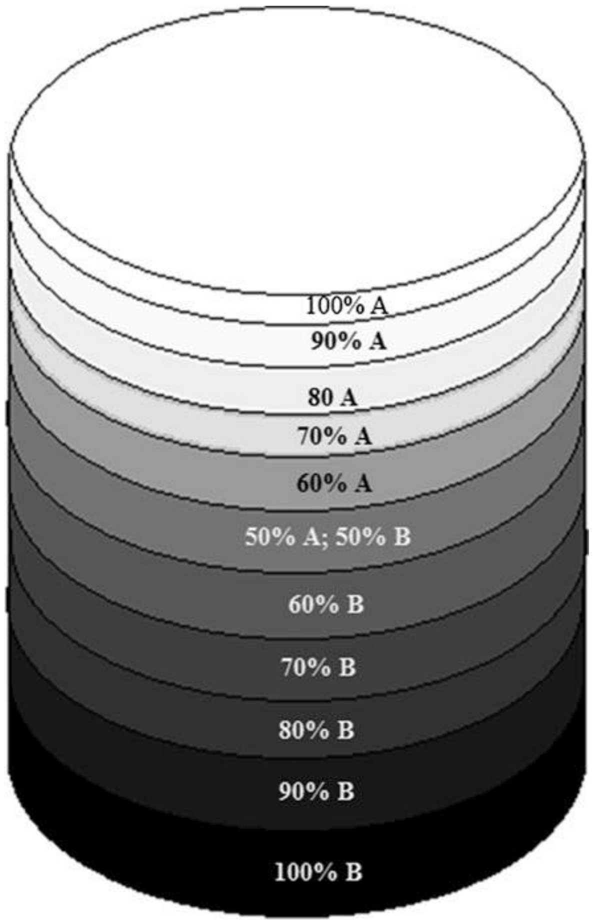
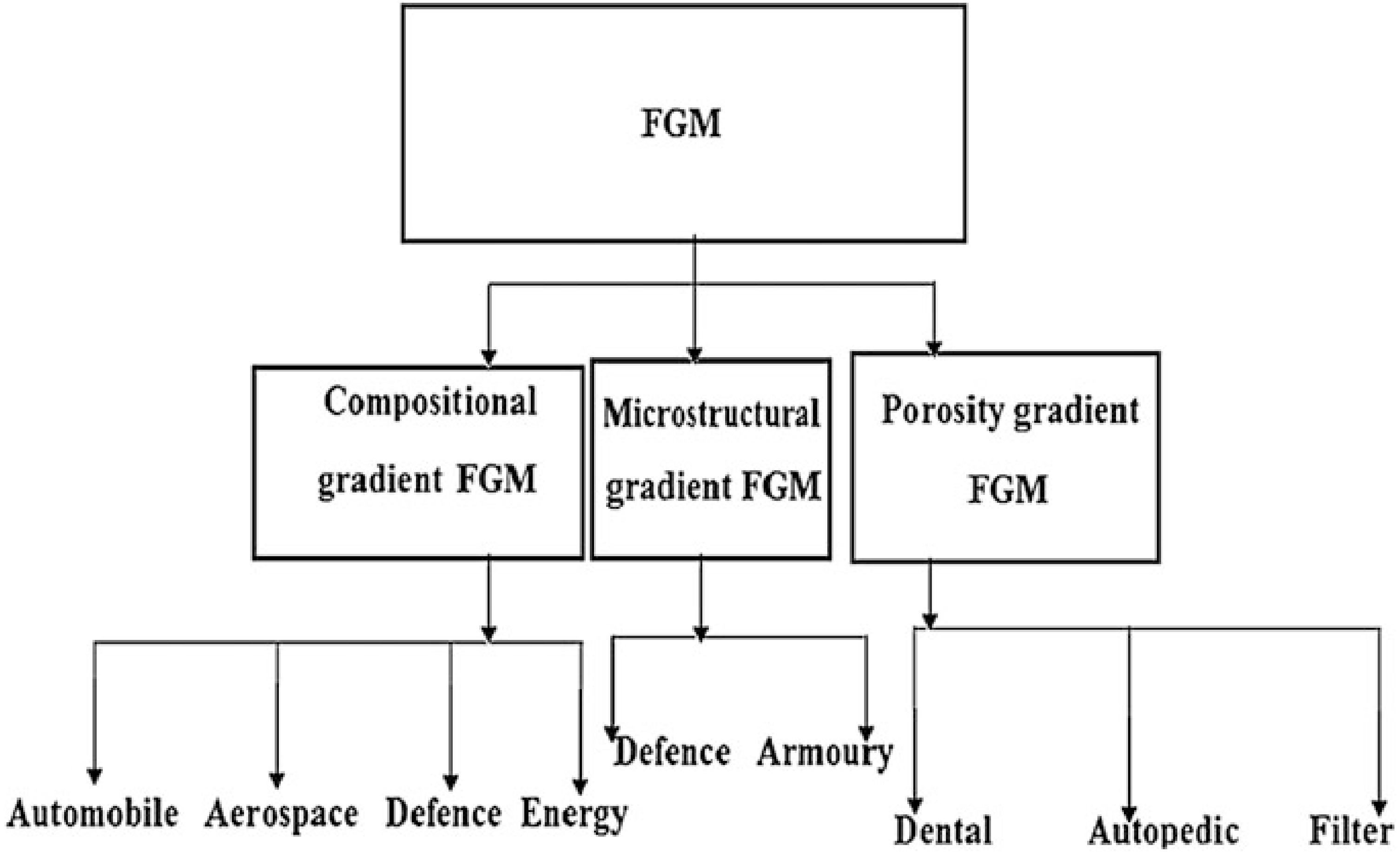
3D Printing of Functionally Graded Materials (FGM) for Biomedical Applications

