

Research Article

LASER MODIFIED MAGNESIUM ALLOY AND HYDROXYAPATITE POWDER FOR CELL VIABILITY STUDIES

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Abstract

Laser is used to surface modify the magnesium alloy which is the prominent material used for biocompatibility. In this research a fiber laser with a maximum output power and frequency of 25 W and 30 kHz, respectively, that emitted a Gaussian beam at 1030 nm was utilized to create laser dimples on the magnesium specimen. Three types of patterns were developed namely circular, diamond and hybrid on the magnesium alloy. The specimens are then coated with Hydroxyapatite powder and cell viability studies were conducted on these three samples. The cell viability studies show 20 ± 1 cell attachment on the circular samples and the cell viability studies on diamond pattern show 76 ± 7.3 cell attachment. Moreover, the cell viability on hybrid pattern shows 183 ± 9.5 cell attachments which is highest among the other 2 samples.

Keywords: Circular, Diamond, Hybrid, Pattern, Cell attachments, Standard error, Coating.

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1. INTRODUCTION

The surface properties of biomaterials have a major impact on their functional performance in biomedical applications. However, the intrinsic surface characteristics of many engineering materials are often unable to meet the strict requirements of wettability, cell adhesion, osseointegration, and biocompatibility. Surface modification is therefore now an essential step in the production of biomaterials. Laser surface texturing has emerged as one of the most promising and versatile surface engineering techniques because it can produce precise micro- and nano-scale patterns while preserving the bulk properties of the substrate. Because laser-induced surface modifications have demonstrated significant promise in enhancing biological responses, such as improved cell adhesion, proliferation, and tissue integration, laser surface patterning has been thoroughly investigated for biomedical implant applications (Mozetič et al. 2019). Kurella and Dahotre (2005) provide a thorough analysis of laser surface changes. They found that there is a great deal of promise for bioimplant applications using the laser surface changes. Pan et al. (2022) used direct laser ablation with

femtosecond pulse duration in air conditioning to extensively examine the wear performance and friction of Ti6Al4V. The surface morphology and roughness, micro-hardness, residual stress, microstructure evolution, and tribological properties of the Ti6Al4V titanium alloy were assessed both with and without FsLSM treatments. The surface micro-hardness of the specimens treated with FsLSM improved by about 16.6%, from a maximum of 350 HV to 408 HV. Obeidi et al. (2022) used CO₂ laser polishing to alter the surface of the Ti-6Al-4V produced samples. The most crucial processing parameters were tuned to achieve around an 80% reduction in the average surface roughness and a 90% reduction in the peak-to-valley distance at a processing time of 0.1 s/mm² and a cost of 0.2 €/cm². Hou et al. (2022) investigated the application of several techniques for surface modification of titanium-based implants in orthopedics. They produced a variety of periodic nanogrid patterns on the titanium surface using laser ablation. They found that different patterns had distinct effects on cell adhesion and differentiation. These results show how accurate and versatile laser modification is

as a surface processing method. In their chapter, Brown and Arnold (2010) provide a succinct overview of the basic ideas guiding laser absorption and propagation as well as the material reactions that follow. They went over how cells and surfaces interact in biological interfaces. According to Kurella and Dahotre (2005), poor osteointegration and insufficient biocompatibility frequently cause hard implants to separate from the host tissue. Biocompatibility is impacted by shifting surface chemistry and topography. It is clear that several researchers have suggested laser-supported surface modification, which has been shown to improve surface biocompatibility and refine grains. In this study, biocompatible investigations are carried out and the magnesium alloy is laser imprinted with various patterns.

