Final Year Project Showcase Batch-2020
Year 2024

Department: Metallurgical Engineering Programme: Metallurgical Engineering	
1	**Project Title** Surface Modification of Magnesium Alloy to Enhance Corrosion Resistance
2	**Project Idea** Magnesium alloys have emerged as a promising candidate for medical implants due to their high biocompatibility. Their Modulus of Elasticity is comparable with that of the natural bone which renders them an ideal material for bone and dental implants. Almost all the other metals employed for implant-related applications own higher modulus and as a result, affect the physiological system adversely. Plasma Electrolytic Oxidation (PEO) is a relatively new technique of surface modification that develops an oxide layer on anodic metals such as Magnesium. The ions traveling to the anode during PEO can carry particles suspended in the electrolyte. In this study, we will deposit Alumina microparticles on Magnesium alloy AZ31B using PEO, to enhance corrosion resistance and wear performance.
3	**Process** Plasma Electrolytic Oxidation is a more recent form of surface modification treatment. It is utilized on metals like aluminum, magnesium, zirconium, titanium, and niobium, along with their alloys, to produce ceramic coatings. The precise combination of sodium hydroxide (NaOH) and sodium metasilicate (Na2SiO3) was achieved after rigorous testing. Following the determination of the NaOH and Na2SiO3 proportions, we proceeded to dissolve these components in distilled water to achieve a specific pH range between 11.5 to 13.5 and a conductivity range of 7 to 9. PEO involves different stages such as normal anodizing, spark anodizing, micro-spark oxidation, and arc oxidation. In the normal anodization phase (0-7 minutes), the voltage rises steadily to about 300 V. During this step, there were no sparks and only some tiny oxygen bubbles were observed on the surface of the sample, which indicates that magnesium alloy substrate begins to dissolve and a thin passive film is formed on the surface. As the process transitions to spark anodization (7-10 minutes), the voltage reaches the breakdown voltage and continues to increase. Micro-discharges begin to occur as orange sparks, which produce a thick, porous oxide layer. At around 10 minutes, the voltage attains an acritical level (approximately 350 V). In this step, more intense discharges occur, resulting in a dense, hard ceramic oxide coating. The voltage then stabilizes around 400 V and is held for a while. As a result, the PEO process ends with the formation of a robust protective layer on the magnesium alloy.
4	**Outcome** The PEO process effectively improved the corrosion resistance, as evidenced by the results of Electrochemical impedance spectroscopy (EIS) and Potentiodynamic Polarization (PDP) tests, showing superior performance compared to uncoated samples. The corrosion resistance of the PEO-coated sample has increased 8.84 times compared to the uncoated Mg alloy. Conversely, the corrosion resistance of PEO coated with alumina additive has increased approximately 2824.17 times compared to uncoated magnesium alloy. SEO analysis reveals a uniform and

	compact oxide layer with the incorporation of alumina particles, which contributes to the increased adhesion and wear resistance demonstrated by the scratch test. These findings highlight the benefits of PEO with alumina additives to enhance the durability and longevity of magnesium alloys for biomedical applications, aligning with the broader objective of developing sustainable and biocompatible materials for medical implants.
5	**Evidence (Theoretical Basis)** Magnesium alloys have emerged as a promising candidate for medical implants due to their high biocompatibility. Moreover, their Modulus of Elasticity is comparable with that of the natural bone which renders them an ideal material for bone and dental implants. Almost all the other metals employed for implant-related applications own higher modulus and as a result, affect the physiological system adversely. Plasma Electrolytic Oxidation (PEO) is a relatively new technique of surface modification that develops an oxide layer on anodic metals such as Magnesium. The ions traveling to the anode during PEO can carry particles suspended in the electrolyte. In this study, we will deposit Alumina microparticles on Magnesium alloy AZ31B using PEO. The addition of alumina powder during PEO is also expected to enhance the durability of the protective layer which will provide a longer lifespan for magnesium alloy implants. This surface modification will not only enhance the corrosion resistance but also align with the broader goal of making it sustainable. The future of medical implants heavily relies on materials like magnesium alloys and this project plays an important role in advancing this field.
6	**Competitive Advantage or Unique Selling Proposition** (Cost Reduction, Process improvement, Attainment of any SDG (Sustainable Development Goal), an increase of market share or capturing a new market or having superior performance over a competitor. In summary, any striking aspect of the project that compels the industry to invest in FYP or purchase it. Some detailed description is required in terms of how, why when what. You can select one or more from the following dropdown and delete the rest of them). Please keep relevant options, delete the rest of them, and correct the sequence. **Good Health and Well Being** This project is directly linked with Good health and well-being. The world is eagerly interested in moving towards magnesium-based implants and devices instead of Titanium due to its several attractive characteristics. However, the major hindrance to this transition is the poor corrosion resistance of Mg and its alloys in a physiological environment. In this study, approximately 2824.17 times improved corrosion resistance has been achieved, in comparison to the uncoated samples. This enhancement is reasonably high enough to be registered as a breakthrough.
a	**Attainment of any SDG** (e.g. How it is achieved and why it is necessary for the region) This Project is related to the development of Biomedical implants and devices from Magnesium alloy. Magnesium is a more biocompatible material, its utilization for implant-related applications will address the shortcomings of the biomedical implants used nowadays.
c	**Cost Reduction of Existing Product** Per Kg cost and density of Magnesium alloys are much lower than Ti alloys. Moreover, with the increased life of Mg-based implants and the absence of re-surgery requirements, the cost of implants will be decreased significantly in the long run.