Hassanen Jaber and Tunde Kovacs

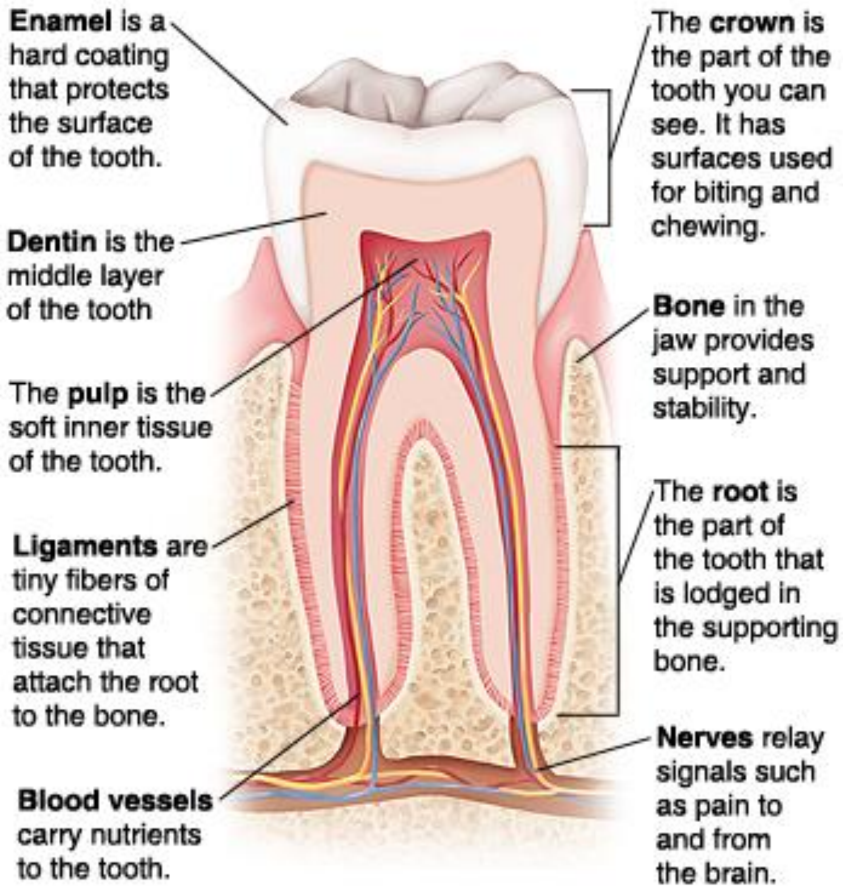
Introduction to Functionally Graded Materials (FGM)

