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NARODOWA STRATEGIA SPÓJNOŚCI

KomCerMet

UNIA EUROPEJSKA
EUROPEJSKI FUNDUSZ ROZWOJU REGIONALNEGO

Wrocław University of Technology

"Metal Matrix Composite Materials Strengthened with Ceramic Fibres and Particles"

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Team: dr hab. inż. Krzysztof Naplocha, dr inż. Adam Kurzawa,
dr inż. Andrzej Janus, dr hab. inż. Kazimierz Granat,
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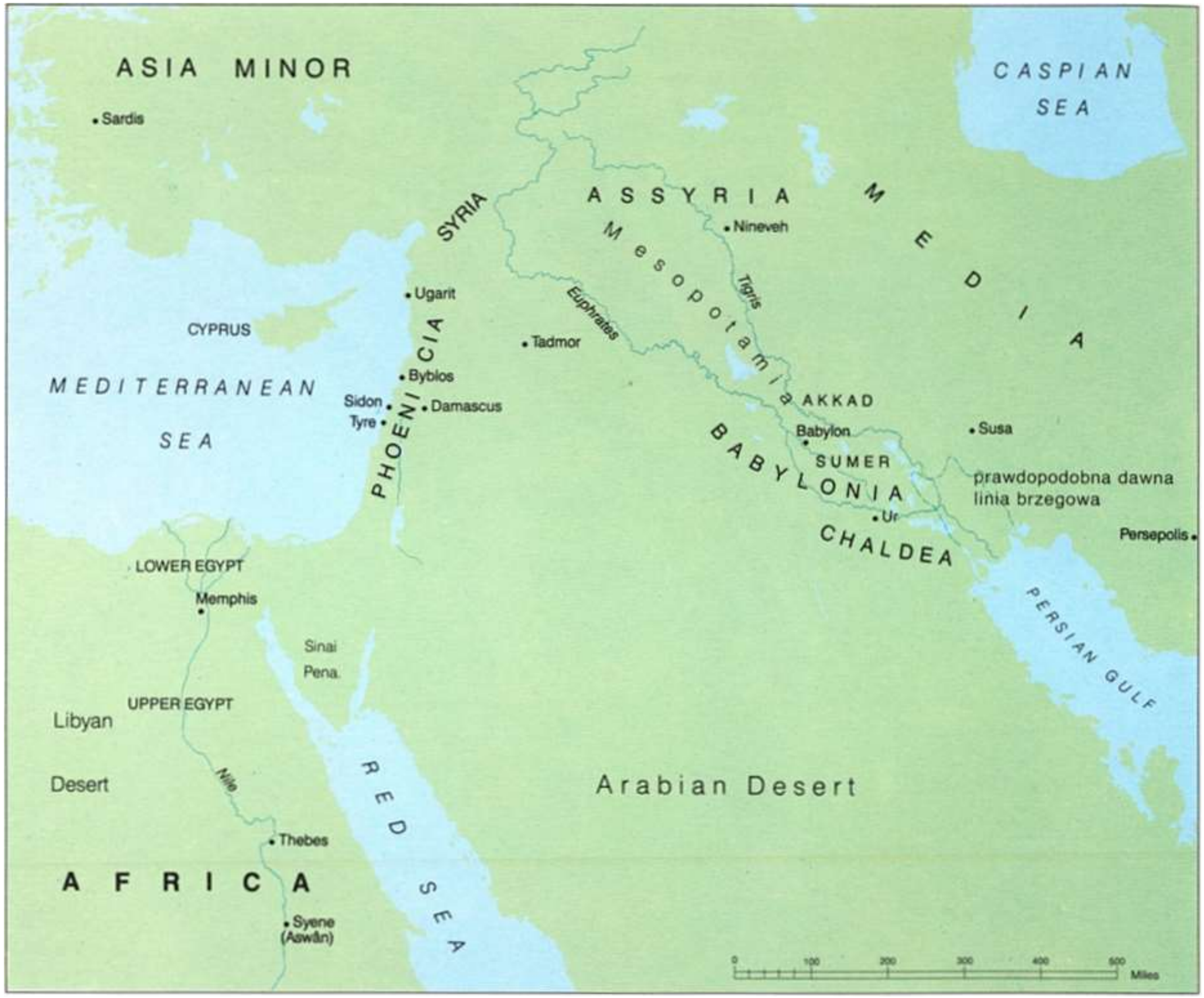
mgr inż. Marcin Wojtkowiak, Czesław Sordyl

Presentation at *PolSCA - Polish Science Contact Agency in Brussel*

Polish Academy of Sciences
PolSCA
Polish Science Contact Agency

Brussel, March 6, 2015

Possible places of first composite materials applications



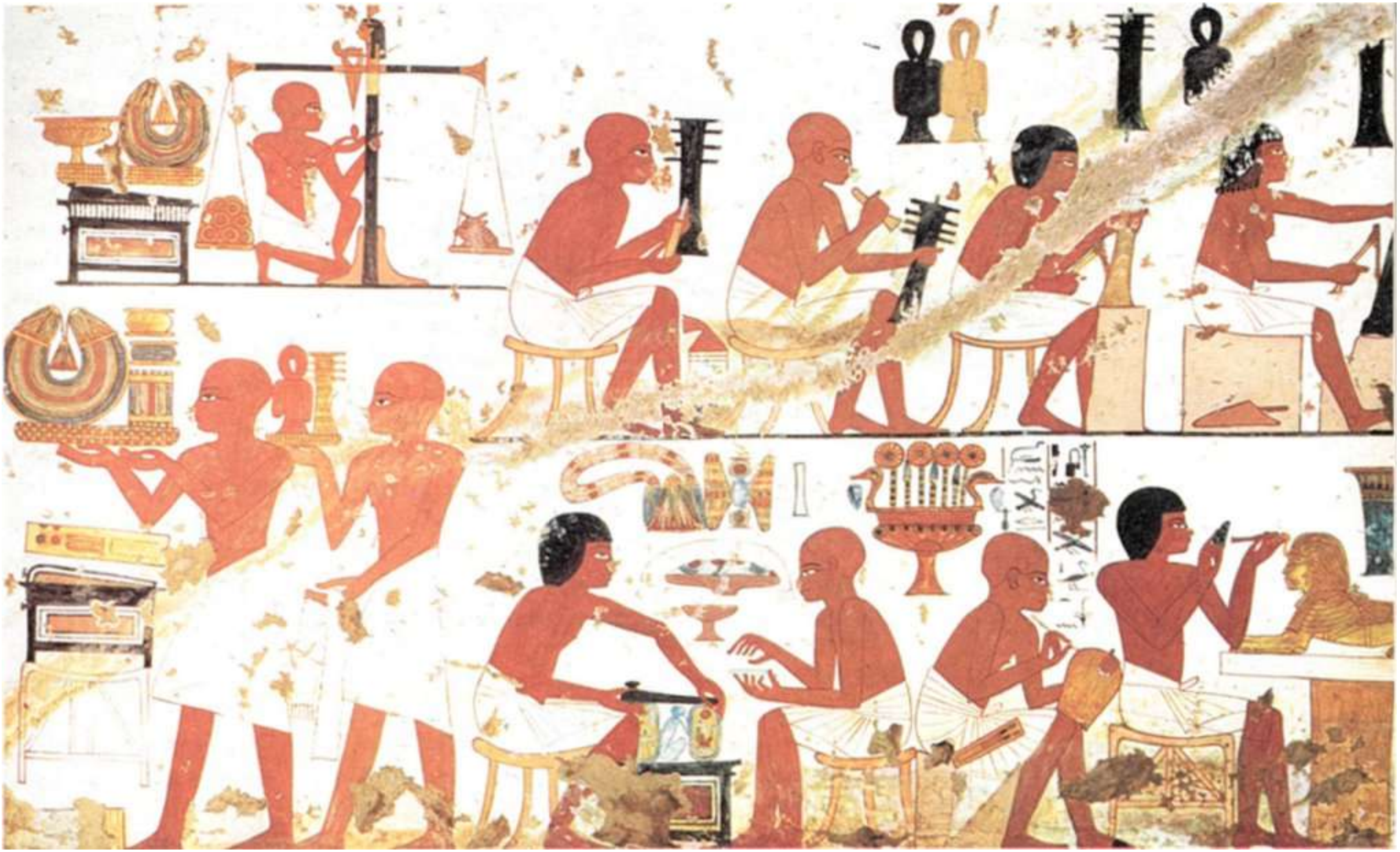
History of Composite Materials

Probably the oldest man made composite materials

http://www.woolfmedia.com/wordpress/2010/04/making-bricks-without-straw

http://www.google.pl/imgresimgurl=http://www.modr.pl/img/sloma.jpg&imgrefurl

Ancient Egypt –Professions



Forming of bricks from clay and straw

Houses and large buildings in Africa built from composite materials

Typical village house in the Middle Africa made of composite materials

Palace in the East Africa built by Dogons made from the composite materilas

Research projects

„KomCerMet", „Kompozyty i Nanokompozyty Ceramiczno-Metalowe dla Przemysłu Lotniczego i Samochodowego", Program Operacyjny Innowacyjna Gospodarka 2007-2013, POIG 1.3.1, 2008-2013, Główny Koordynator: Prof. Michał, Basista Instytut Podstawowych Problemów Techniki, Polska Akademia Nauk w Warszawie.

„Micro- and Nanocrystalline Functionally Graded Materials for Transport Applications", (*„Mikro- i Nanokrystaliczne Gradientowe Materiały Funkcjonalne do Zastosowań w Transporcie*"), Akronim projektu: MATRANS Umowa:
CP-FP 228869-2 MATRANS; Projekt realizowany w ramach 7 programu Ramowego Unii Europejskiej, 2010-2013Główny Koordynator Prof. Michał Basista, Instytut Podstawowych Problemów Techniki, Polska Akademia Nauk w Warszawie.

Jacek W. Kaczmar*: Wytwarzanie, właściwości i zastosowanie elementów z materiałów kompozytowych*, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2014 (several smaller research projects)

Specific strengths of chosen materials

Material	Tensile strength [MN/m^2]	Density [kg/m^3]	Specific gravity [N/m^3]	Specific strength [km]
Titanium alloy TiAl6V4	900	4500	44145	20,38
Magnesium alloy MgAl10ZnMn	430	1800	17658	24,35
Al - alloys	460	2700	26487	17,36
Cast iron	175	7870	77204	2,27
Carbon tool steel	800	7870	77204	10,36
Polypropylene (PP)	30	900	8829	3,39
Polystyrene (PS)	55	1050	10300	5,33
Composite material – matrix epoxy resin – carbon fibres	7000	2000	19620	356,78
Polyoksymethylene (POM)	66	1410	13832	4,77
Polycarbone (PC)	61	1200	11772	5,18
Polyurethane (PUR)	75	1050	10300	7,28

Activities of the research group in the area of metal matrix composite materials

Metal alloy based composite materials

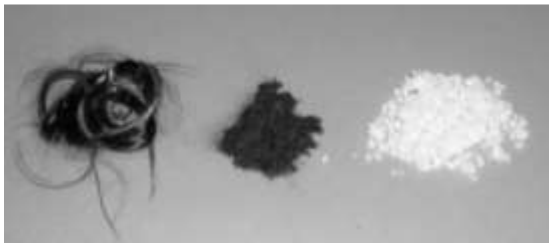
1. Copper based composite materials strengthened with ceramic particles