<table>
<tr><td>d</td><td colspan="2">Process Improvement which Leads to Superior Product or Cost Reduction, Efficiency Improvement of the Whole Process (e.g. What is the issue is current process and what improvement you suggest)

Currently employed techniques have not proven to be successful in rendering Mg alloys a suitable material for implants.</td></tr>
<tr><td>7</td><td colspan="2">Target Market (Industries, Groups, Individuals, Families, Students, etc) Please provide some detail about the end-user of the product, process, or service.

Biomedical implants and device manufacturers can benefit from the project. Industries may acquire the processing services at our lab. The prepared product will be useful for patients suffering from trauma, aging, and diseases.</td></tr>
<tr><td>8</td><td>Team Members (Names along with email address)</td><td>BE Students (Batch 2020) and Co-supervisor
1. S. Habib Uddin (uddin4303212@cloud.neduet.edu.pk),
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5. Dr. Muhammad Ali (m.siddiqui@cloud.neduet.edu.pk)</td></tr>
<tr><td>10</td><td>Supervisor Name (along with email address)</td><td>Dr. Muhammad Rizwan (engr.rizwan@neduet.edu.pk)</td></tr>
<tr><td>11</td><td>Video (If any)</td><td>Please provide the link to the video</td></tr>
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Pictures (to be pasted below)

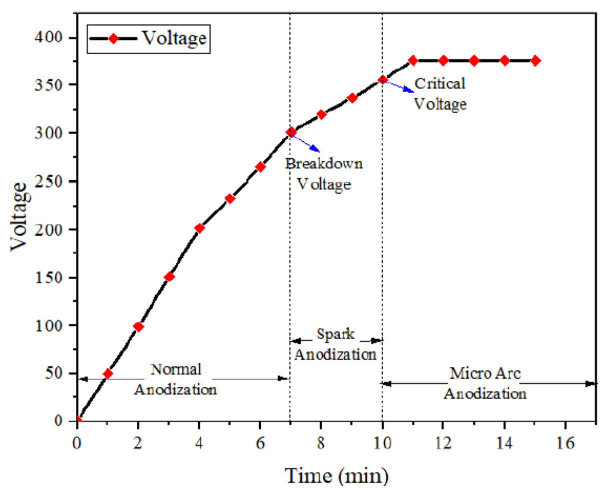

Fig1: Voltage-Time Plot of PEO Process

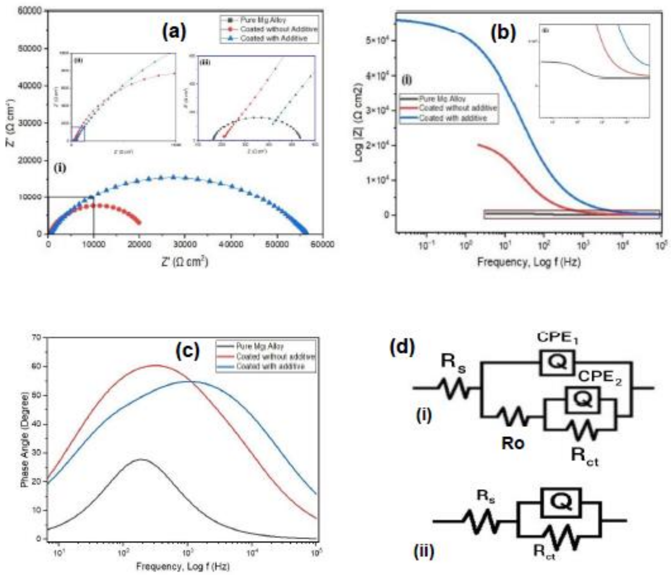

Fig2: EIS results for Uncoated Mg Alloy, PEO Coated Mg Alloy and PEO with Alumina Additive: (a) Nyquist plot (b) Bode magnitude plot, (c) Bode phase plot, (d) Electrical Equivalent Circuit