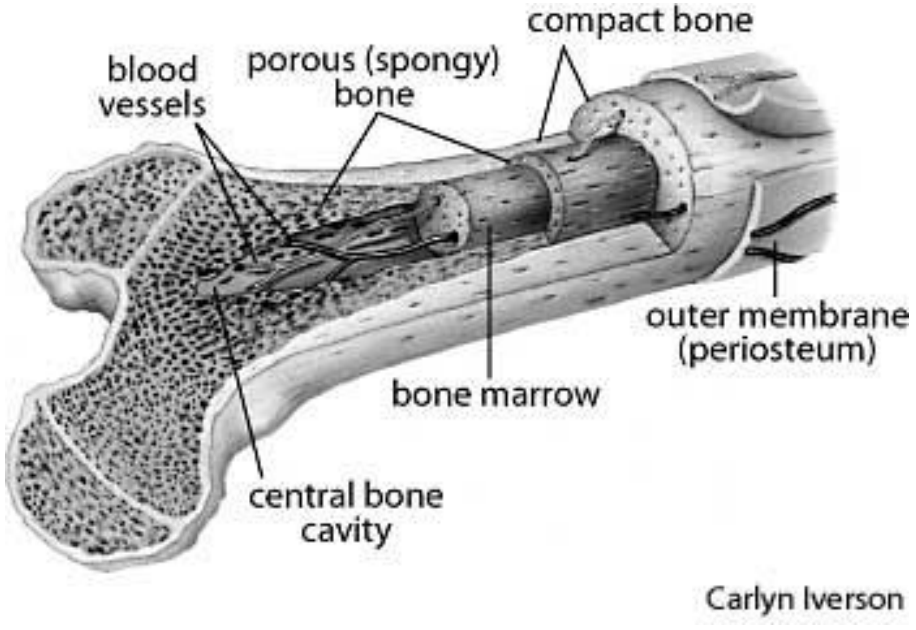


Areas of applications for the three types of functionally graded materials

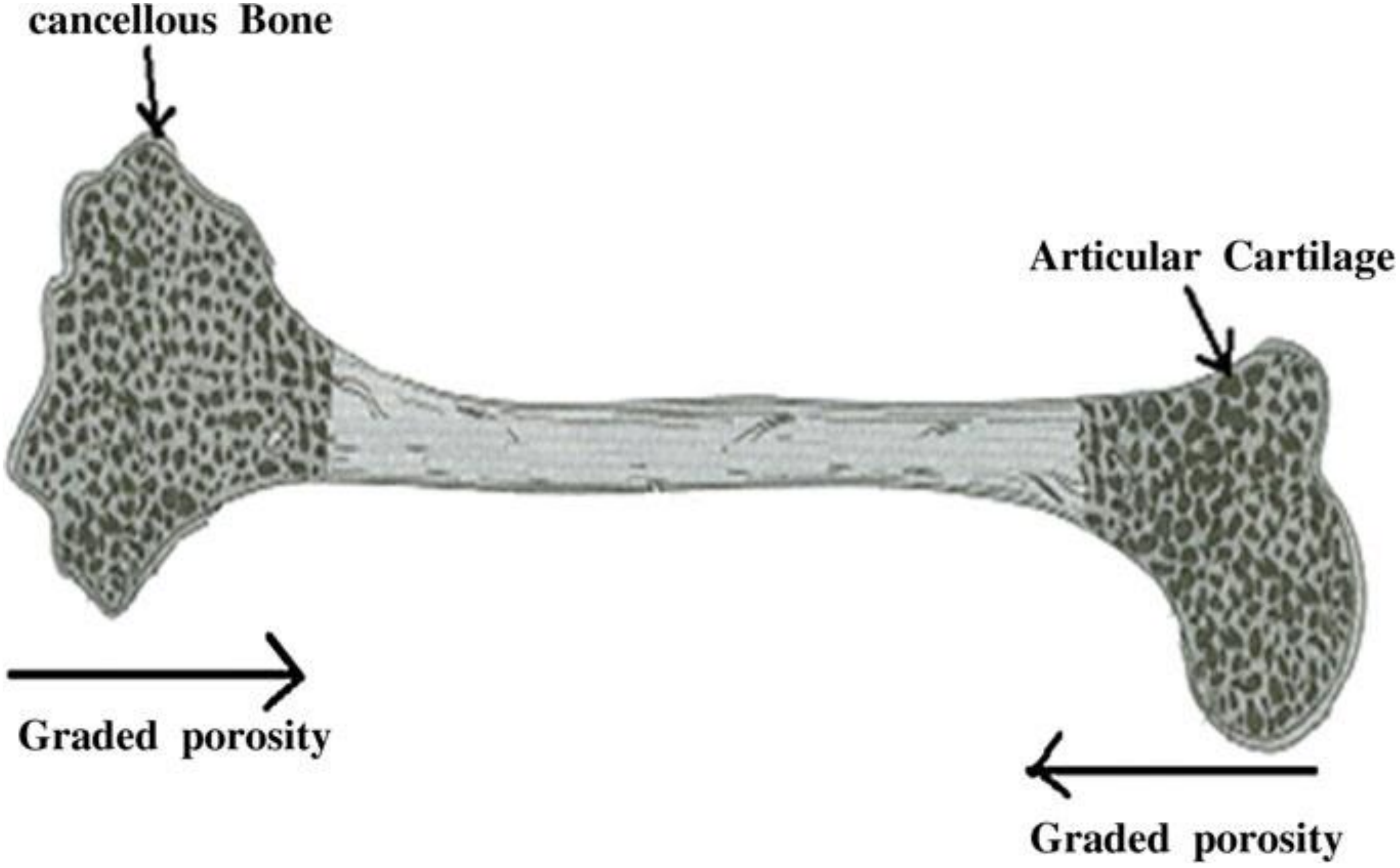


Functionally Graded Materials in Nature



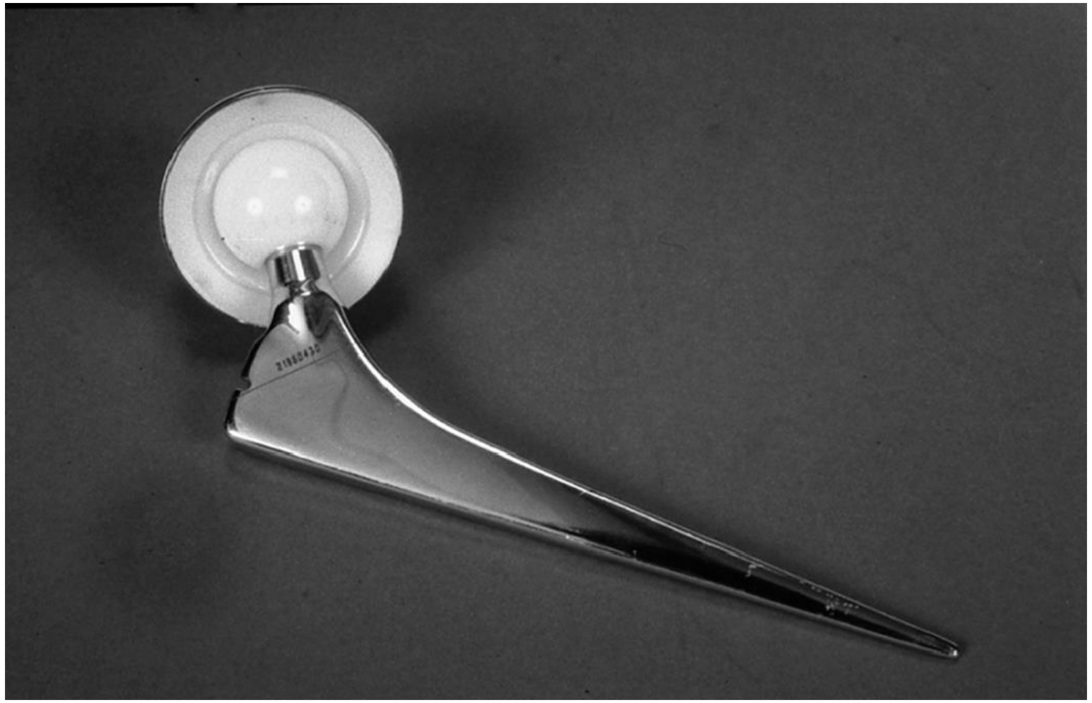


Functionally Graded Materials in Nature



Applications

Artificial hip made of titanium

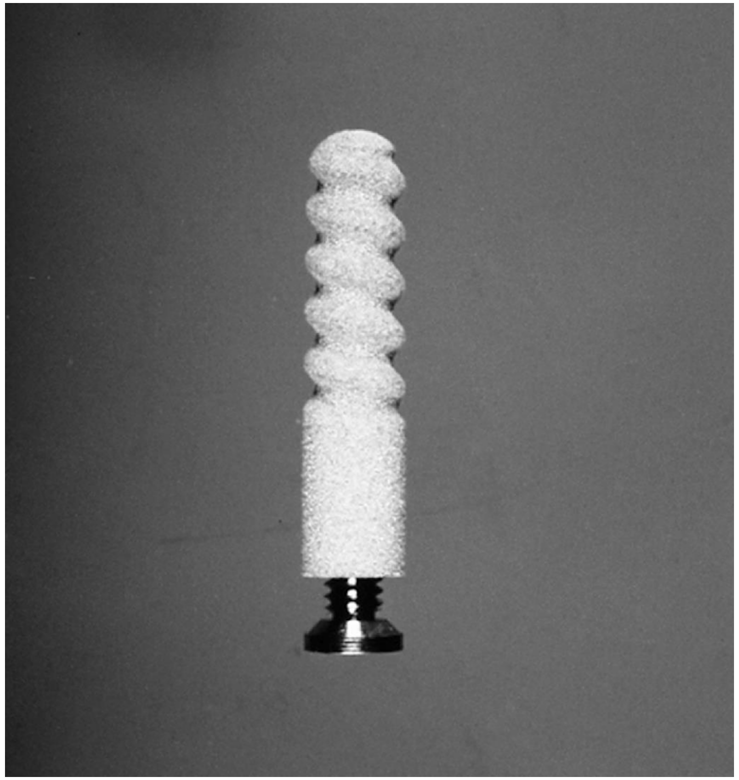


A total knee replacement joint

Applications

Shoulder joint prosthesis

Hydroxyapatite-coated titanium root implant



Composition of orthopedic implant alloys