2. Copper based composite materials strengthened with ceramic fibres SAFFIL

3. Aluminium alloy (2024, 7075, EN AC-4420) based composite materials strengthened with ceramic fibres SAFFIL

4. Aluminium alloy (2024, 7075, EN AC-4420) based composite materials strengthened with ceramic particles

Production of ceramic fiber preforms

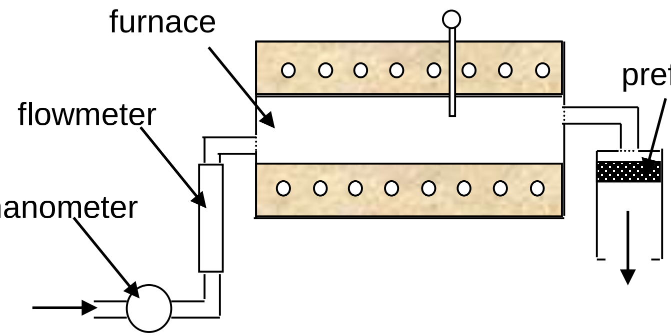


Mixing in water solution of silica binder

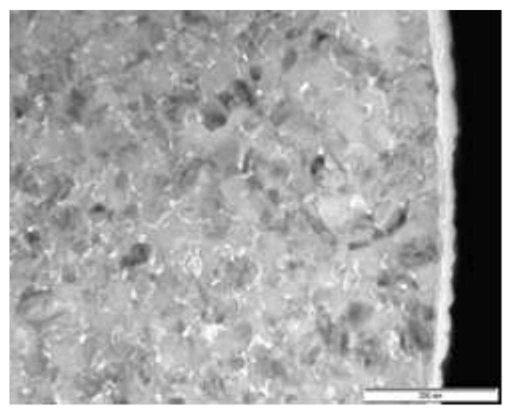
Forming and drying

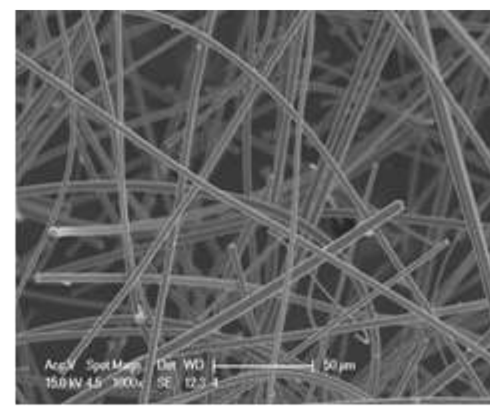
Firing at 950°C

Installation diagram



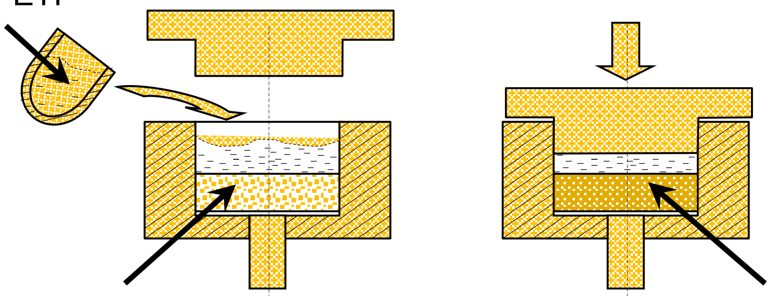
Fibre and preform structure





Production of copper based composite materials reinforced with Al2O3 particles

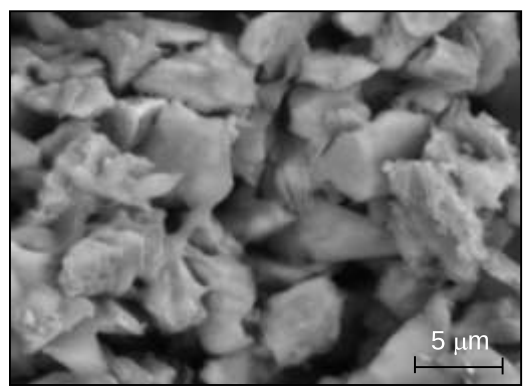
Cu-ETP

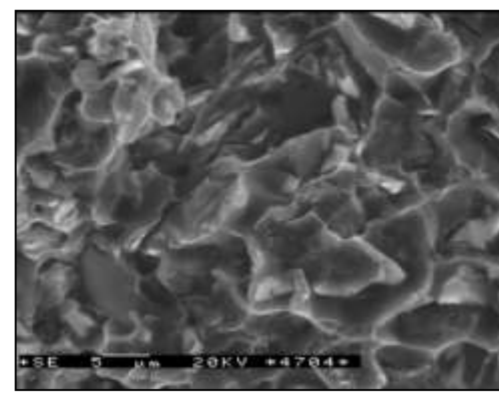


POROUS PREFORM

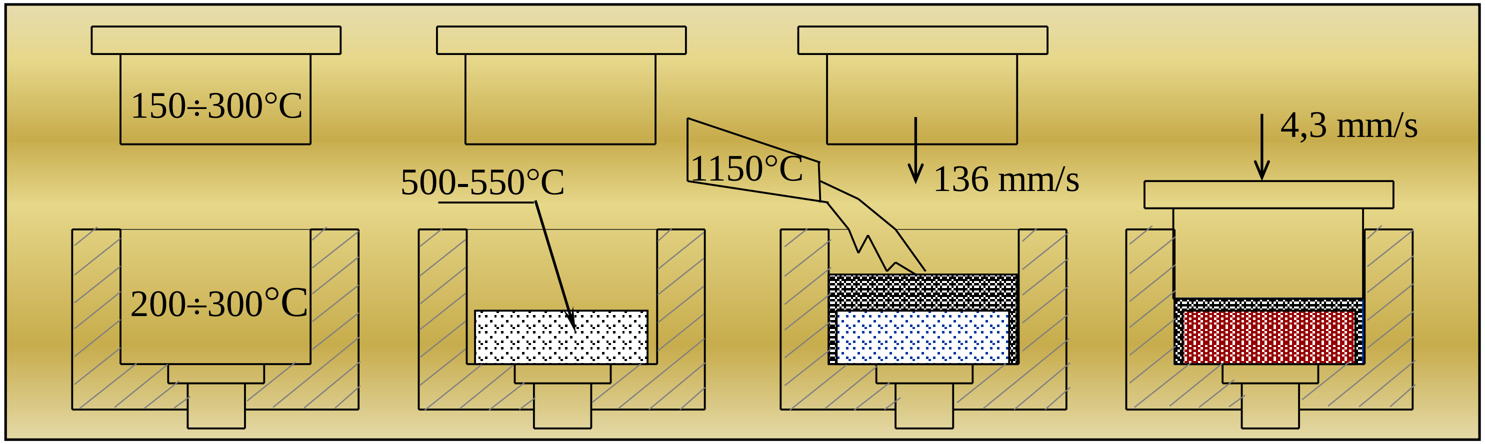
COMPOSITE MATERIAL

Diameter	3-6µm
Al_2O_3 content	> 99%
Admixtures	Na_20, K_20, CaO, SiO_2, Fe_2O
Density	3,95 +/-0,5 g/cm^3
Bulk density	1,52-1,85 g/cm^3
Hardness	> 9 in Mohs scale





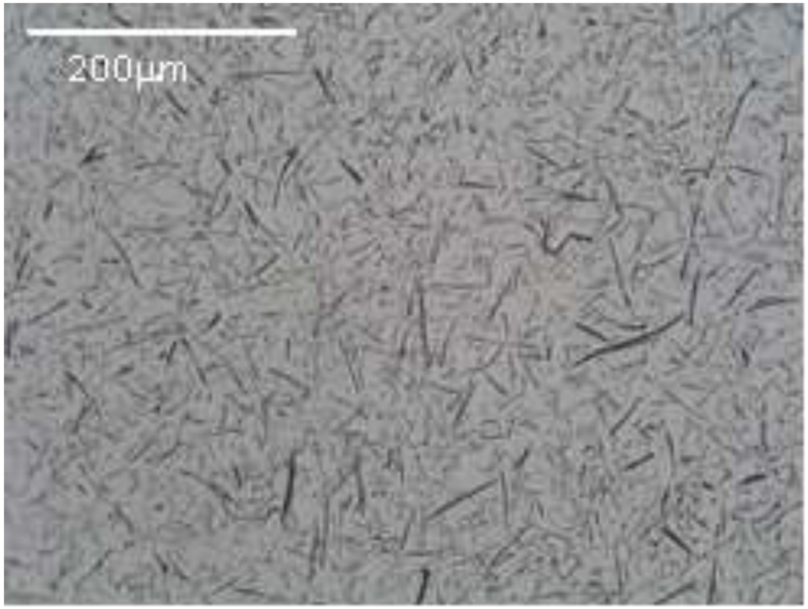
Squeeze casting parameters of Cu-based composite materials



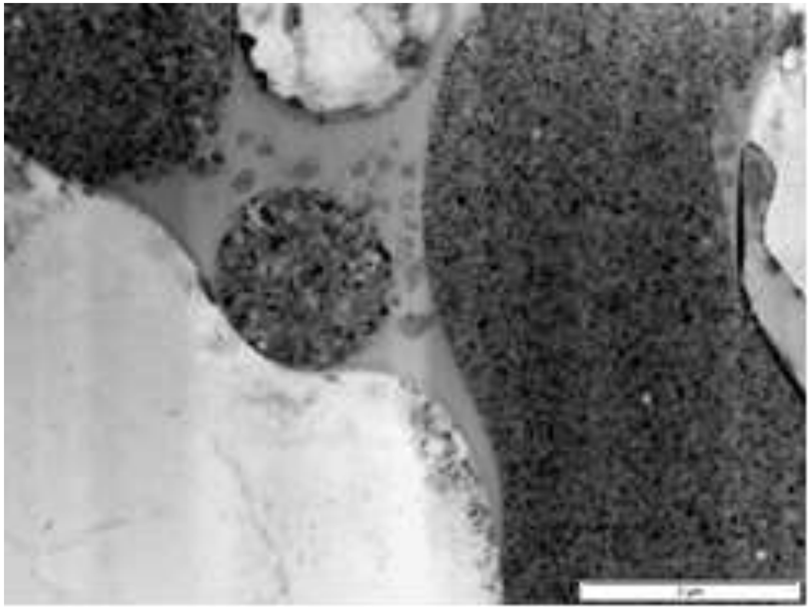
Pleacing of preform

Squeeze casting proces

Microstructure of composite materials



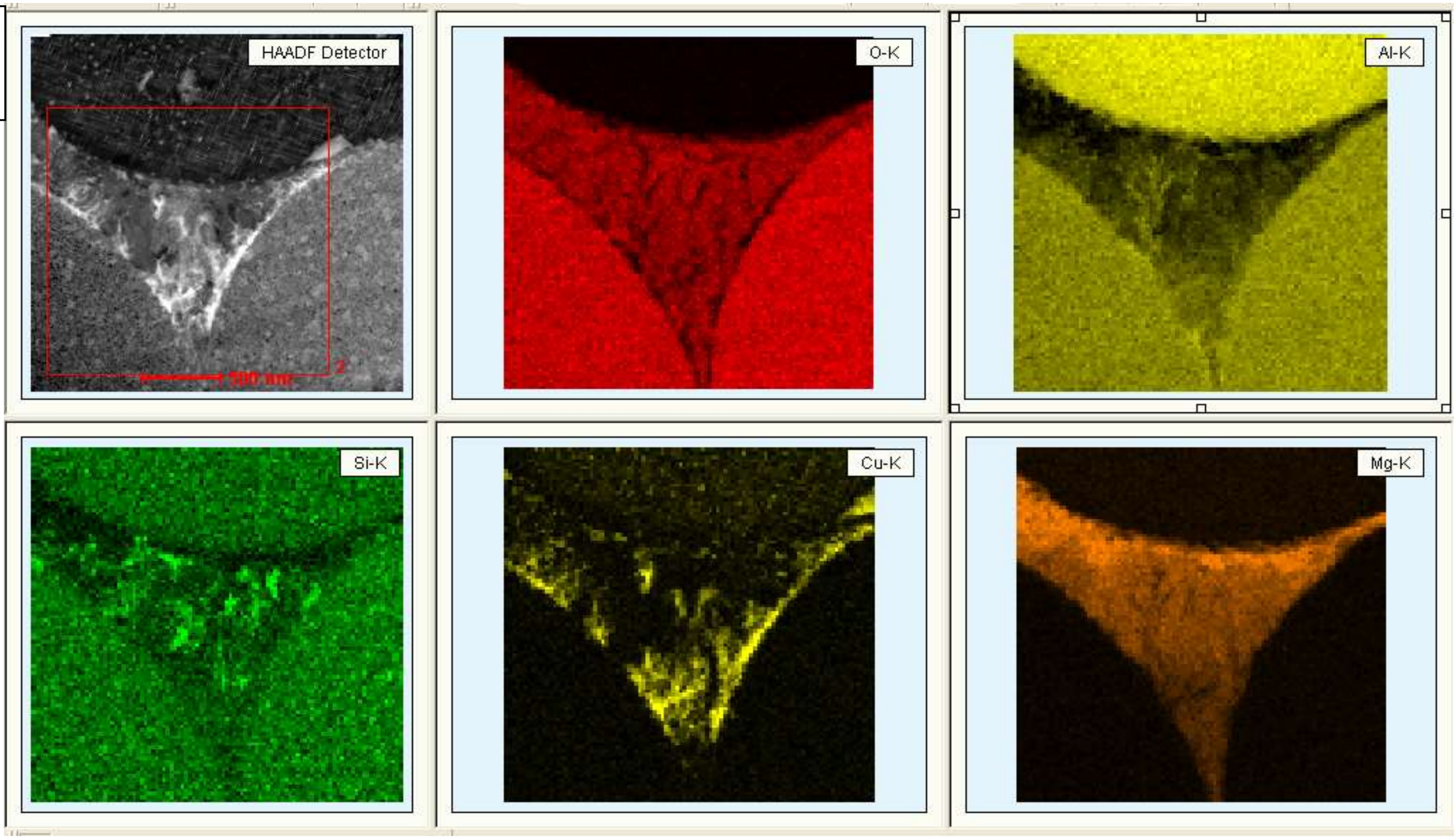
Structure of material Al 7075-10 vol.% Saffil fibers, plane *xy*,



Composite material Al 7075 with the bridge between fibres with the amorphous and crystalline SiO2 (Electron Transmission Microscopy- photograph taken by Prof. J. Morgiel IMIM-PAN Cracow)

Microstructure of composite materials

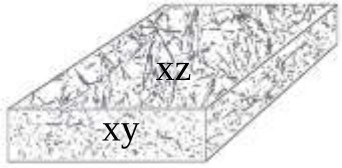
a)

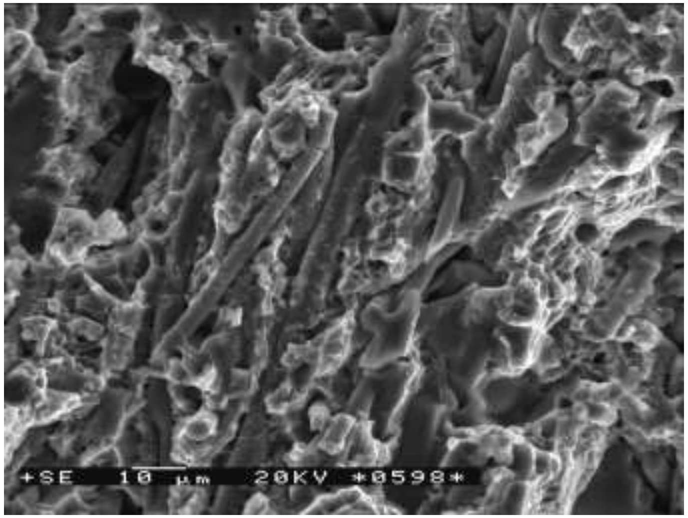


Maps of chosen elements (O, Al, Si, Cu i Mg) after pressure infiltration of ceramic preforms with 2024 Al alloy

