Surface engineering of a WE43 magnesium alloy for orthopaedic scaffold applications

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Problem Background:	The gold standard implants used for bone regeneration surgeries are autografts i.e. bone harvested from the patients themselves. Biodegradable metallic bone graft substitutes, also known as scaffolds, are an evolving area of research in orthopaedics. Magnesium alloys, particularly WE43, stand out among metals for having a stiffness value comparable to bone and presenting very low toxicity. However, their high corrosion rate and the release of hydrogen gas during degradation are their major drawbacks and restrict their orthopaedic load-bearing applications. Non-line of site surface engineering techniques on WE43 can improve the alloy's corrosion resistance *in vivo*.
Project Objective(s):	• To review the literature on the corrosion protection of Mg-alloys. • To familiarize with non-line of site surface engineering techniques suitable for magnesium alloys. • To characterize WE43 pre- and post-surface engineering. • To assess the corrosion resistance of the chosen surface engineering solution.
Project Resources:	• Indicate source of funds: Internal Research Grants. • Equipment: Potentiostat, optical microscope, Scanning Electron Microscope (SEM) and X-Ray diffractometer (XRD).
Industrial Partners involved:	• N/A
Expected Project Deliverables:	• A dissertation reporting on the degradation results of pre- and post-surface modified WE43 magnesium alloy. An analysis on the corrosion improvements of a WE53 magnesium alloy with an orthopaedic application target.
Student background / interest:	• Biomaterials, Corrosion Science and Surface Engineering
IP Issues	☐ The project is IP sensitive; please specify.
Ethical and Data Protection Procedure	Before the start of any research project at the University of Malta, including final-year projects, a student must fill in the UREC form on-line available at: https://www.um.edu.mt/eng/students/facultyresearchethicscommittee This form is reviewed by the Faculty Research Ethics Committee (FREC) and a decision of whether further investigation or referral to the University Research Ethics Committee (UREC) is required. The

	student can only start the research once all the issues raised in the form have been resolved.

Reduced Graphene Oxide Foams: A Scaling Up Study

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Problem Background:	Three-dimensional graphene-based structures in the form of foams allow for novel materials with low densities, high specific surface areas, high porosities, stable mechanical properties, and high electrical conductivities. These graphene foams are being studied for a wide range of applications such as filtration and absorption, pressure sensors, batteries and supercapacitors. Research at DMME is focusing on developing reduced graphene oxide foams (rGOFs). A synthesis procedure that produces compressible, elastic, electrically conductive rGOFs has been established in-house. However, the final rGOFs obtained with the current set-up have small outer dimensions. The proposed project aims at scaling up the synthesis procedure and set-up to produce larger rGOFs. The project will also aim at establishing a relationship between the outer dimensions of the produced rGOF and its properties. Success in scaling up will render the synthesis procedure developed at DMME promising for real-world applications.
Project Objective(s):	• To review literature on the challenges and solutions found to scale up the synthesis of rGO foams and aerogels. • To synthesise larger rGOFs using an already established protocol. • To derive a relationship between the outer dimensions of the rGOFs and its properties (internal morphology, mechanical and electrical properties).
Project Resources:	• Indicate source of funds: UM Research Funds • Equipment/Software/Literature: Available at DMME
Industrial Partners involved:	N/A
Expected Project Deliverables:	• Final year dissertation • A relationship between rGOF outer dimensions and properties
Student background / interest:	• Nanotechnology
IP Issues	☐ The project is IP sensitive; please specify.
Ethical and Data Protection Procedure	Before the start of any research project at the University of Malta, including final-year projects, a student must fill in the UREC form on-line available at:

	https://www.um.edu.mt/eng/students/facultyresearchethicscommittee This form is reviewed by the Faculty Research Ethics Committee (FREC) and a decision of whether further investigation or referral to the University Research Ethics Committee (UREC) is required. The student can only start the research once all the issues raised in the form have been resolved.

A study of the electrical properties of reduced graphene oxide foams: applications in pressure sensing