2. EXPERIMENTAL SETUP

A fiber laser with a maximum output power and frequency of 25 W and 30 kHz, respectively, that emitted a Gaussian beam at 1030 nm was utilized to create laser dimples on the magnesium specimen. A standoff distance of 0.7 mm was maintained (Jagannathan et al., 2025). To investigate their impact on surface properties, three distinct surface patterns the circular pattern, the diamond pattern, and the hybrid

pattern were used (Figure 1). Hydroxyapatite powder is electrochemically applied to the laser-marked patterns. In the current investigation, magnesium alloy was chosen as the implant material. Energy dispersive X-ray spectrometry (EDS) made of EVO MA18 was used to confirm the chemical composition of the magnesium alloy. The specimen is cut with dimensions of 40 mm in diameter and 3 mm in thickness, and the EDS analysis shows the presence of Mg (59.81%). During the electrochemical procedure, pure copper was utilized as the tool electrode. The electrolyte was a sodium nitrate aqueous solution (0.208M/L). To achieve a range of concentrations, pure HA powder (99.5 weight percent) with an average particle size of 20.40 nm was added to the electrolyte. A variety of concentrations of HA (0, 6, 10, and 14 g/L) and an anodic voltage range of 11 to 14 V were employed. The anode and cathode retain a 1 mm inter-electrode spacing. Every experiment maintains the same other electrochemical parameters (Ansari et al., 2025). After extensive trial and error, a voltage of 14V was chosen for the machining condition, and an 80% duty ratio was used for this experiment. After 30 minutes of surface coating, the specimens were left outside for ten minutes before being cleaned with an acetone-based ultrasonic cleaner and dried with a hair dryer.

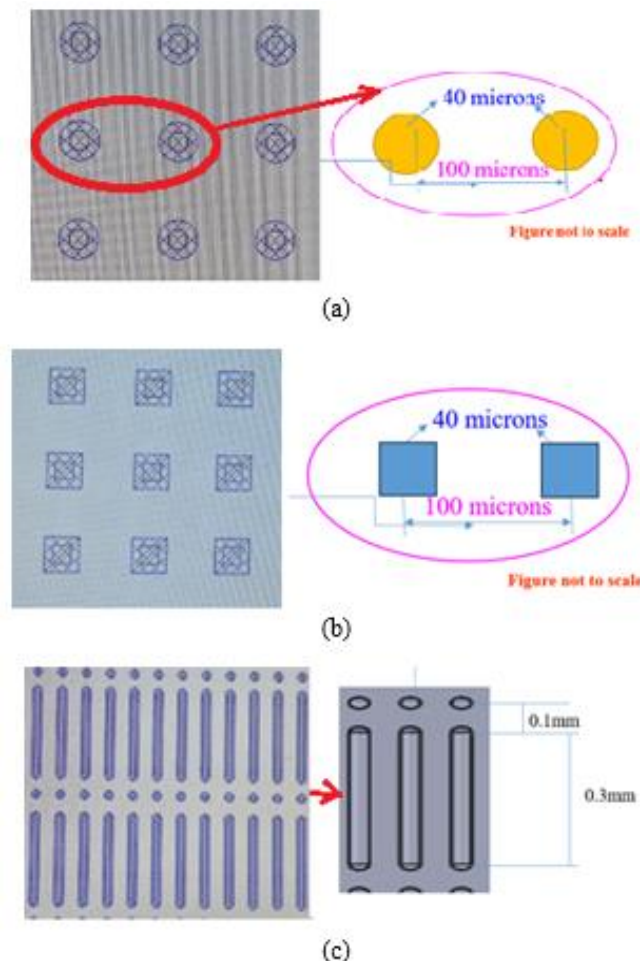


Figure 1: Laser hatched patterns (a) Circular (b) Diamond (c) Hybrid

2.1. HYDROXYAPATITE COATING (HA)

Enhancing the surface bioactivity of magnesium alloys and making them more suitable for orthopedic implant applications was the aim of HA coating. The sample surfaces were successfully coated with a consistent, continuous layer of hydroxyapatite. After 18 to 24 hours of coating, the thickness of the HA coating was found to be in the range of 20 to 30 μm , indicating successful deposition (Ansari et al., 2024). Because of the appropriate preparation and regulated pH levels, the coating showed good adherence and coverage. The enhanced surface properties of the coated surfaces are advantageous for biological interactions. It is anticipated that the HA coating presented in Figure 2 will improve the material's overall biocompatibility by increasing wettability and cell adhesion.



Figure 2: HA coated specimen

3. CELL VIABILITY

The test was carried out in multiple trials to ensure accurate sample preparation and reliable biological assessment. The results obtained from each trial are presented below.