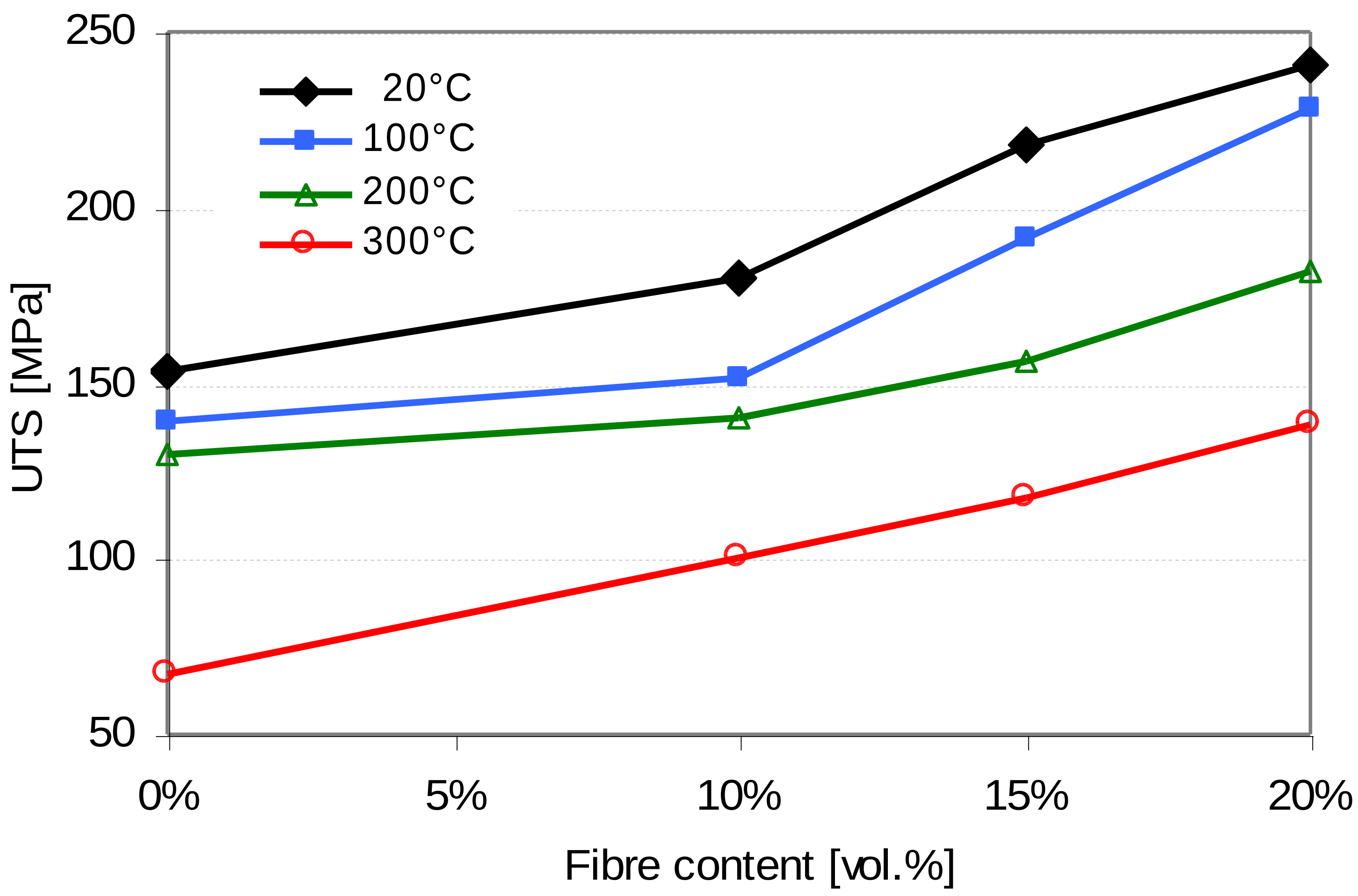
Composite materials
Aluminium alloy EN AC-44200-fibres SAFFIL
(10,5-13,5%Si; 0,4%Fe; 0,35%Mn; 0,1%Zn; 0,15%Ti)

Fracture at xz plane



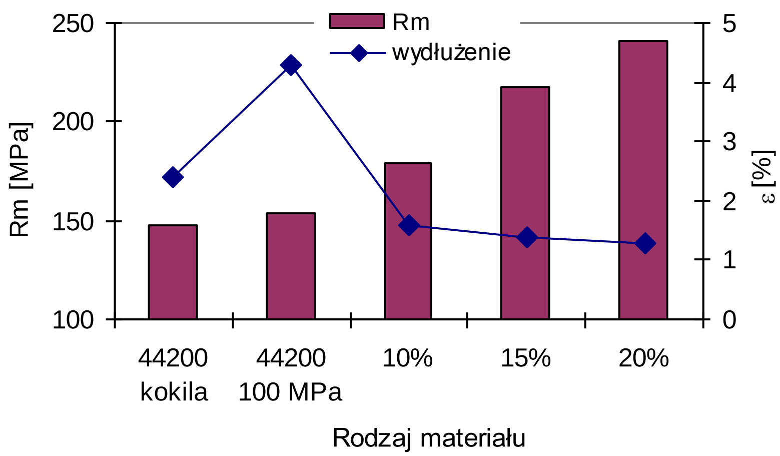


Ultimate tensile strength of unreinforced aluminium matrix EN AC-44200 (0%) and composite materials in 20-300ºC

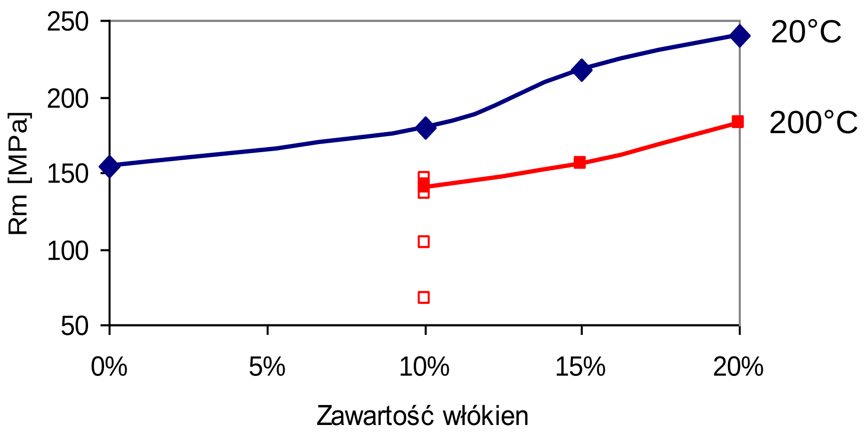


Tensile strength of unreinforced EN AC-44200 and composite materials

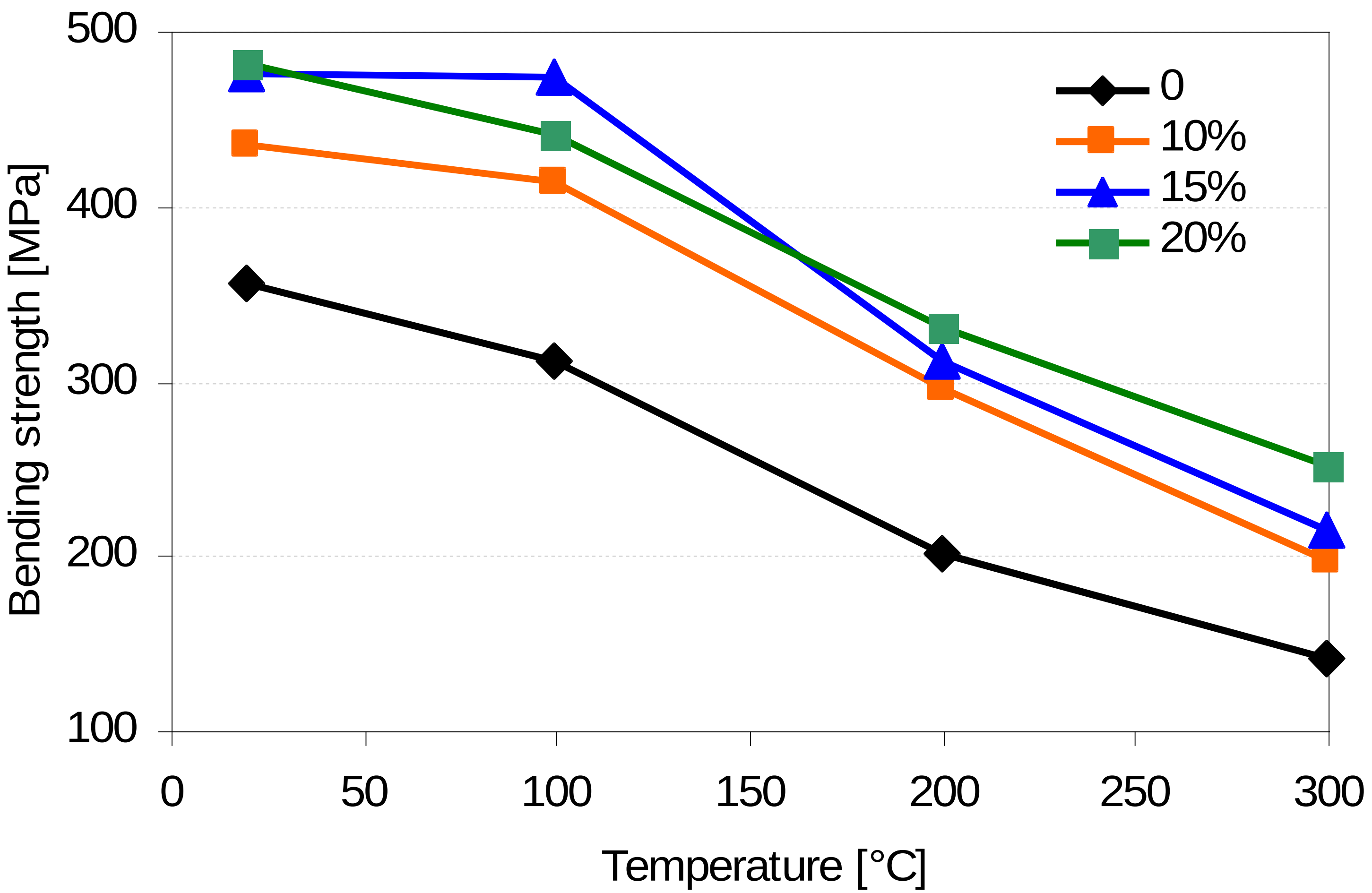
Tensile strength and elongation ε of cast EN AC -44200 cast conventionally, under pressure and of composite materials



Tensile strength at the temperatures of 20°C and 200°C

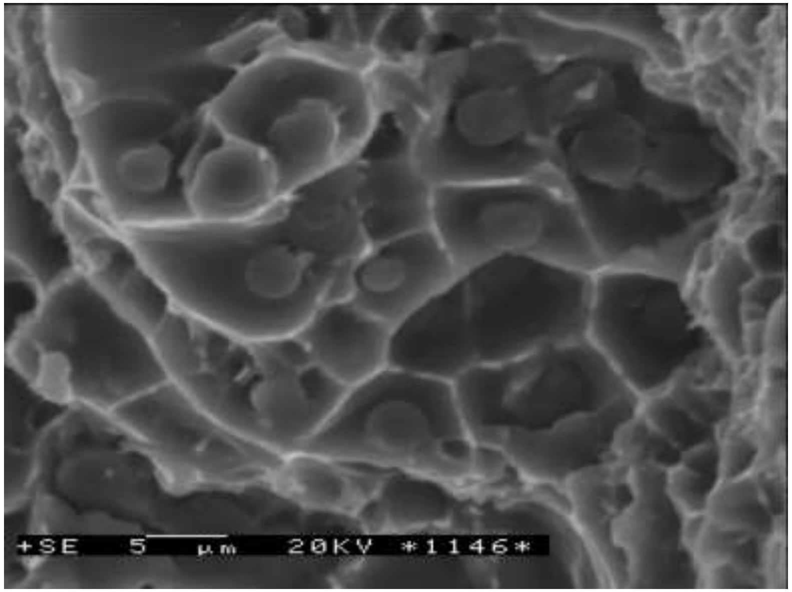


Bending strength in 20-300°C of unreinforced aluminium alloy EN AC-44200 and composite materials reinforced with 10, 15 i 20% of fibers