Sample	Icorr (Amp/cm^2)	Ecorr (Volts)	Corrosion Rate (mpy)
Uncoated Mg Alloy	3.85×10^{-5}	-1.38	33.89
PEO Coated Mg Alloy	4.37×10^{-6}	-1.47	3.838
PEO Coating with Alumina Additive	5.67×10^{-7}	-1.42	0.012

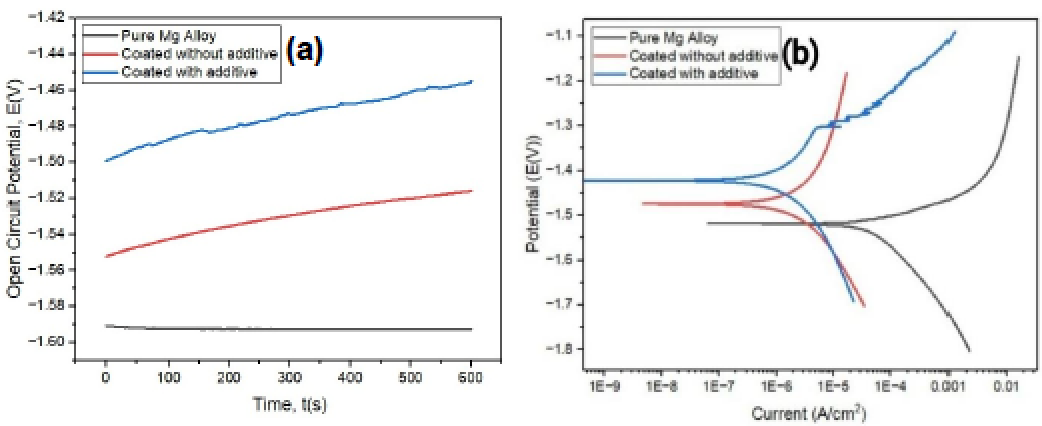

Fig3: (a)OCP curves and (b) PDP Plot of Uncoated Mg alloy, PEO coated Mg alloy and PEO coating with alumina additive

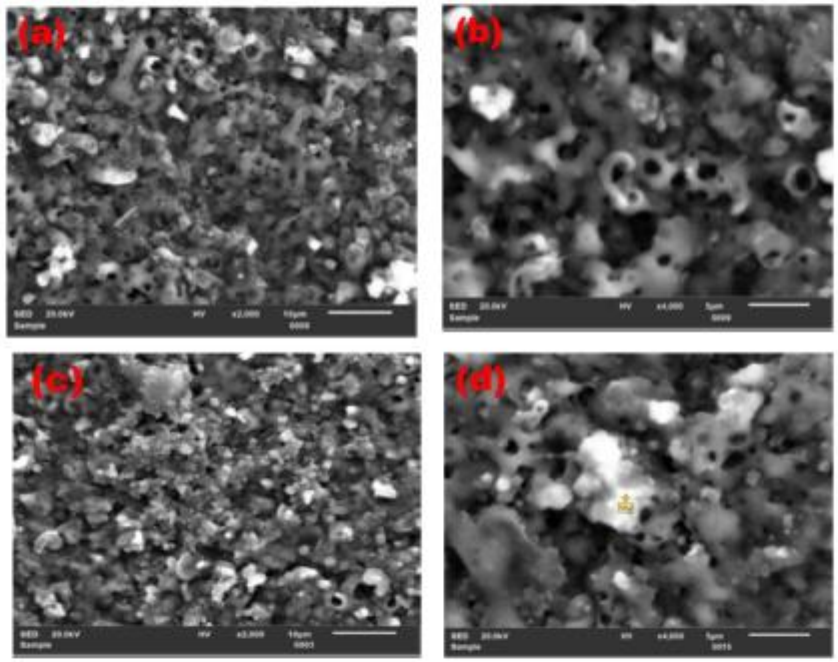

Fig4: (a)PEO coated without alumina additive at 2000X (b) PEO coated without alumina additive at 4000X (c) PEO coated with alumina additive at 2000X (d) PEO coated with alumina additive at 4000X