Table 12.1 *Composition of orthopedic implant alloys (wt%); from Bonfield, 1997.*

Element	*Cobalt-based alloys*			*Stainless steel*		*Titanium alloys*	
	ASTM F75 cast	*ASTM F90 wrought*	*ASTM F563 isostatically pressed*	*ASTM F138/A*	*ASTM F138/9B*	*Commercial purity titanium*	*Ti–6Al–4V*
Co	Balance	Balance	Balance	–	–	–	–
Cr	27–30	12–19	18–22	17–20	17–20	–	–
Fe	0.75 max	3.0 max	4–6	Balance	Balance	0.3–0.5	0.25 max
Mo	5–7	–	3–4	2–4	2–4	–	–
Ni	2.5 max	9–11	15–25	10–14	10–14	–	–
Ti	–	–	0.5–3.5	–	–	Balance	Balance
Al	–	–	–	–	–	–	5.5–6.5
V	–	–	–	–	–	–	3.5–4.5
C	0.35 max	0.05–0.15	0.05 max	0.03 max	0.08 max	0.01 max	0.08 max
Mn	1.0 max	2.0 max	1.0 max	2.0 max	2.0 max	–	–
P	–	–	–	0.03 max	0.025 max	–	–
S	–	–	0.01 max	0.03 max	0.01 max	–	–
Si	1.0 max	1.0 max	0.5 max	0.75 max	0.75 max	–	–
O	–	–	–	–	–	0.18–0.40	0.13 max
H	–	–	–	–	–	0.01–0.015	0.012 max
N	–	–	–	–	–	0.03–0.05	0.05 max

The most important issues for metallic implant materials

- Osteolysis and aseptic loosening
- Lack of bioactivity
- Metallic ion releasing
- Mismatch of the Young's modulus between bone (10–30 GPa) and metallic implant materials (110 GPa for Ti and 248 GPa for CoCrMo alloy)