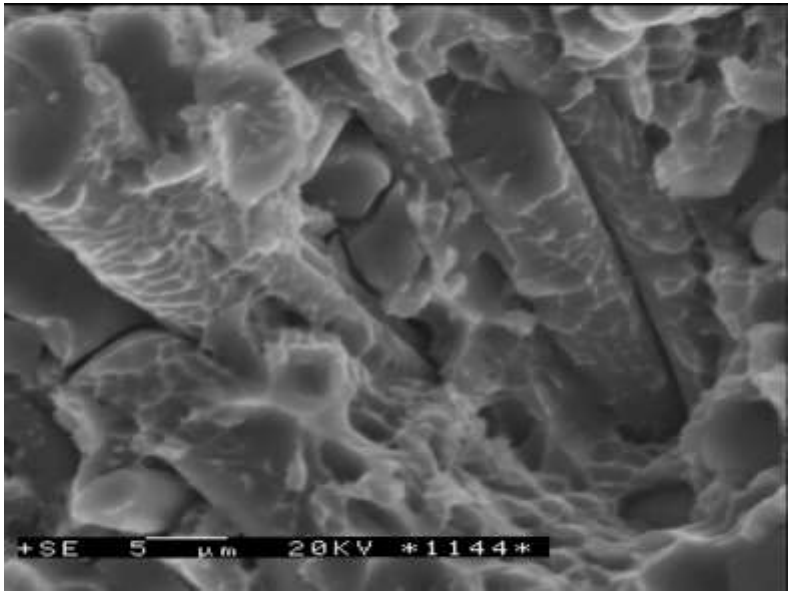


Scanning investigation of composite fracture after bending test at 100°C

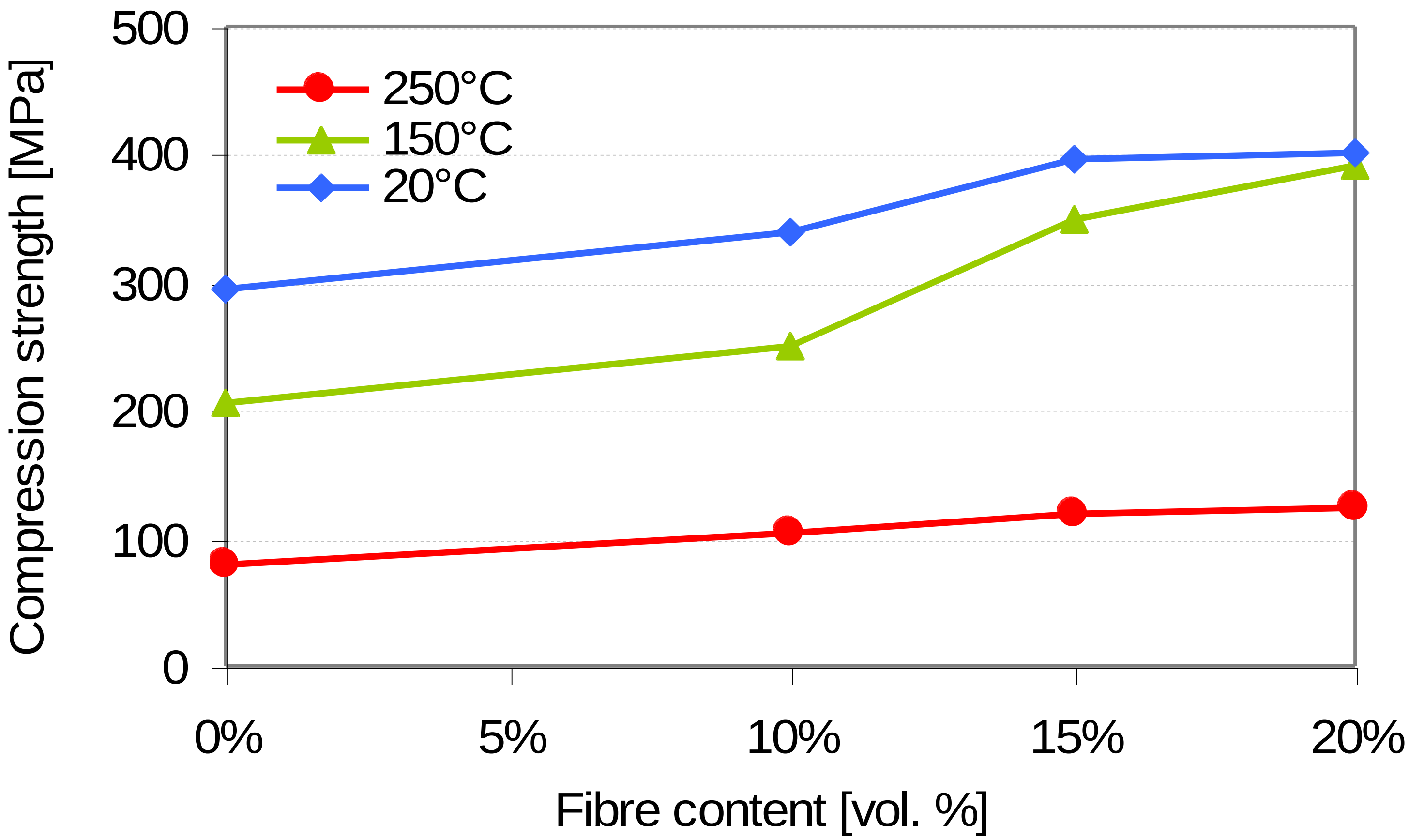
Fibers normal oriented to fracture



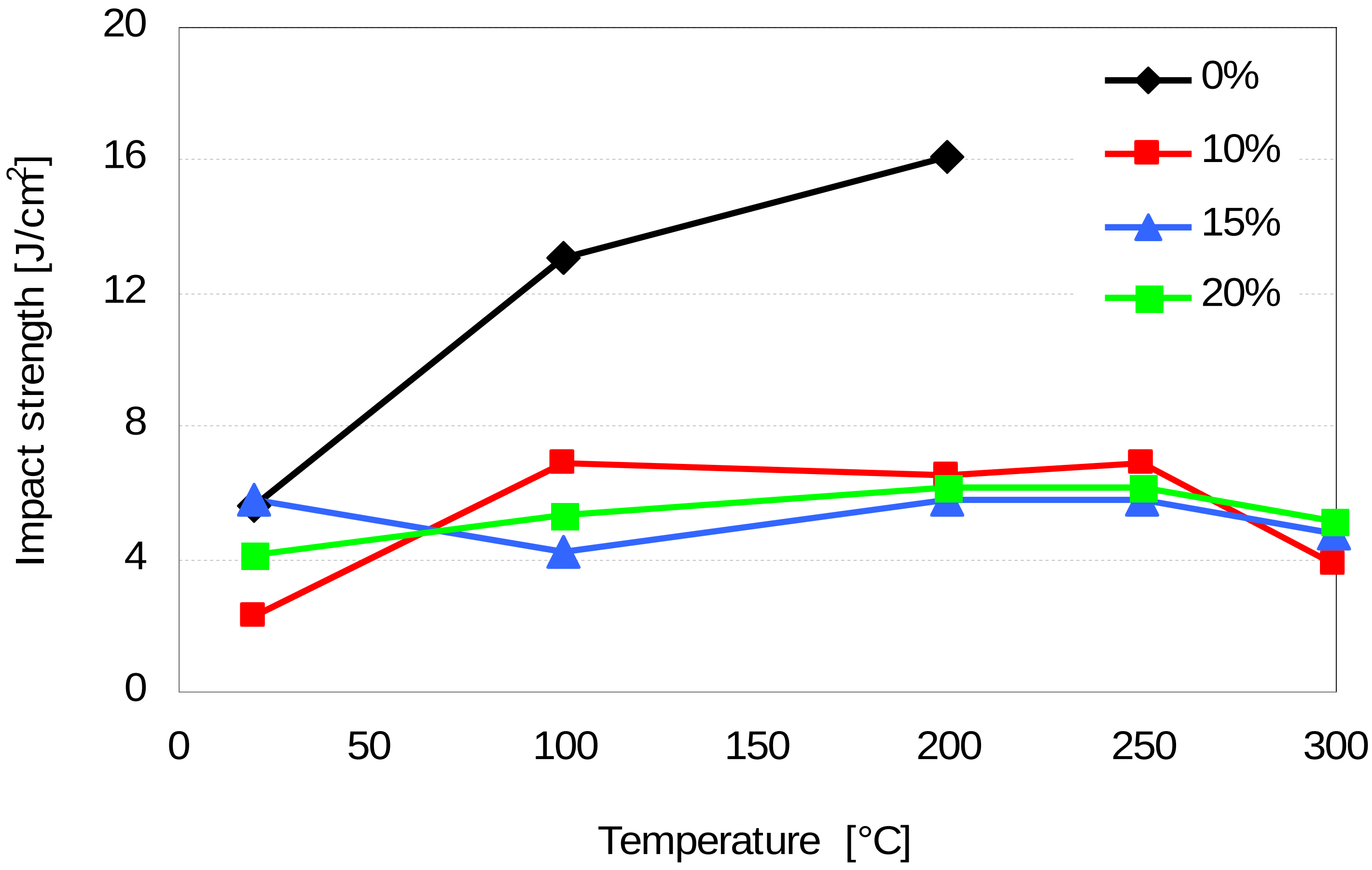
Fibers parallel oriented to the fracture



Compression strength in 20-300°C of unreinforced aluminium alloy 44200 (0%) an composite materials reinforced with 10, 15 i 20% of fibers

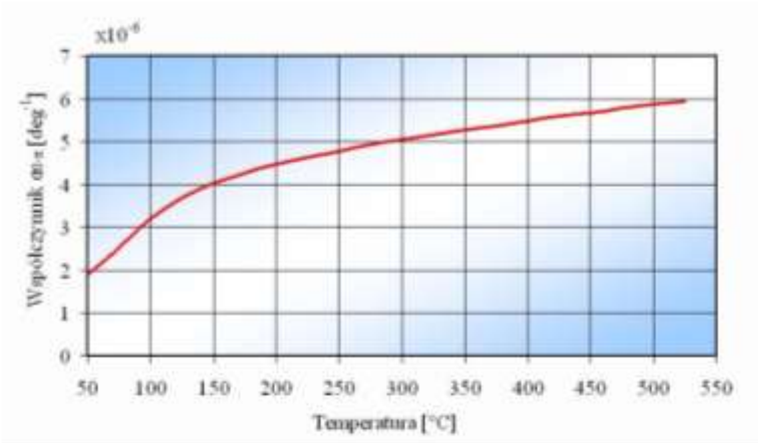


Impact strength of unreinforced 44200 alloy (0%) and composite materials reinforced with 10, 15 i 20% of fibres at 20-300°C

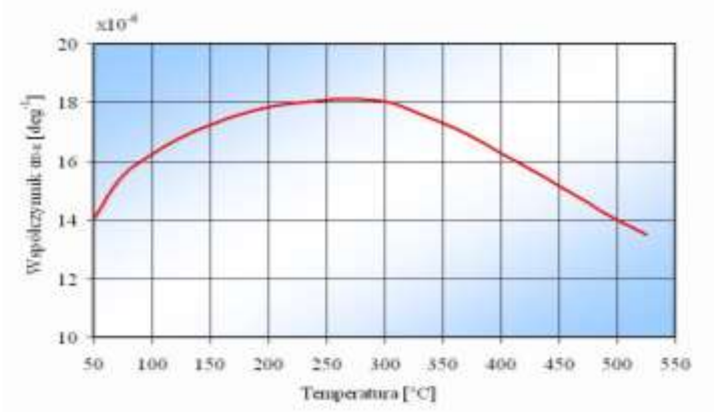


Dilatometric investigations

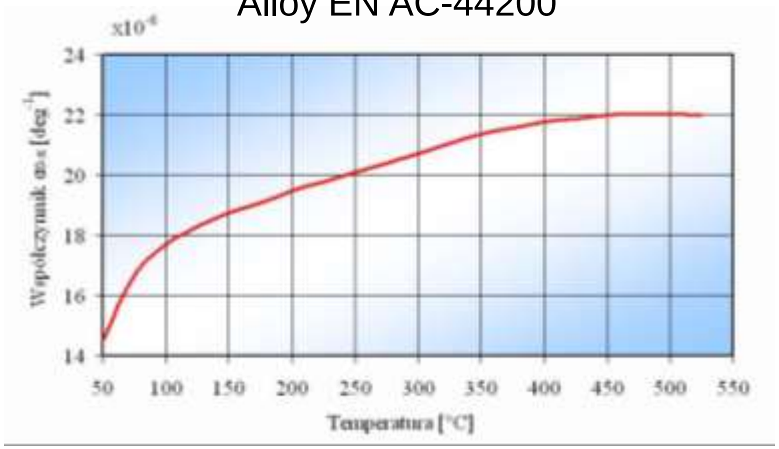
Preform from Saffil fibres



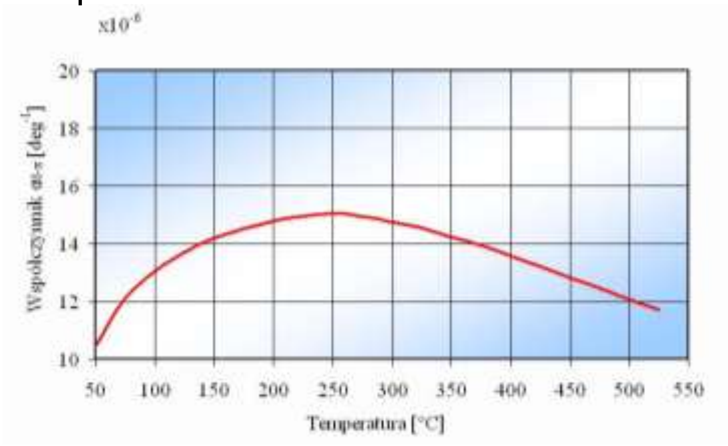
Composite material 44200-10 vol. % SAFFIL



