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Mechanical Properties of 3D printed, wire cut Alsi10mg alloy using SEM/EDS analysis

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ABSTRACT - The Additive Manufacturing refers to production of complex geometrics from digital files using a machine. The AM era is evolving at an immense rate and at the same time, its rising multiple challenges based of the mechanical properties, metallurgical properties to ponder and quench a right remedy for its growth. Many researchers in the past have explored the various methods of Additive Manufacturing methods, like a study on raw materials chemical proposition used in AM, Tessellation techniques, temperature evolution behaviors in AM, build parameters in AM, pre-processing and post-processing methods in AM, microstructure behaviors of the print product based on different temperatures, various support techniques can be equipped in AM, thermal conductivity and diffusivity of the AM raw materials at different relative densities. To explore, evaluate, and optimize the mechanical properties like hardness using SEM/EDS analysis after wire cutting the Alsi10mg alloy.

Keywords: Additive Manufacturing, Tensile stress, Chemical composition, surface hardness, microstructures

I. INTRODUCTION

"Rapid manufacturing" (RM) is innovative production using Additive manufacturing techniques which began in 1980s. Quick tooling (RT) was traditionally known as rapid prototyping (RP) [1]. RM can replace manufacturing parts via technology, bespoke parts, and restricted manufacturing which can be done at the customer level as well. Well-known name for this kind of portable production is additive manufacturing (AM). Around 30 types of manufacturing techniques are available in markets today based of their materials used and process exhibited [2]. Upon closer look the manufacturing processes varies on how they build the product and manufacture via AM machines and the two AM techniques which we are going to discuss are DMLS plus SLM, which are called as direct method laser sintering, selective laser melting. The powder quality used and temperature generated because of laser projecting inside the build chamber are key in this AM systems. Many researchers have educated that AM technique [3], base used, thickness of the later, laser injecting property, methods used in building and post-processing will impact the mechanical and surface qualities of the product [4]. In 20 years of evolution, Additive manufacturing paced at an immense rate by evolving technologies in both mechanical and digitally. Initial additive manufacturing was progressed with the build of models and prototypes. Material incremental manufacturing (MIM) was the primary source of AM, which differs in traditional removal of build support structures. Equipped with digital-programmed controllable laser as the primary source of energy [5], additive manufacturing progress with layer-by-layer deposition and joined by making use of support structures, and the deposition materials are usually powdering material. Initial steps in Additive manufacturing begins with a computer aided design model and followed by mathematically split techniques using tessellation techniques. Once the CAD model is converted into STL file as input to the metal printing machine would sinter the

