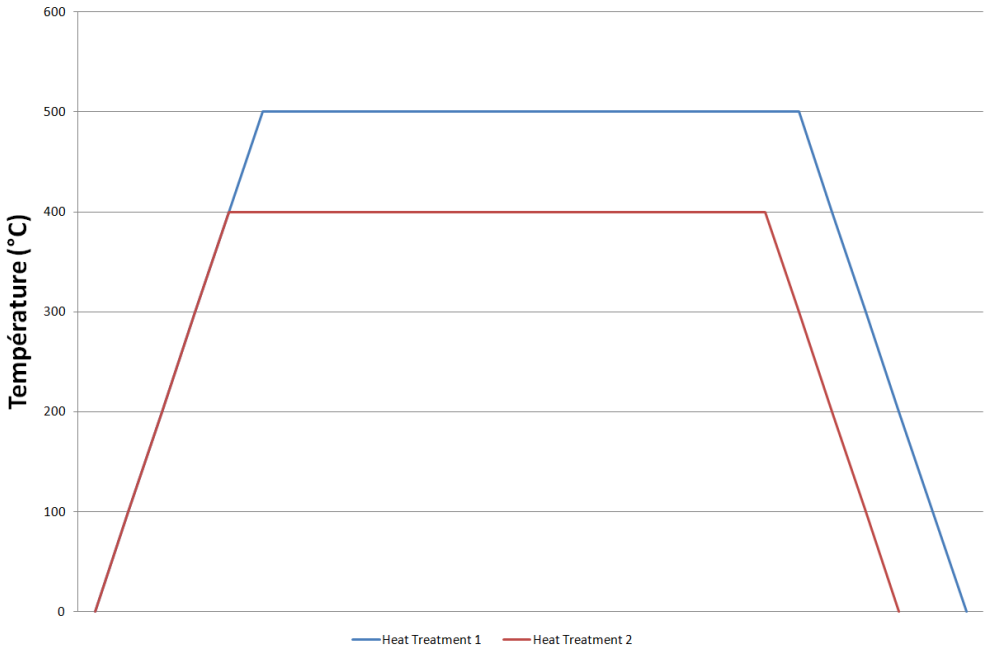


CF weave on sputteringdrum

Experimental

- Heat Treatment
  - 400°C - 500°C
  - 3h
  - Ar atmosphere

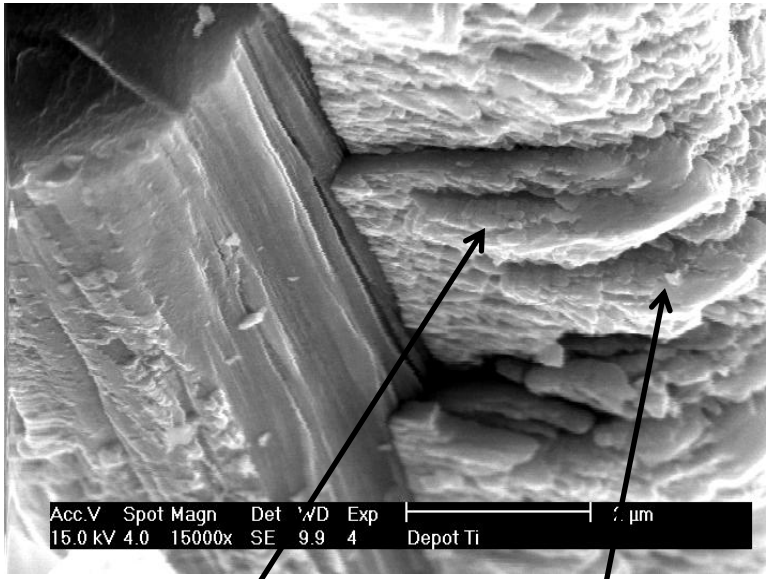
$$Zr + C \rightarrow ZrC$$
$$Ti + C \rightarrow TiC$$