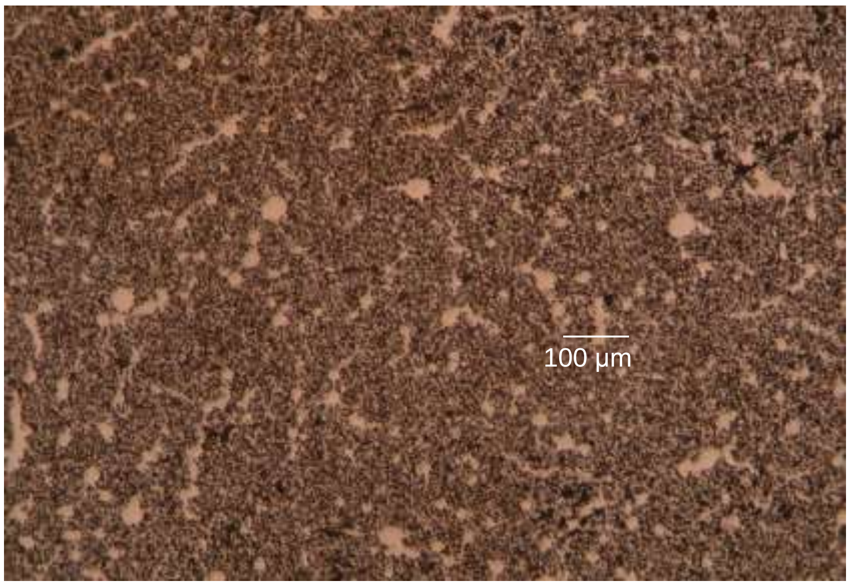
Alloy EN AC-44200

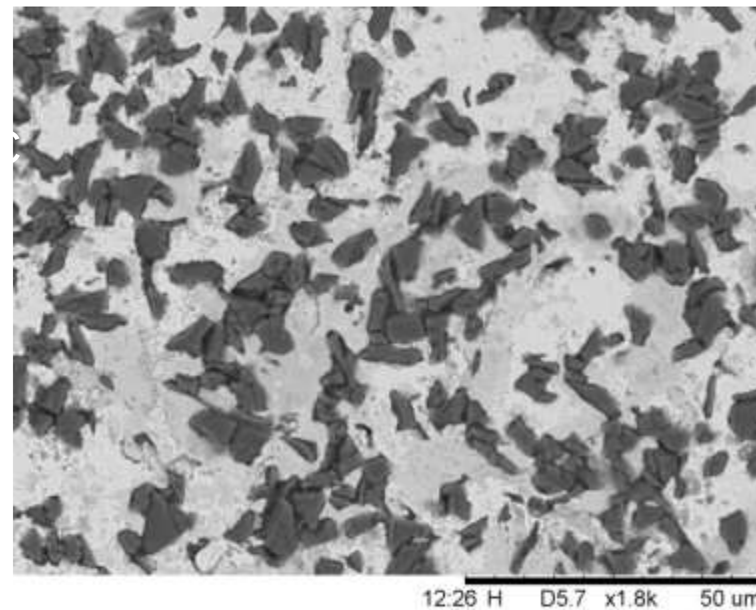


Composite material 44200-20 vol. % SAFFIL



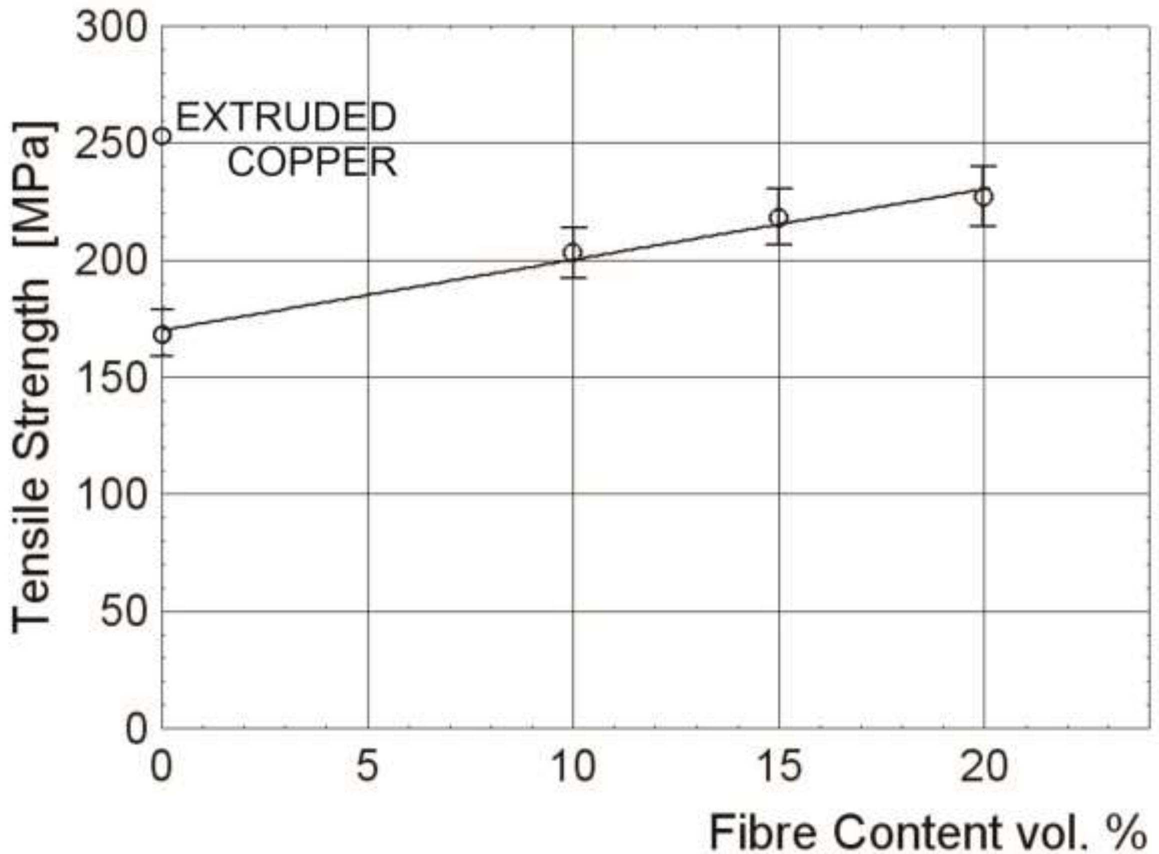
Microstructure of copper based composite materials with ceramic particles





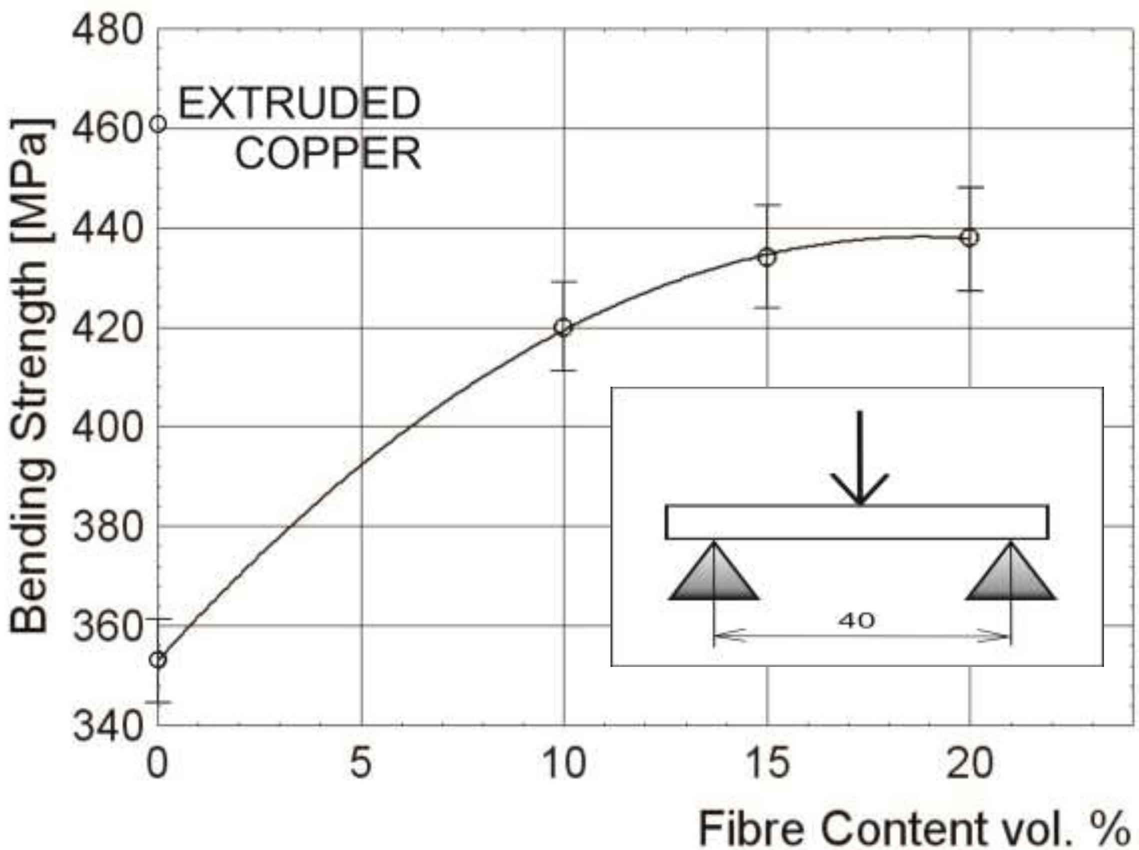
Mictrostructure of copper based composite materials with 30 vol. % Al_2O_3

Cu-based composite materials -Tensile strength



Tensile strength
of
Cu-SAFFIL 10,15, 20 vol.%

Bending strength



Bending strength
of
Cu-SAFFIL 10,15, 20 vol.%

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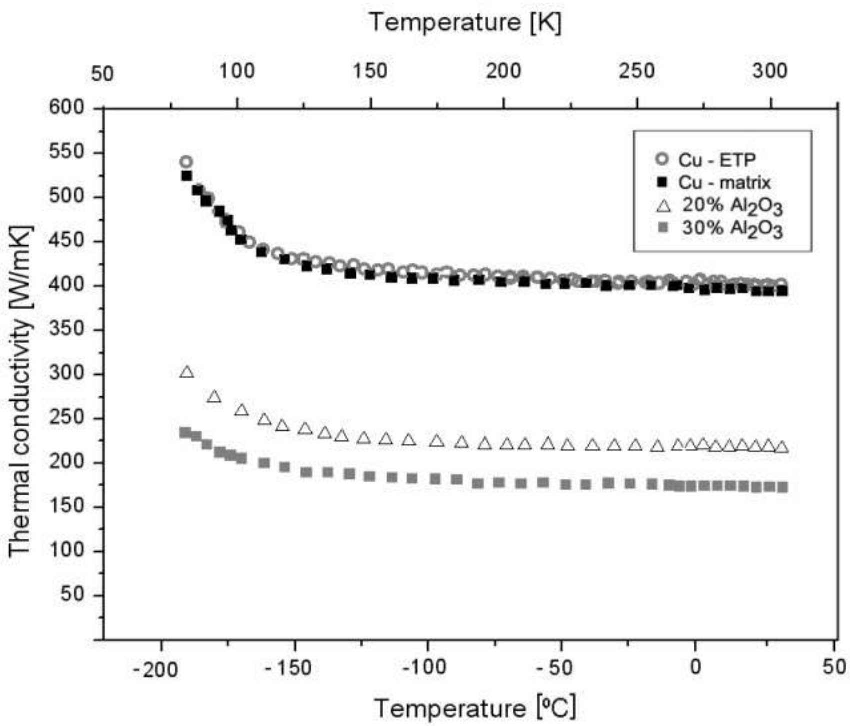
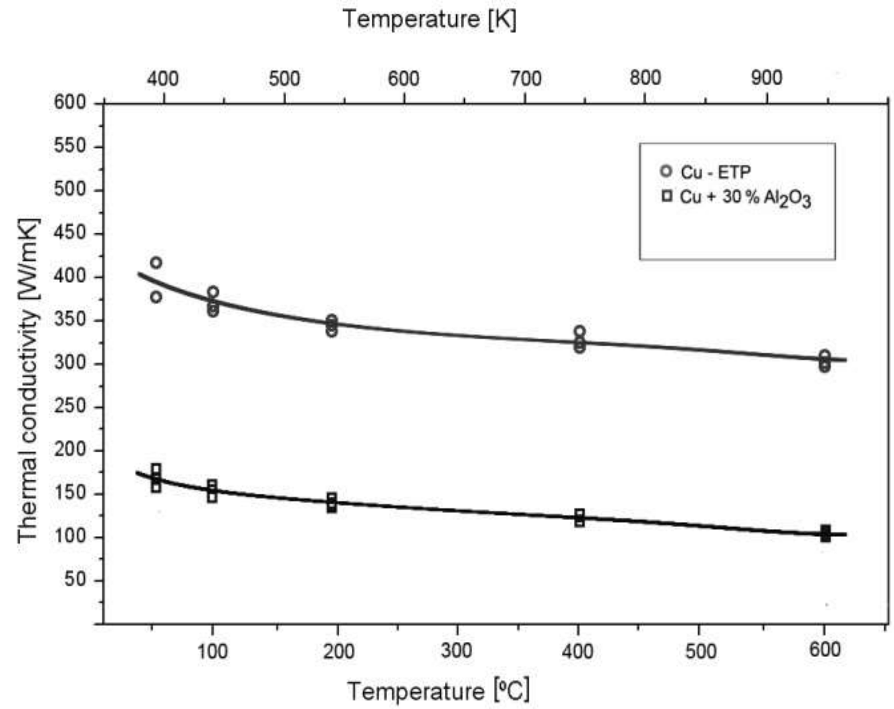
Thermal conductivity



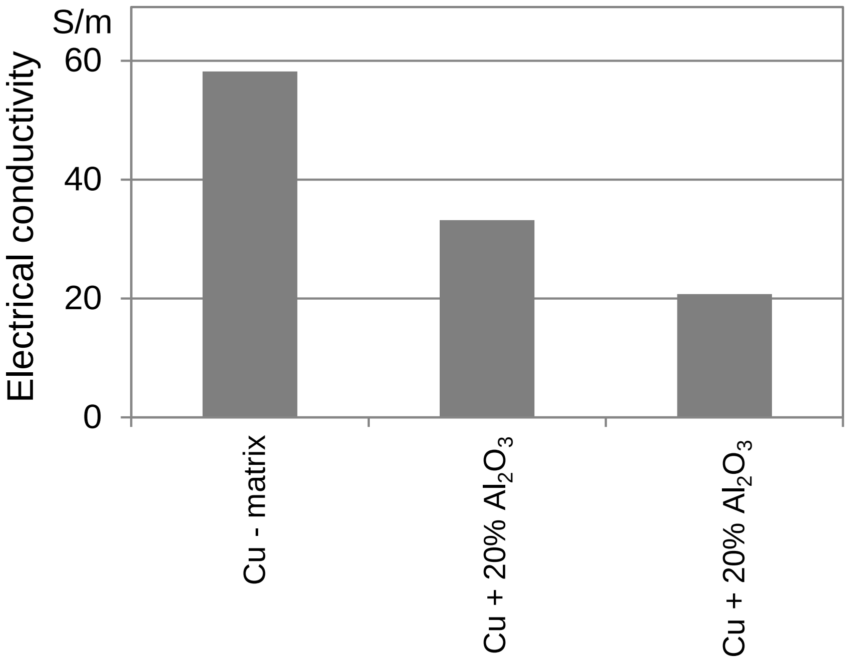
The temperature range -200 to 25°C



The temperature range 50 to 600 °C,

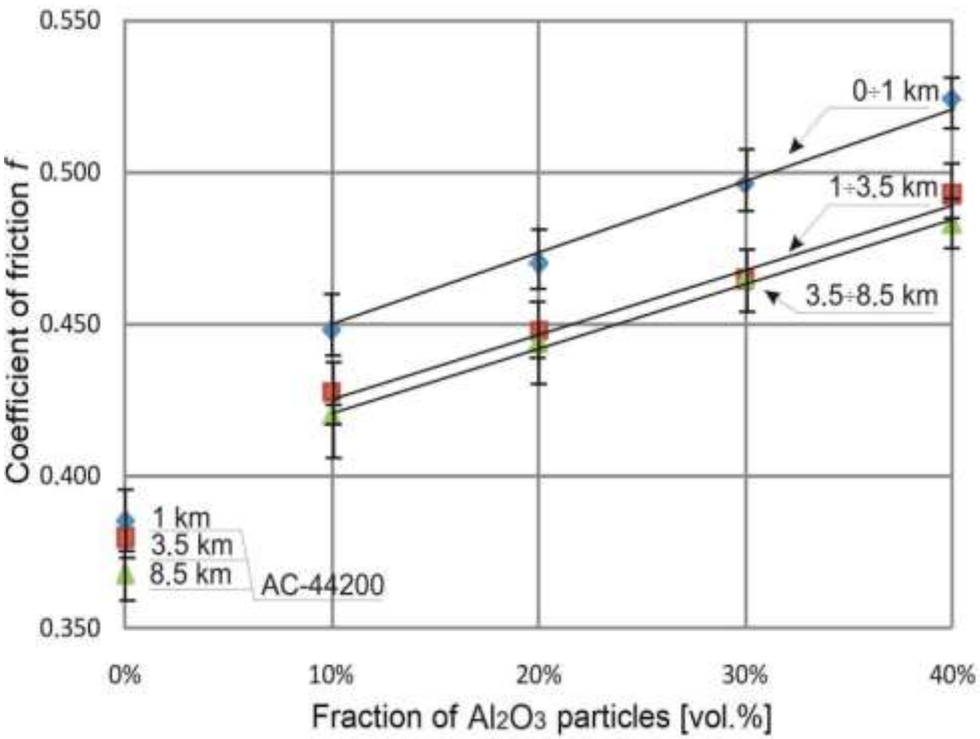
Electrical conductivity

Materials	σ [S/m]	$\rho[\Omega\cdot mm^2/m]$	[% IACS]
Cu - ETP	58,35	0,01714	100,6
Cu - matrix	58,20	0,01718	100,3
Cu + 20% Al_2O_3	33,20	0,03012	57,2
Cu + 30% Al_2O_3	20,70	0,04831	35,7