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Problem Background:	3D graphene-based structures in the form of foams allow for novel materials with low densities, high specific surface areas, high porosities, stable mechanical properties, and high electrical conductivities. These graphene foams are being studied for a wide range of applications including pollution abatement, pressure sensing, electromagnetic shielding, batteries and supercapacitors. Electrically conductive reduced-Graphene Oxide Foams (r-GOFs) with good compressibility and elastic properties were recently synthesised at the Department of Metallurgy and Materials Engineering laboratories. Such foams could find use in pressure sensing applications such as pressure-sensitive wearable devices. In this project we propose to (i) modify the existing synthesis procedure for r-GO foams to further improve their mechanical integrity and durability to cyclic loading, and (ii) in conjunction with the Department of Electronics Systems Engineering, set up a test rig for measuring the piezoelectrical properties of r-GO foams and evaluate thier use in pressure sensing applications.
Project Objective(s):	• To carry out a literature review of the state of the art dealing with r-GO foams, and their electrical and pressure sensing properties. • To modify an established synthesis route for r-GOF in an attempt to improve the mechanical durability of the foams • To set up a test rig for measuring the piezoelectrical properties of r-GOFs • To measure the piezoelectrical properties of r-GOFs
Project Resources:	• Source of funds - UM Research Funds • Equipment/Software/Literature: Available at DMME and DESE
Industrial Partners involved:	N/A
Expected Project Deliverables:	• Final year dissertation • A relationship between the compressibility of rGOF and electrical properties

Student background / interest:	• Nanotechnology and electrical properties of materials
IP Issues	☐ The project is IP sensitive; please specify.
Ethical and Data Protection Procedure	Before the start of any research project at the University of Malta, including final-year projects, a student must fill in the UREC form on-line available at: https://www.um.edu.mt/eng/students/facultyresearchethicscommittee This form is reviewed by the Faculty Research Ethics Committee (FREC) and a decision of whether further investigation or referral to the University Research Ethics Committee (UREC) is required. The student can only start the research once all the issues raised in the form have been resolved.

PVD Nitride Coatings and Triode Plasma Nitriding for Biomedical applications

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Problem Background:	This final year project delves into advanced surface engineering techniques by investigating the synthesis, characterisation and testing of PVD nitride coatings through magnetron sputtering (MS) and electron beam (EB) deposition, alongside triode plasma nitriding (TPN) applied to austenitic stainless steel. Beginning with an extensive literature review, the project lays the foundation for experimental exploration of surface engineered materials prepared using state-of-the-art surface engineering treatment facility within the DMME. The surface engineering facility has the capability to reactively deposit nitride coatings using EB and MS and to carry out TPN treatments. Investigation of these cutting-edge processes with synergistic integration of PVD nitride coatings and triode plasma nitriding is pursued to achieve treatments with tailored thickness, composition and surface characteristics crucial for biomedical performance. Advanced characterisation and testing technique such as EDX, SEM, XRD, surface profilometry, hardness testing and electrochemical testing will be employed to investigate the treated surfaces.
Project Objective(s):	• To review the literature on reactive PVD and TPN treatments of austenitic stainless steel. • To familiarize with PVD and TPN treatment parameters. • To characterize surface engineered specimen. • To evaluated hardness, adhesion of treated surfaces and assess their corrosion resistance in Ringer's solution.
Project Resources:	• Indicate source of funds: Internal Research Grants. • Equipment: PVD coating facility, Potentiostat, optical microscope, Scanning Electron Microscope (SEM), Hardness testers, X-Ray diffractometer (XRD) and Surface profilometer.
Industrial Partners involved:	• N/A
Expected Project Deliverables:	• A dissertation reporting on the synthesis, characterisation and testing results of surface engineering stainless steel.
Student background / interest:	Surface engineering and Materials characterisation

IP Issues	☐ The project is IP sensitive; please specify.
Ethical and Data Protection Procedure	Before the start of any research project at the University of Malta, including final-year projects, a student must fill in the UREC form on-line available at: https://www.um.edu.mt/eng/students/facultyresearchethicscommittee This form is reviewed by the Faculty Research Ethics Committee (FREC) and a decision of whether further investigation or referral to the University Research Ethics Committee (UREC) is required. The student can only start the research once all the issues raised in the form have been resolved.

Avoiding Martensite Formation in Shot Peened AISI 304 Intended for Biomedical Applications.

Project Proposer: Prof Maurice Grech maurice.grech@um.edu.mt

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Last year one of the undergraduate projects involve a study on the stress induced transformation of EN 1.4410 (AISI 320) and EN 1.4301 (AISI 304). It is well established that surface induced plastic deformation resulting from shot peening or other means, results in compressive stresses that can have a profound effect on the in-service performance of a component. For general applications the target is to induces sufficient stress to promote the transformation of the austenite structure to martensite. The formation of martensite is accompanied by an expansion which increases the induced compressive stresses further and as a result improves the material's characteristics even more prominently.

In general, austenitic stainless steels have a martensite start temperature, M_s that is well below zero, however some of these steels have a maximum temperature at which plastic deformation is capable of transforming the meta-stable austenite into martensite, M_d, that is higher than room temperature. EN 1.4410 (AISI 320) and EN 1.4301 (AISI 304) are potentially two such steels and offer the gross potential of forming components with a soft, tough core and a hard wear resistant surface.