The mechanical properties of some natural and biomaterials

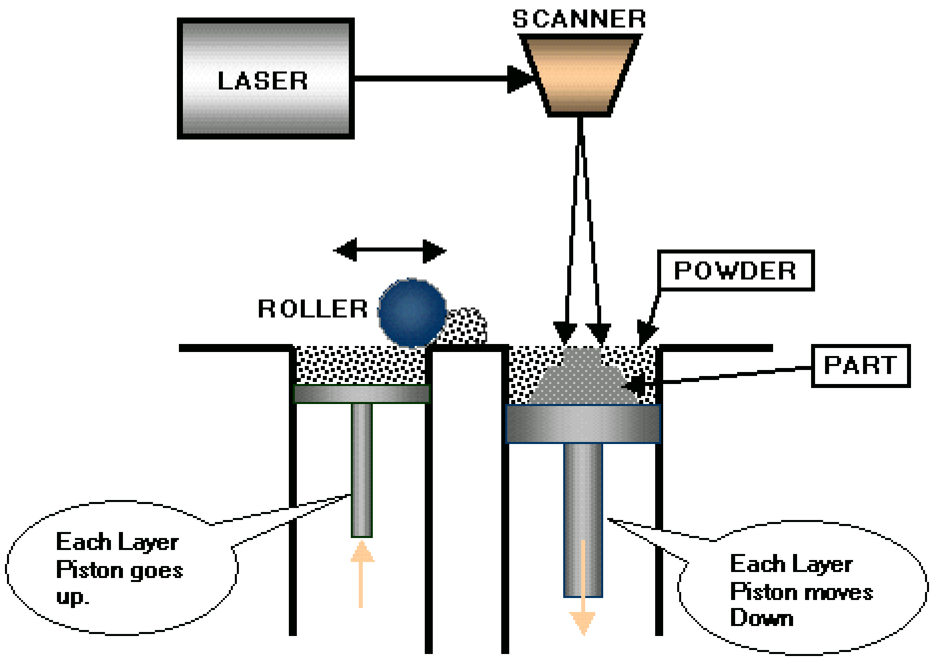
Table 12.2 *The mechanical properties of some natural and biomaterials.*

Material	*Elastic modulus* ($GN\ m^{-2}$)	*Tensile strength* ($MN\ m^{-2}$)	*Elongation (%)*	*Fracture toughness* ($MN\ m^{-3/2}$)	*Fatigue strength* ($MN\ m^{-2}$)
Austenitic stainless steel	200	200–1100	40	100	200–250
Cobalt–Chromium	230	450–1000	10–30	100	600
Ti–6Al–4V	105–110	750–1050	12	80	350–650
Alumina	365	–	<1	–	400
Hydroxyapatite	85	40–100	–	–	
Glass fiber	70	2000	2	1–4	
PMMA	2.8	55	8	–	20–30
Bone cement	2.3–3	1.5	1–2	400	
Polyethylene	1	20–30		1–4	16
Nylon 66	4.4	700	25		
Silicone rubber	6×10^{-3}	1.4			
Polycarbonate	2	60			
Bone (cortical)	7–25	50–150	–	2–12	
Bone (cancellous)	0.1–1.0	50–150		2–12	
Tooth enamel	13	240	–	–	
Tooth dentine	–	135		–	
Collagen, tendon, wet	2	100	10	–	

Physiochemical, mechanical and biological properties of HAp

Properties	**Experimental data**
Chemical composition	$Ca_{10}(PO_4)_6(OH)_2$
Ca/P molar ratio	1.67
Crystal system	Hexagonal
Young's modulus (GPa)	80 - 110
Elastic modulus (GPa)	114
Compressive strength (MPa)	400 – 900
Bending strength (MPa)	115 – 200
Density (g/cm^3)	3.16
Relative density (%)	95 – 99.5
Fracture toughness ($MPa.\ Mm^{1/2}$)	0.7 – 1.2
Hardness (HV)	600
Decomposition Temp. (ºC)	>1000
Melting point (ºC)	1614
Thermal conductivity (W/cm. K)	0.013
Biocompatibility	High
Bioactivity	High
Biodegradation	Low
Cellular-compatibility	High
Osteoconductivity	High

Laser Sintering/melting System



Tasks

Selection and characterization of the base materials

Production of metal-ceramic homogeneous composites

Metallurgical, Mechanical and wear characterization of metal-ceramic homogeneous composites

Processing of functionally graded components

Characterization of functionally graded components

Production of the reduced scale final component

Papers and thesis writing.