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laser at the selected powder material positions on the bed and the same is repeated layer by layer with the help of support structures wherever required. This digital approach of manufacturing is also called as digital manufacturing or e-manufacturing, solid free form fabrication [6]. Imprinting using the laser technology as innovative ideas would influence all the manufacturing sectors and their production ideas [7]. Each and every manufacturing process are designed with unique based processing principles. However, the original stereolithography (STL) printing process are included in either fused deposition modelling or selective laser sintering or fused deposition modelling or by laminated object manufacturing. Low melting materials are used in many manufacturing processes as the current manufacturing of the product would be efficient, when compared to high melting point polymer powder materials [8]. The rapid prototyping machines are so efficient in production development using computer aided design (CAD) files. Additive manufacturing is in evolving stage and gained the prominent place in aerospace, rapid prototyping and biomedical industries [9]. Every additive manufacturing is evolving like anything to produce complex shaped components metallic components and alloys as well, which are complicated to manufacture using the traditional methods [10]. The end use components in the additive manufacturing are being progressed and utilising the most 3 common procedures in any digital additive manufacturing, which are laser sintering, laser melting and laser metal deposition [11] and these procedures are well known by various names based of the business forms or institutions. When it comes to the metal manufacturing process, it is called by name SLM (selective laser melting), where the Powder material is sintered using laser power. This has opened the doors in various research exploring methodologies for a proper way of production of powder polymers in the manufacturing industry. Due to its precision, it has been standard at a rapid stretch to fabricate various functional parts [12]. For example, A grade CU-tool Steel was inserted into the patient body and found to be more heat transfer because of the material used and when it was replaced by the component, which is built by using the SLM technology PM-100 and found to be more efficient, when compared to the CU-tool graded one [13]. The selective laser melting in manufacturing process is a production of a component layer by layer, which is by sintering on the selected powder polymer by making use of laser power and by utilising the support structures wherever required, and then removing of these support structures by post processing methods or by surface polishing [14]. Hence well-balance powder polymer is needed to select and the aluminium based of alloys, which are manufactured by making use of SLM process are seem to be very efficient when manufactured by using aluminium silicon alloys and are most prominent used one in the light weight 3D metal printing manufacturing process and these are easily weldable, because of minimal difference between the liquids and solidus temperature [15]. AlSi10Mg alloy is seem to be very reasonable for metal printing processes using sintering techniques. This alloy is also seen to be very optimised, when compared to high melting aluminium alloys, which requires more heat treatment to toughen, for this reason this alloy is used in irrespective of many industries like food chemicals, aircraft and car industries. which rely on this AlSi10Mg alloy. Its chemical composition is identical to that ISO 3522 which causes the precipitation of AlSi10Mg, which is 3x3 Matrix without altering its mechanical characteristics gradually [16]. This highly customisable geometrical complexity with the aluminium based productions is opening doors to many new possibilities in applications mostly in light-weight structures and heat sintering utilisation methods. This research primarily examines the SLM of AlSi10Mg mainly on the surface quality of the specimens printed based of L9 orthogonal array parameter selections, there by examining the best specimen quality from SEM/EDS analysis. Initially, we thought of experimenting with two AlSi10Mg powder polymers which are supplied from two different firms [17]. However, it may result in multiple 3D metal printing of specimens based of L9 orthogonal approach method and resulting in high expenses. The quality of the specimens differs because of the varied process parameters like laser power, scan speed and hatching distance, also with respect to the production of chemical compositions being used in the Powder polymer. These factors contribute a difference in the product print quality, melting behaviour deposition of layers behaviour and consolidated layers difference due to the variations as discussed above. This was the initial step towards the choice of this alloy selection AlSi10Mg in SLM [18]. Process parameters like laser power, scanning speed and hatching distances in this 3D printed products are investigated by using the SEM/EDS analysis to find out the best specimen print quality. From the investigation, it is found at the castable and the corrosion resistance of this aluminium silicon alloy are good [19] and this approach would help in selection of the process parameters in the production of parts which are planned to build by making use of this alloy in irrespective of areas like home, aircraft, automatic and other sectors as well, as the desired mechanical characteristics and heat conductivity and their low weight property are very important in the selection of this 3D metal printing any two manufacturing process [20].

II. EXPERIMENTAL PROCEDURE

2.1 AlSi10Mg Material

German company SLM solution group AG provides the metal powder with the chemical composition of the AlSi10Mg alloy, as stated in Table 1. The size distribution of the powder particles varies between 20 and 63 µm. Tensile testing is conducted on the SLM-AlSi10Mg specimens in accordance with ASTM standard E8/E8M. The specifications of the circular-bar rod specimen are as follows: a 100 mm long total diameter, a 25 mm long gauge diameter, and a 6 mm fillet radius (Figure 1).

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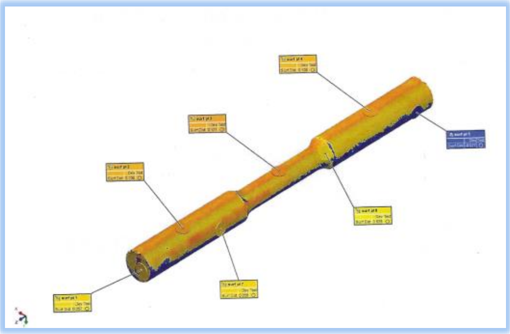
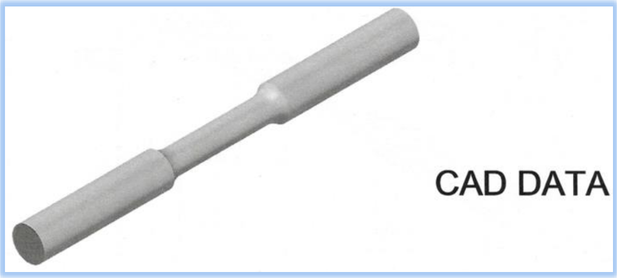
Table 1. Chemical composition of AlSi10Mg alloy [6].

Al	Si	Fe	Cu	Mn	Mg	Zn	Ti	Ni	Pb	Sn	Other total
Balance	9.00– 11.00	0.40	0.03	0.10	0.25 – 0.45	0.10	0.15	0.05	0.05	0.05	0.15



(a)



(b)

Figure 1. a) Line diagram b) 3D model.