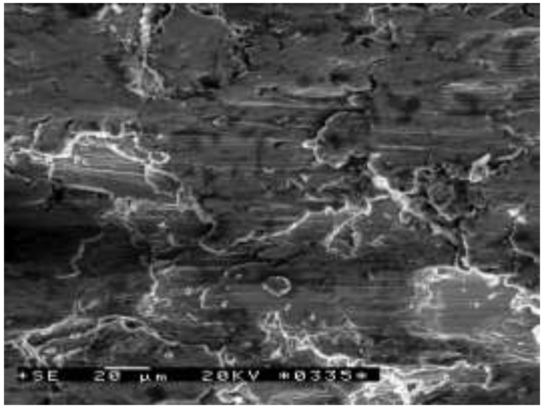
Wear test

Pin-on-disc tester

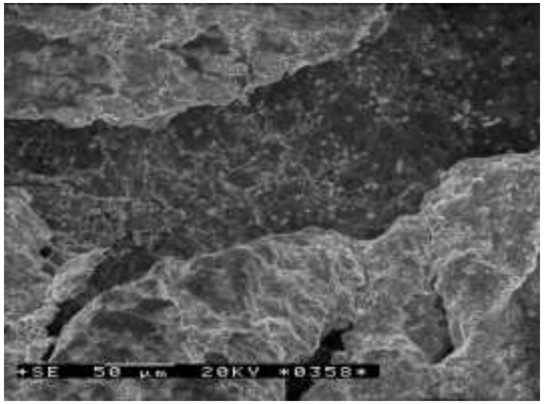


Wear test

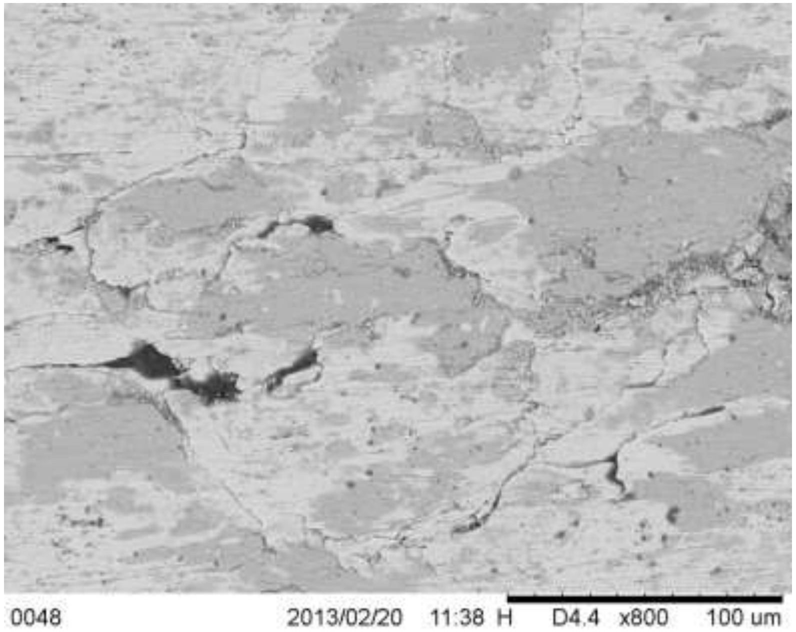
Cu



Cu + 20 vol. % Al2O3



Cu + 20 vol. % Al2O3



Applications of composite materials

1. Composite brake Drums, Traverse City, Michigan, USA

2. Brake discs, REL, Calumet, Michigan, USA

3. Connecting rods, MX Composites, Linköping, Sweden

Applications of composite materials in the military vehicles

Technical and military specifications of tank of Type 10 manufactured by Mitsubishi Heavy Industries, Japan

Mass: 43.25 tonnes, 48.0 tonnes fully equipped, Length/width/height: 9.485 m/3.24m/2.30m, crew 3
Armor: non-crystal steel (nor Triple Hardness Steel), modular ceramic composite armor, light weight upper armor

Hemp as a raw material for industrial applications

America

Housing, windows, balustrades, terrace

External elements

Europe

Architecture and furniture

Internal elements

Asia

Architecture and furniture

External and internal elements

EFS

ZPORR

Problem statement

Natural fibres display good mechanical **fibre properties**, BUT:

As reinforcement in polymer composites, these properties are **not transferred** and the intended composite **strength** is not achieved

Natural Fibres

Advantages

Low density
No waste problems
CO_2 neutral life cycle
Low costs
Recyclable

Disadvantages

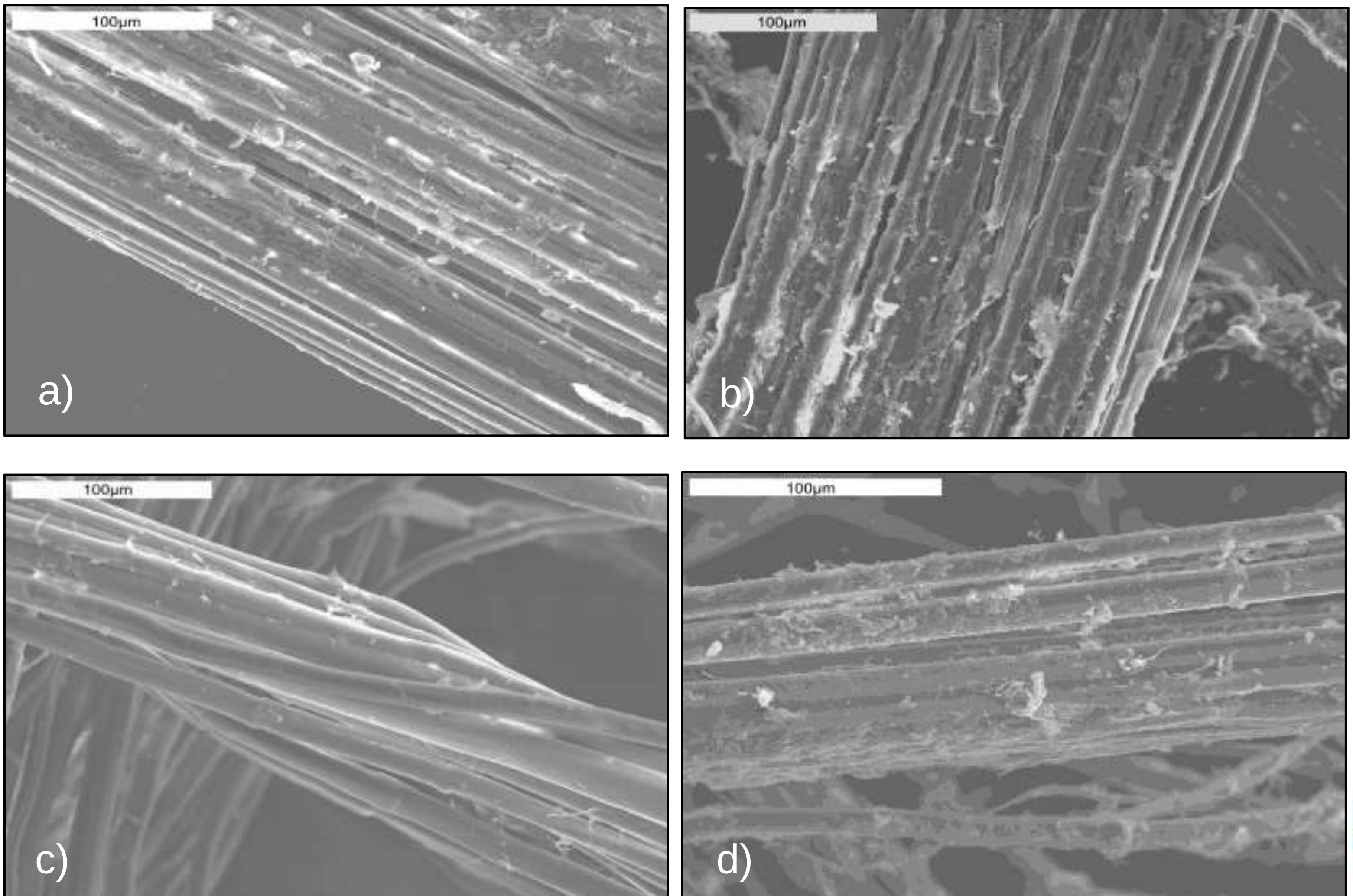
Hydrophilic
Variable properties

EFS

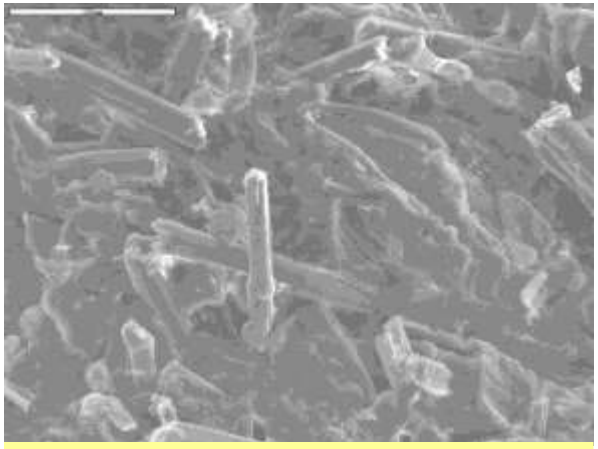
ZPORR
Zintegrowany Program Operacyjny Rozwoju Regionalnego

SEM of hemp fibres

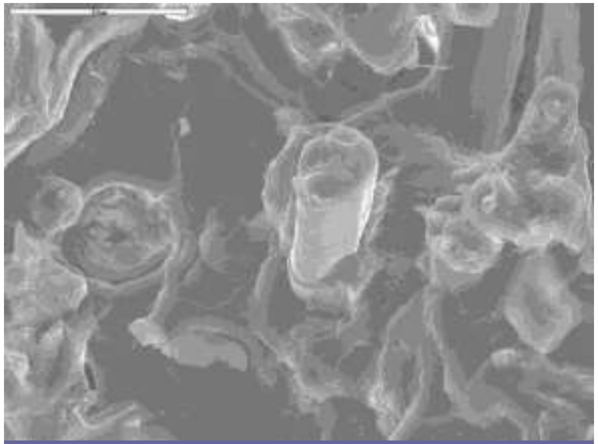
a) raw, non-modified hemp fibres (x 400),
b) fibres modified with the maleic anhydride (x370),
c) fibres mercerised with the 8% NaOH (x400)
d) fibres acetylated (x500).



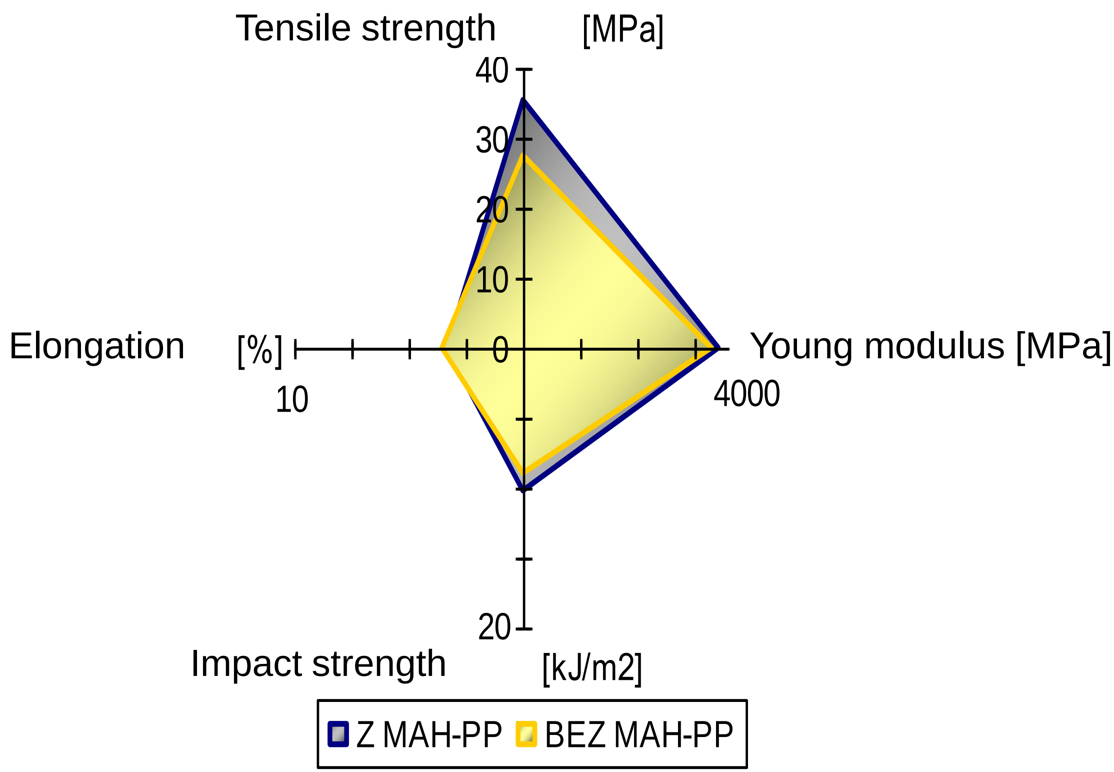
SEM of polypropylene composites fracture