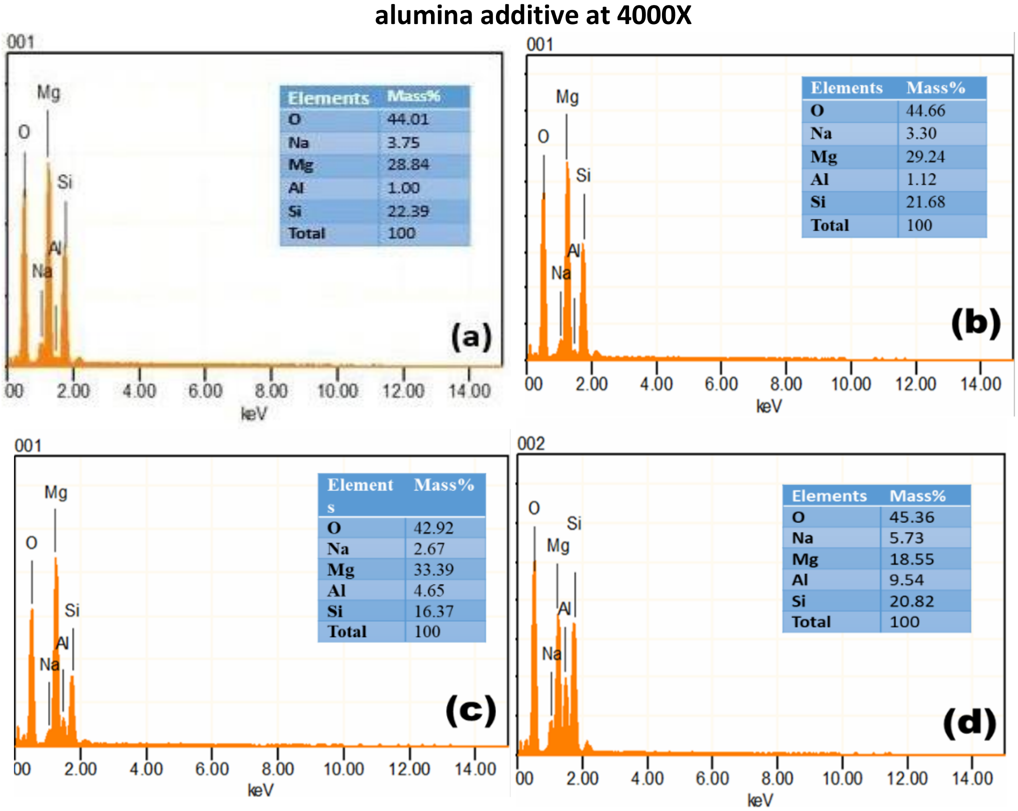

Fig 5: EDS results of (a & b) PEO coated Mg without alumina additive (c & d) PEO coated Mg with alumina additive

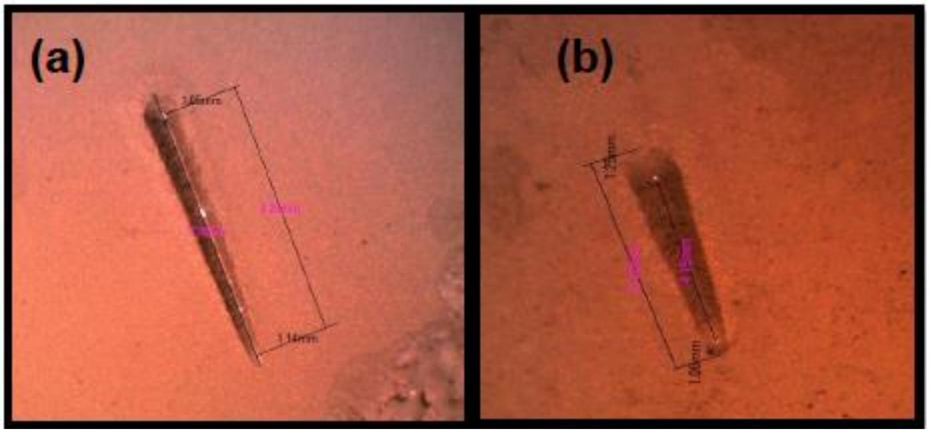

Fig6: Measurement of total and chipping lengths on (a) PEO coated Mg alloy (b) PEO with alumina additive