For medical applications the generation of compressive stresses is still desirable, but the formation of martensite is not. Generally, all metal implants are required to be non-magnetic and compatible with magnetic resonance imaging (MRI) techniques and visible under X-Ray imaging.

In this study, we shall concentrate on AISI 304, a material used for medical implants. Samples will be shot peened using steel shots but now the target would be to induce the maximum amount of stress whilst avoiding the transformation of martensite. Based on experience a range of pressures lower than 1 bar will be investigated. The distance from the nozzle will be fixed and peening shall be carried out for a fixed duration.

Metallographic and microhardness techniques will be used to assess conditions yielding the largest depth of hardening and overall induced stresses. X-Ray residual stress analysis will be used to determine the residual induced stress. Controlled polishing and wear testing will then be carried out on discs shot peened using the optimal parameter.

Project Objective(s):

- To establish shot peening parameters yielding largest depth of hardening and optimal hardness profile whilst avoiding the formation of martensite.
- To assess stresses induced at various depths.
- To compare the wear resistance of the as-delivered and shot peened and subsequently polished AISI 340.

Project Resources:

- The shot peening machine is available at the DMME labs
- Facilities at DMME include amongst other, XRD, SEM, metallographic lab, microhardness testing machine and wear testing facility.
- The high carbon cast steel shots and the 25mm AISI 304 bars are available. Minimal amounts of 50mm diameter AISI 304 need to be

	purchased. This material will be used for wear testing.
Industrial Partners involved:	• None
Expected Project Deliverables:	• To establish the maximum stress that can be induced without the formation of martensite. • To compare the wear resistance of surface treated AISI 304 with the as-purchased material
Student background / interest:	• Interest in shot peening. • Interest in material characterization.
IP Issues	□ None
Ethical and Data Protection Procedure	Before the start of any research project at the University of Malta, including final-year projects, a student must fill in the UREC form on-line available at: https://www.um.edu.mt/eng/students/facultyresearchethicscommittee This form is reviewed by the Faculty Research Ethics Committee (FREC) and a decision of whether further investigation or referral to the University Research Ethics Committee (UREC) is required. The student can only start the research once all the issues raised in the form have been resolved.

Evaluating PLA and ASA polymers for use as biomedical materials

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Co-supervisor (if any):	Prof. Maurice Grech, maurice.grech@um.edu.mt
Problem Background:	Additive manufacturing using the Fused filament fabrication (FFF) methodology is arguably one of the most flexible manufacturing technologies, especially for the fabrication of one off highly customized component on demand. Allowing for the manufacture of very intricate designs with various degrees of fill ratios, this technology affords an unprecedented control on stiffness, weight, and wall thicknesses which is unparalleled with the traditional technologies. This is precisely what is required with medical orthotics and implants. This project seeks to investigate the rate at which the mechanical properties of the implant or orthotic device change as it degrades with time. The generated data can then be used to establish the best printing strategy to achieve predictable mechanical properties.
Project Objective(s):	• To research FFF printing strategies such as: build plate materials and temp, fill ratio, head temp, printing speeds, chamber temperatures, …) and printing conditions for PLA and ASA polymers. • To select a typical implant or orthotics application and research the required material properties for such an application (from scientific publications). • To calculate the material cross section and shape that will meet such required specifications. • To investigate the effect of post annealing of the printed components on their mechanical properties. • To print a series of miniature specimens intended to test the resulting properties and iterate until a satisfactory compromise is reached. • To investigate the mode of failure of the printed samples so as to understand the effect of the printing parameters used.
Project Resources:	• Indicate source of funds: Internal research Funds • Equipment/Software/Literature: Available; PLA filament to be acquired but it can be easily sourced locally
Industrial Partners involved:	• Partners, if any:
Expected Project Deliverables:	• Establish the properties required for an application of choice. • Design a suitable strategy and establish parameters for printing components with the required mechanical properties. • Measure the change in mechanical properties (Impact strength, elongation, impact strength, and hardness) with exposure time. • Identify the effect of printing weld joints and internal void

	configurations used, on the mechanical properties and the mode of failure.
Student background / interest:	• 3D printing, Rapid Prototyping, Engineering Design, Polymeric Materials
IP Issues	☐ The project is IP sensitive; please specify. NA
Ethical and Data Protection Procedure	Before the start of any research project at the University of Malta, including final-year projects, a student must fill in the UREC form on-line available at: https://www.um.edu.mt/eng/students/facultyresearchethicscommittee This form is reviewed by the Faculty Research Ethics Committee (FREC) and a decision of whether further investigation or referral to the University Research Ethics Committee (UREC) is required. The student can only start the research once all the issues raised in the form have been resolved.