Without compatibilisator MAHPP



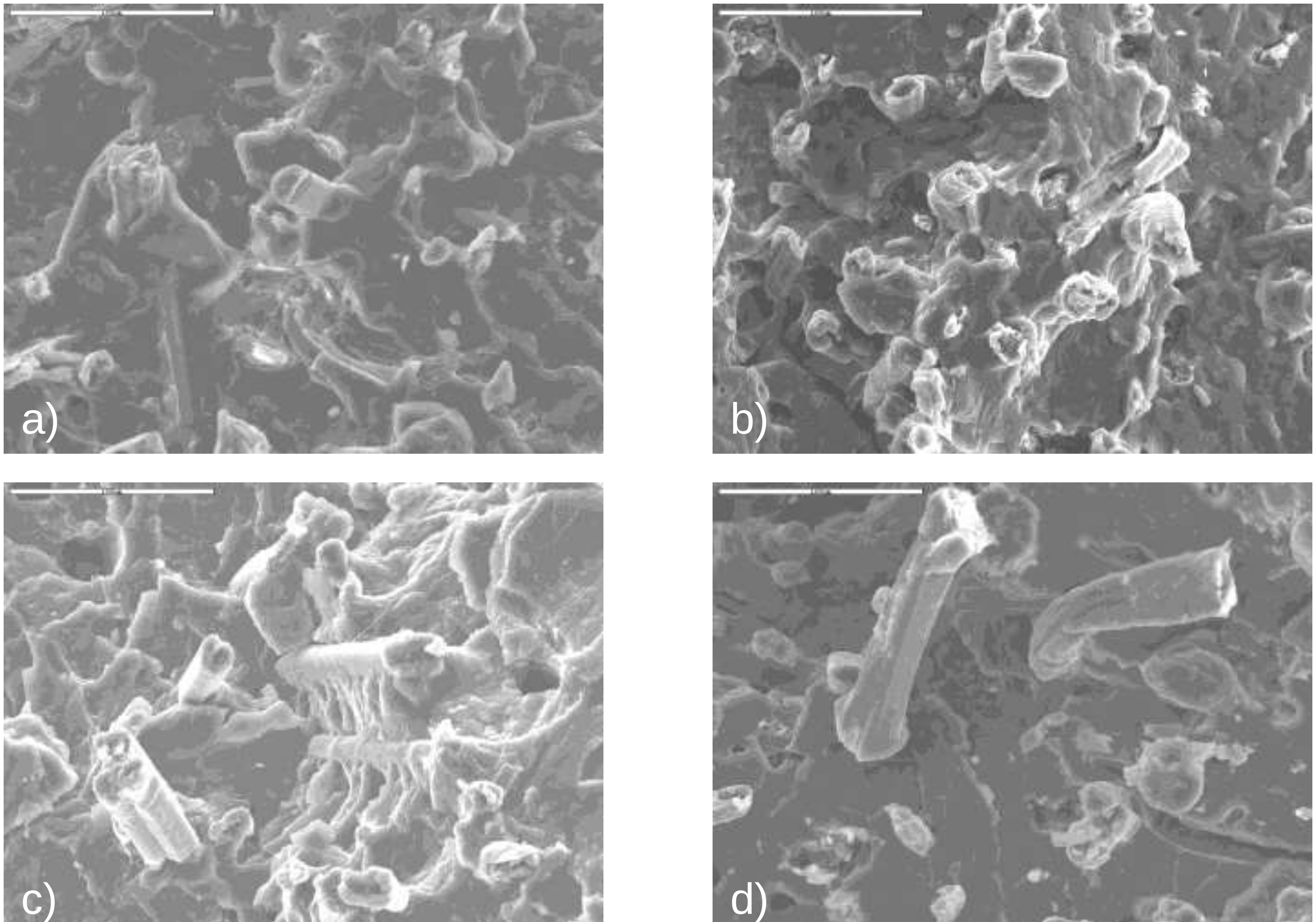
With compatibilisator MAHPP



Polypropylene composite with 20% non-modified hemp fibres

SEM of polypropylene composites freacture, enlargement x 450. Composites consist of polypropylene, MAHPP compatibilisator and hemp fibres

a) raw, non-modified hemp fibres, **b)** fibres mercerised with the 8% NaOH **c)** fibres modified with the maleic anhydride, **d)** fibres acetylated