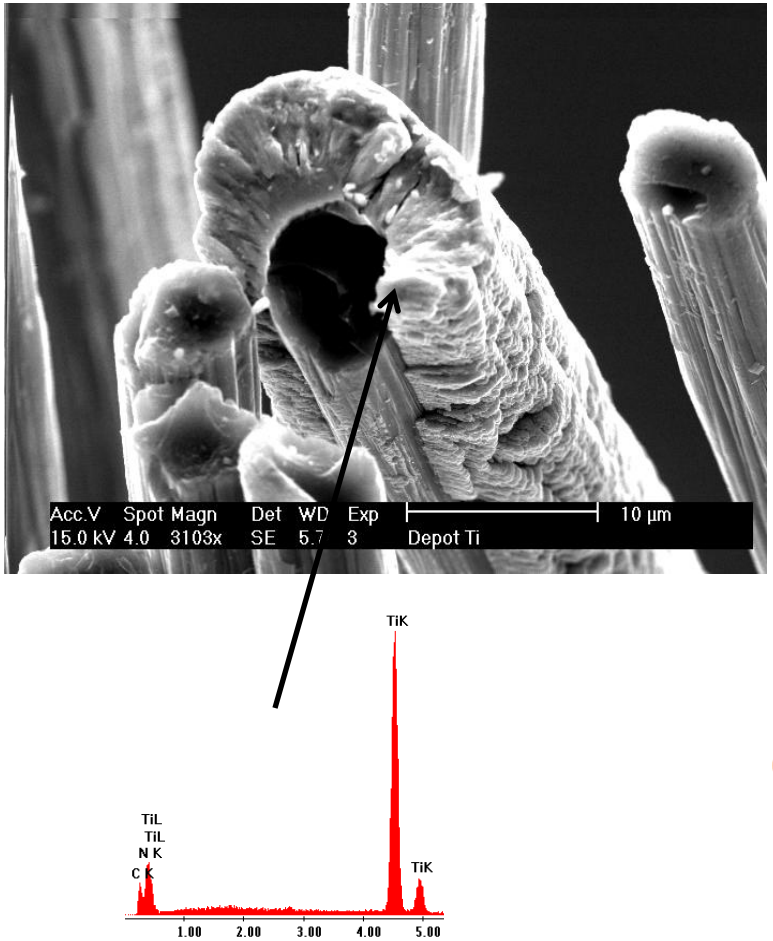


Results & Discussion

- SEM Analysis (Ti) (3h, 500°C)

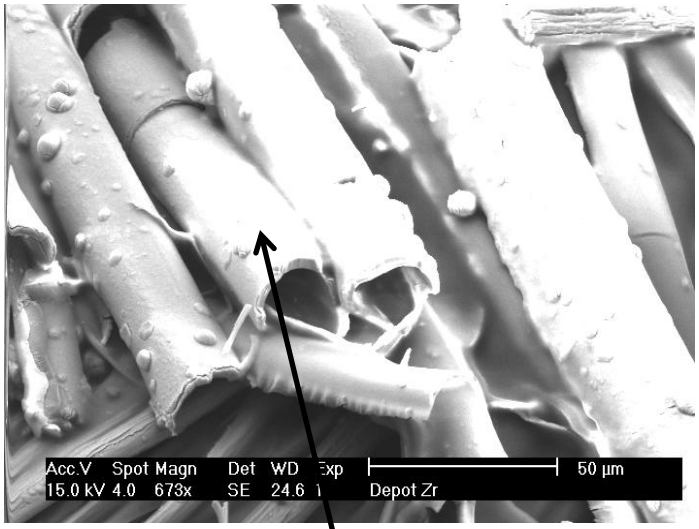
- Diffused Carbon
- Uncertainness on hypostoechiometry

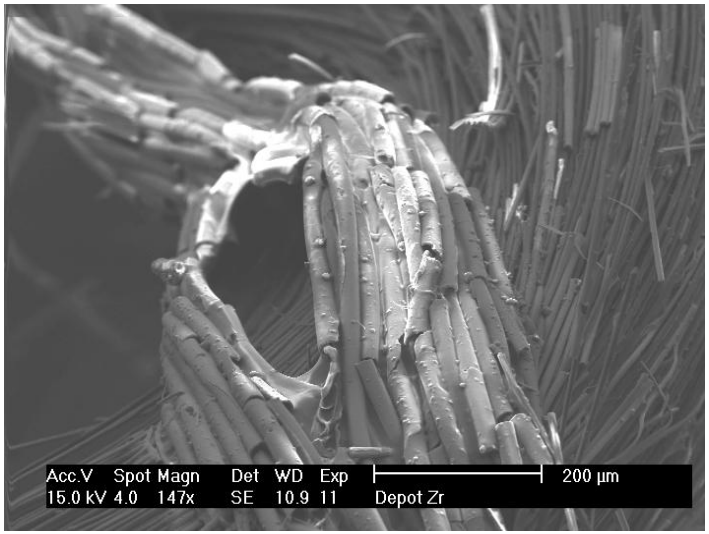


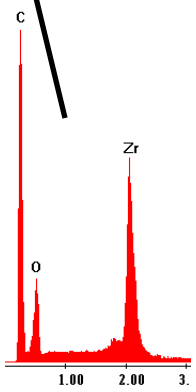


Results & Discussion

- SEM Analysis (Zr) (3h, 500°C)







- Seems to be more brittle
- Higher carbon content
- Presence of oxygen

Conclusions

- CMg MMC research is promising because :
  - Reachable mechanical properties are high
  - Several strategies to improve wettability are existing
  - Experiments show carbon diffusion in refractory metals
- But a lot of developpments are required:
  - Thermodynamic study of Ti & Zr activity in Mg alloys
  - Set optimal heat treatment
  - Compare metals to oxides as fibres coatings
  - Consider the squeeze casting process (mold, injection technique, erosion of coating, …)
  - Optimize the process to improve the mechanical properties of CMg MMC