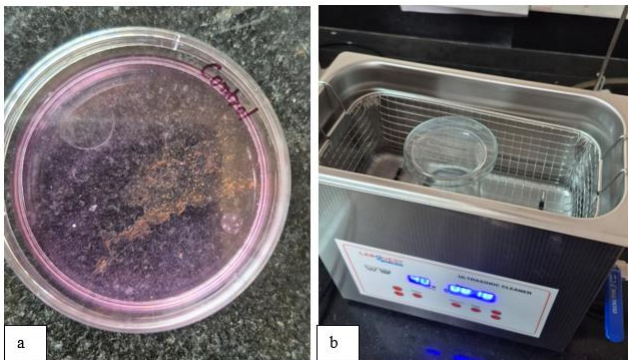


Figure 3: (a): Medium used for cell viability (b): Ultrasonic cleaning

3.1. TRIAL 1

The first trial was conducted on laser surface modified samples. During the experiment, it was observed that the cells did not survive after the medium replacement stage, leading to failure of the test. The exact cause of cell death could not be conclusively determined; however, it may be attributed to improper sample preparation, insufficient cleaning, or handling conditions. Due to this issue, the affected samples became unsuitable for further analysis, and approximately six

specimens were rendered unusable (Ganesan & Rajasekaran, 2021).

3.2. TRIAL 2

The second test was done on well-prepared LSM samples with improved cleaning and handling procedures. The samples were sent to biological testing under controlled laboratory conditions. The cell viability test results show that the average no. of cell attached with the specimen was 20 ± 1 standard error of the mean. The cell viability of the sample with circular marking depicted in Figure 4.



Figure 4: Cell viability on circular pattern

3.3. TRIAL 3

The third trial involves hydroxyapatite (HA) coated samples with diamond pattern markings. These samples were submitted for cell viability evaluation to study the effect of HA coating on biological response (Kumar et al., 2021; Thanigaivelan et al., 2020). The testing results shows $76 \pm 7.3^*$ cell attachment as presented in Figure 6.



Figure 5: Cell viability samples

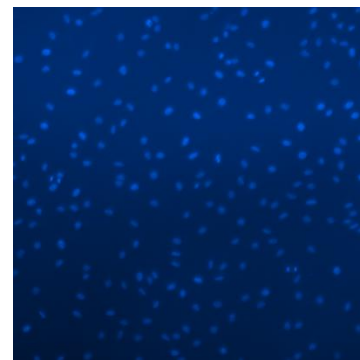


Figure 6: Cell viability on diamond pattern

The fourth trial involves hydroxyapatite (HA) coated samples with hybrid pattern markings. These samples were submitted for cell viability evaluation to study the effect of HA coating on biological response. The testing results shows $183 \pm 9.5^*$ cell attachment as presented in Figure 7.

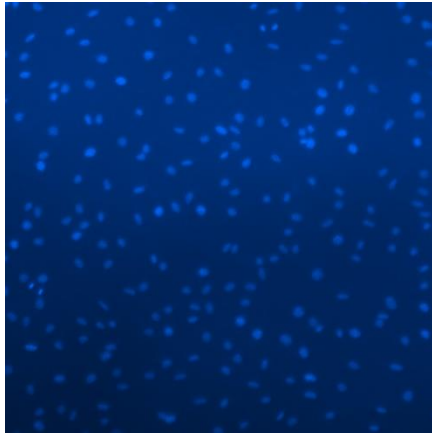


Figure 7: Cell viability on hybrid pattern

4. CONCLUSIONS

1. The laser marking on Magnesium alloys was marked with circular, diamond and hybrid patterns successfully.
2. The laser marked samples were successfully coated with HA powder using electrochemical process.
3. The cell viability studies were performed on these samples and circular pattern shows 20 ± 1 cell attachment i.e. average number of cells/100pixel $\pm$ standard error of the mean.
4. The cell viability studies on diamond pattern shows 76 ± 7.3 cell attachment.
5. The cell viability on hybrid pattern shows 183 ± 9.5 cell attachment which is highest among the other 2 samples.

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CONFLICT OF INTEREST

There is no conflict of interest among the authors.

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