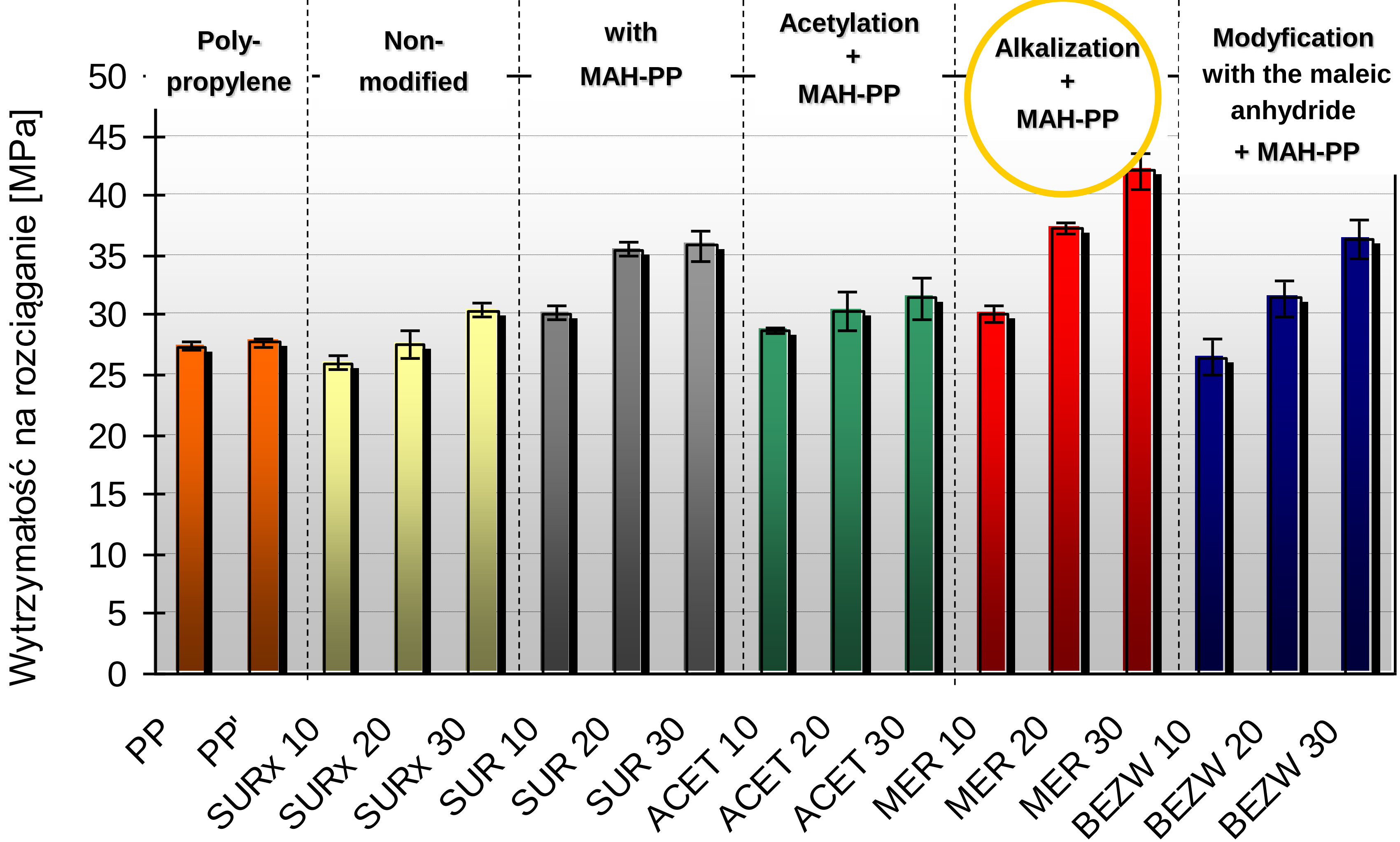


Politechnika Wrocławska

Plastics Processing Laboratory

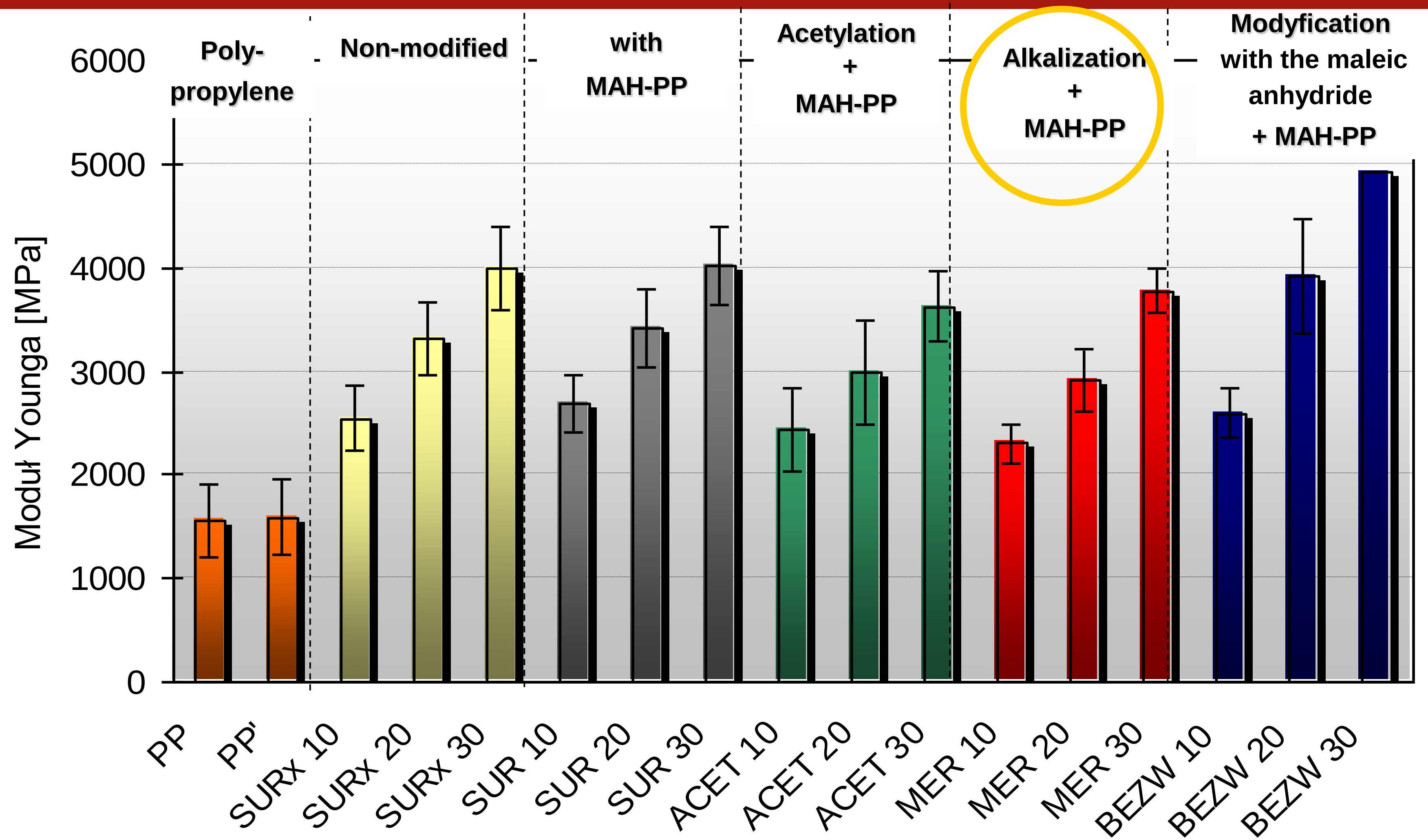
TENSILE STRENGTH

PN-EN ISO 527

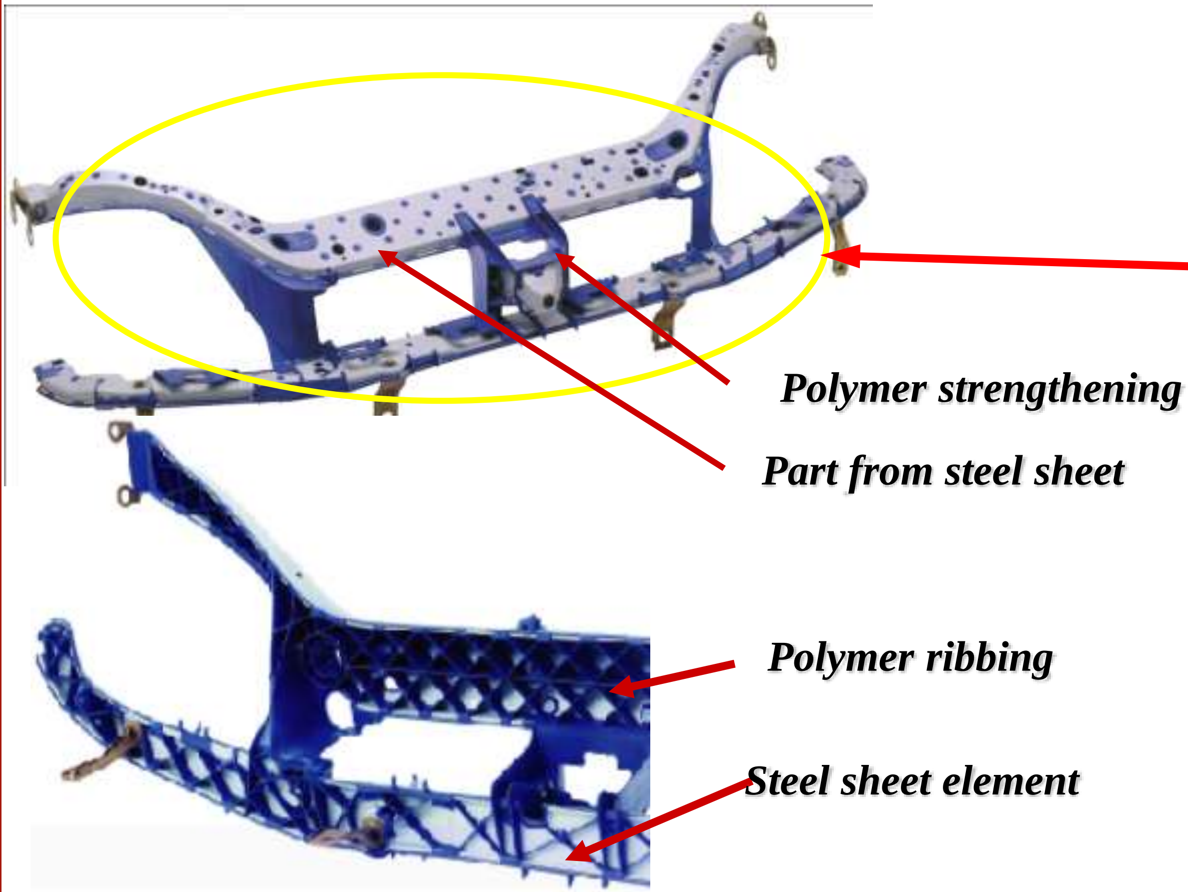


PN-EN ISO 527

YOUNG MODULUS



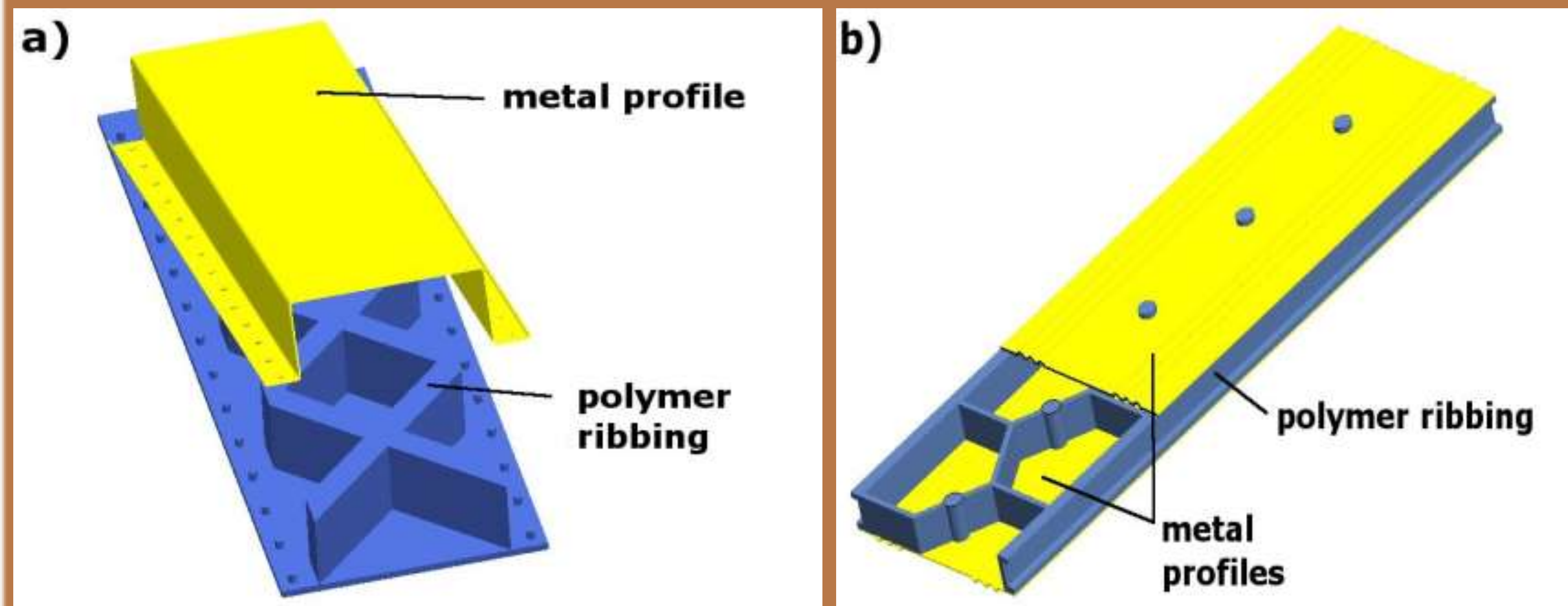
Application of hybrid elements of polymer-metal type in the car industry



Hybrid elements find applications as the front part of almost all passenger cars

Front of FORD Focus with visible polymer ribbing

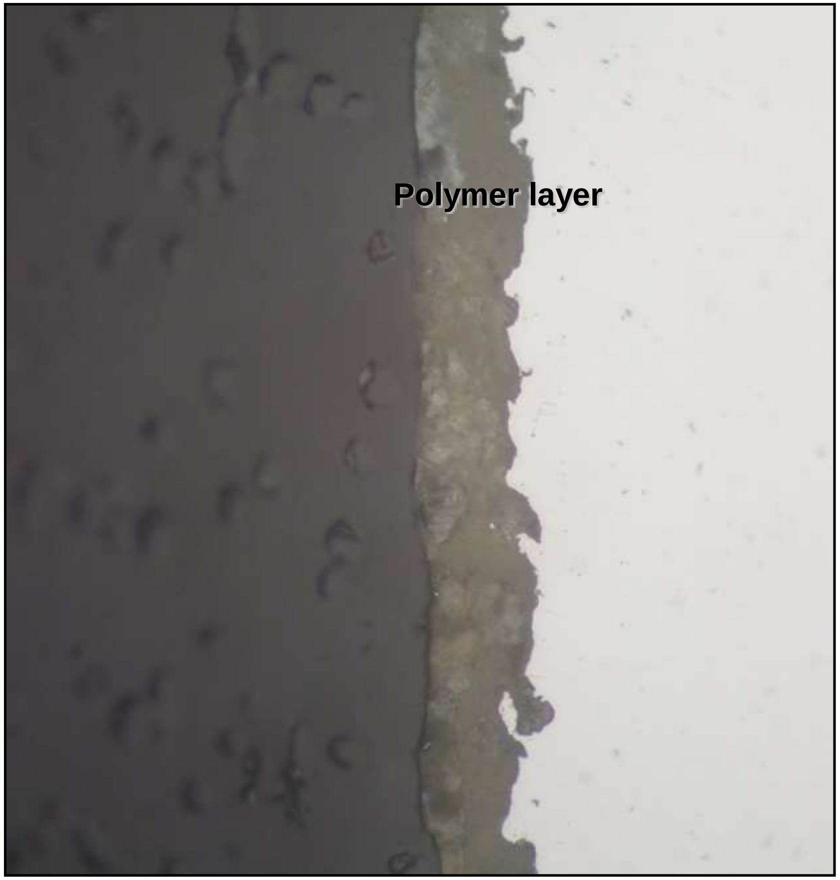
Metal-polymer hybrid elements



Bonding between metal and polymer

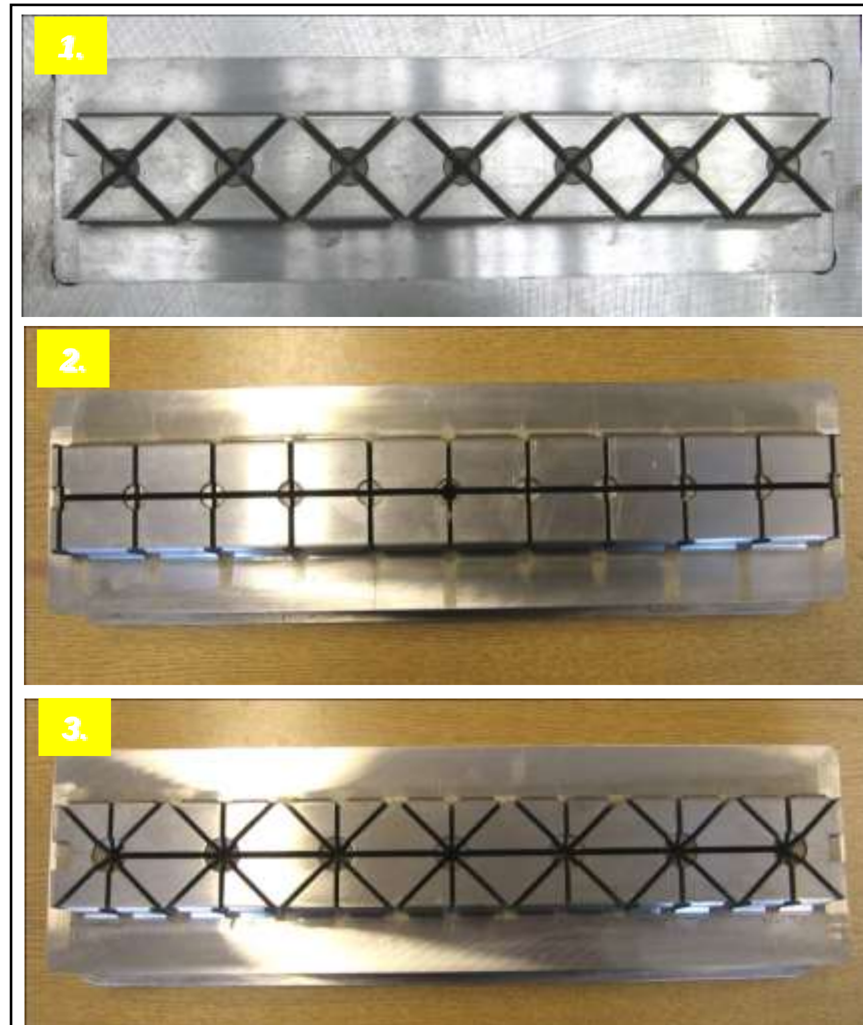
Polyamide with 30% of glass fibres

DC04 Steel sheet



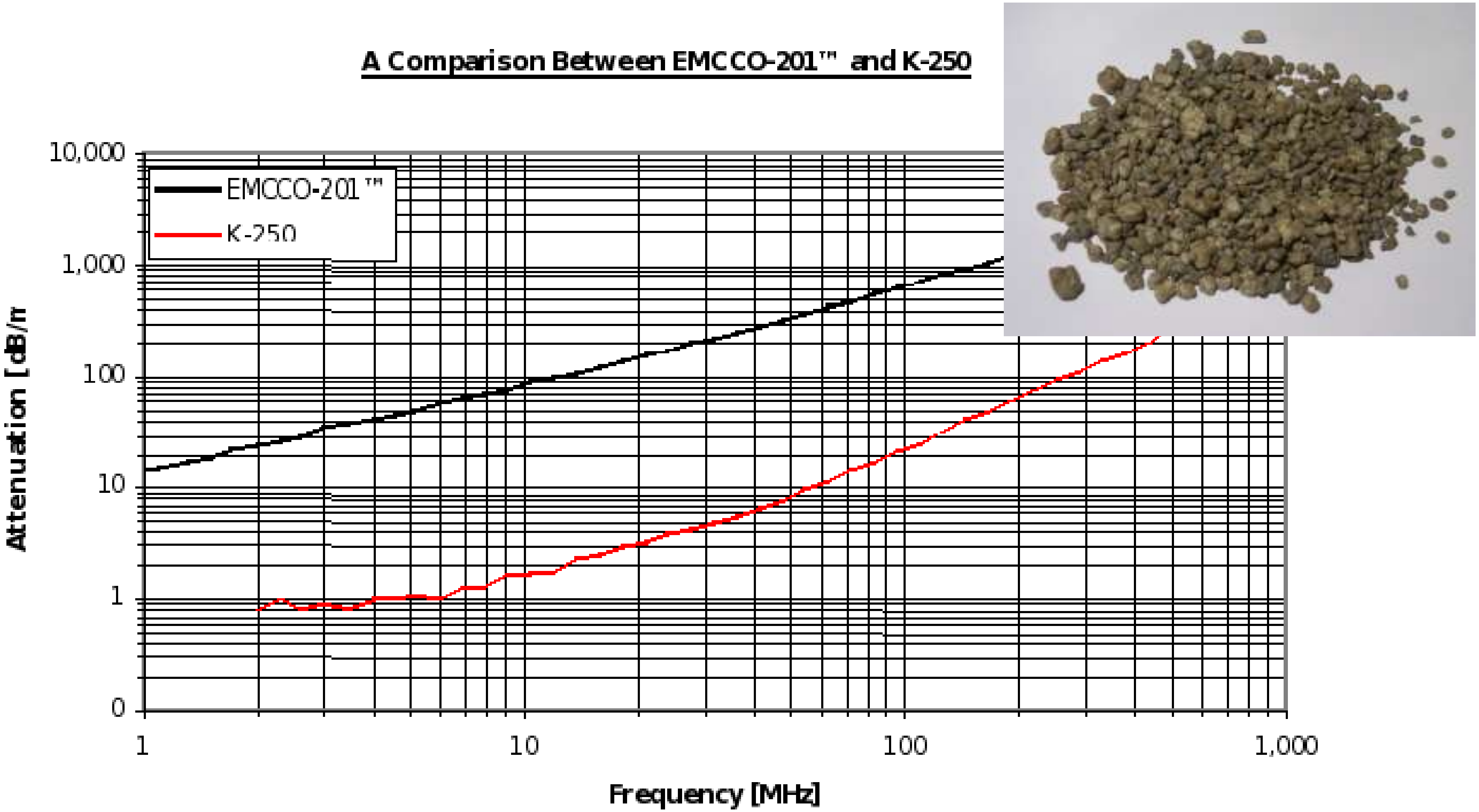
Tools for the manufacturing of the basic metal-polymer elements

Injection mold for the investigations of bonding between metal and polymer



EMCCO – attenuation in comparison with K-250 material

Materials disigned at University of Wrocław, Department of Chemistry



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MA.TRANS

Wrocław University of Technology

THANK YOU FOR YOUR ATTENTION

Chair, of Foundry, Polymers and Automation

KMM.VIN