My Publications

1-Preparation and Synthesis of Hydroxyapatite Bio-Ceramic From Hungarian Bio-Waste by Thermal Heat Treatment

FEMS Junior EUROMAT 2018

The Main Event for Young Materials Scientists

junior-euromat2018.fems.eu

July 8-12, 2018
Budapest, Hungary

FEMS 30

MAGYAR ANYAGTUDOMÁNYI EGYESÜLET

16 January, 2018

Dear Hassanen Jaber,

On behalf of the Organizing Committee, we are pleased to inform you that your abstract (Preparation and Synthesis of Hydroxyapatite Bio-Ceramic From Hungarian Bio-Waste by Thermal Heat Treatment) has been **accepted for oral presentation** at the FEMS Junior EUROMAT 2018 conference to be held between 08-12 July, 2018 in Budapest, Hungary.

2-Similar and Dissimilar Resistance Spot Welds of DP600 and X8Cr17 steels sheets: Welding Current and Fracture Toughness

International Engineering Symposium at Bánki
27 November 2017
Efficiency, Safety and Security

ÓBUDA UNIVERSITY
Donát Bánki Faculty of Mechanical and Safety Engineering

[BK] Editor Decision

19 م 2:58 2018

من: Ágota Drégelyi-Kiss

To: Hassanen jaber

Hassanen jaber:

We have reached a decision regarding your submission to Bánki Közlemények (Bánki Reports), "Similar and Dissimilar Resistance Spot Welds of DP600 and X8Cr17 steels sheets: Welding Current and Fracture Toughness".

Our decision is to: Accept Submission

Ágota Drégelyi-Kiss
dregelyi.agota@bgk.uni-obuda.hu

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Bánki Közlemények (Bánki Reports)

3-The Effect of Nano-Quenching Media on the Tensile Properties and Microstructure of Medium Carbon Steel

XI. ORSZÁGOS ANYAGTUDOMÁNYI KONFERENCIA
2017. OKTÓBER 15-17. BALATONKENESE - TELEKOM HOTEL

Your article is uploaded and now "at Editor".
They will let you know the review soon.

----- Továbbított üzenet -----
Feladó: Hohol Róbert <hoholr@diamond-congress.hu>
Címzett: juhos sandorne <juhos.sandorne@bgk.uni-obuda.hu>
Elküldött üzenetek: Tue, 23 Jan 2018 10:00:47 +0100 (CET)
Tárgy: OATK 2017 - Értesítés cikk státuszáról

Tisztelt Jaber Hassanen!

Örömmel értesítem, hogy "The Effect of Nano-Quenching Media on the Tensile Properties and Microstructure of Medium Carbon Steel" című cikke adatbázisunkba sikeresen fel lett töltve, státusza: *szerkesztőnél*.

Az online beadás lezárult, további módosításokra egyelőre nincs lehetőség. A bírálatok eredményéről a bírálati folyamatot követően fogjuk tájékoztatni, ebben a levélben küldjük majd el a bizottság javítási kéréseit is.

A szervezőbizottság nevében üdvözlettel:

Hohol Róbert
szervező

4- Dissimilar spot welding of dual phase steel / low carbon Steel: phase transformations and mechanical properties

2nd International Conference on Vehicle and Automotive Engineering, University of Miskolc, Hungary

[VAE2018] Editorial Decision on Abstract

نوفمبر، 2017 12:10 م 15

من: admin

To: Mr Hassanen Jaber

Cc: Hassanen Jaber

Mr Hassanen Jaber:

Congratulations, your abstract Dissimilar spot welding of dual phase steel / low carbon Steel: phase transformations and mechanical properties has been accepted for presentation at 2nd International Conference on Vehicle and Automotive Engineering which is being held 2018-05-23 at Miskolc. You may now submit your paper for further review.

Thank you and looking forward to your participation in this event.
admin
altkota@uni-miskolc.hu

Outline of current and future work

1- Additive manufacturing of functionally graded structures for biomedical applications.

2- Dissimilar Laser, frication stir spot and resistance spot welding of second generation and Third generation of advanced high strength steels AHSSs: phase transformations and mechanical properties.

	2017	2018		2019		2020	
		1st Sem	2st Sem	1st Sem	2st Sem	1st Sem	2st Sem
1							
2							

For Your Attention