2.2 SLM Printing Process

To investigate the alloy, process parameters in this manufacturing process and their impact like mechanical qualities, surface roughness and the experimental design was designed using three factors and with the three levels, which are layer thickness, scan speed and the build direction where the design elements. And the plan is shown in both the tables given below. Additionally, we have set the other parameters as constant and which can impact the mechanical attributes and quality. Manufactures also suggested specific process parameters like scan speed, layer thickness to be utilised during the printing as the each and every machine is restricted by the limits based on their machine specifications. Figure shows the 3D printing being used in the production of the specimens and the figure to the relative positions of the build chamber and the Powder polymer component build direction. The process parameters, mechanical characteristics like surface roughness and powder polymer component, dimensional may affect by the build direction degrees. Since many of the SLM machines in market provide a laser power with a limit range of up to 200 W - 400 W. However, a new SLM machine with upgraded hardware software help boost the process of system consuming the maximum laser power, when increased by 1 kilowatt. Hence resulting in great efficient manufacturing beyond 5 mm^3. This manufacturing unit is equipped with a laser source for projecting laser based of power KW set and also consists of ellipsoid forms the beam profile, Enhanced Additive manufacturing concept is used in provision AlSi10Mg powder in a regulated environment which makes favourable for using with reactive materials. As seen in figure 3, this machine has 400 wat, fibre laser and 75 µm laser beam diameter, which manufacturers at a maximum of 150 µm of beams width and also, we have tested the scanning rates, laser powers of the printing samples, which help to decrease the deformation caused by his stresses.

Figure 2: SLM printing process [20].

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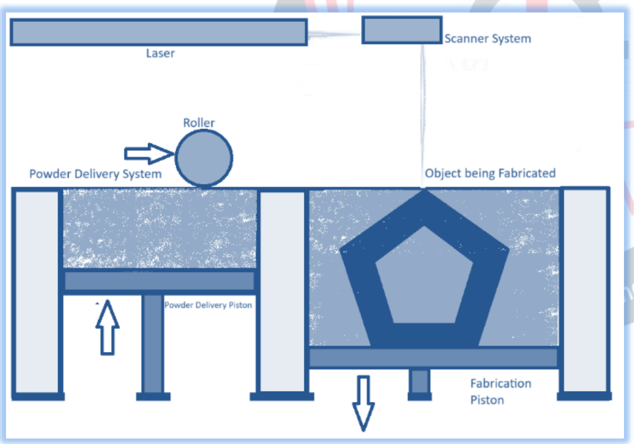
Table 2: Levels and their Factors for SLM of AlSi10Mg alloy.

Parameters	**Level 1**	**Level 2**	**Level 3**
Laser power in Watts	250	300	350
Scan speed in mm/s	1200	1400	1600
Hatching distance in µm	120	140	160

Table 3: Used L9 orthogonal array as per DoE (Minitab).

Trials No.	**Laser power (Watt)**	**Scan speed (mm/sec)**	**Hatching distance (µm)**
T1	250	1200	120
T2	250	1400	140
T3	250	1600	160
T4	300	1200	140
T5	300	1400	160
T6	300	1600	120
T7	350	1200	160
T8	350	1400	120
T9	350	1600	140



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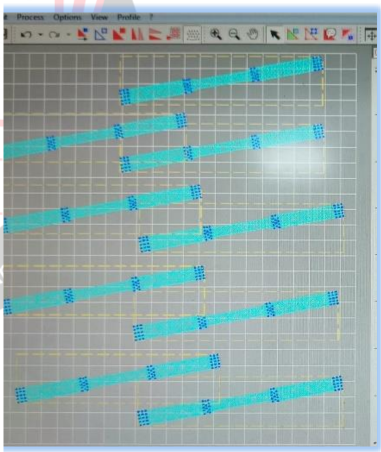

(b)

(c)

Figure 3. SLM schematic diagram, printing process and final 3D Metal printed specimens.

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III. Results and Discussion

All test parts were manufactured utilizing a set of design of process parameters (3^3) that result in maximum mechanical characteristics, with the aim of promoting the optimal mechanical qualities of AlSi10Mg components generated by SLM. Next, we'll optimize the process settings by considering the material's exceptional mechanical qualities.

3.1. Mechanical properties

Using a Shimadzu Autograph AG-IS 50 kN universal testing machine at a testing speed of 2 mm/min and a maximum force of 50 kN, the tensile characteristics were assessed according to the ISO 6892-1:2009 standard for metallic materials at room temperature. The results are shown in Figure 4. Figure 5 shows the results of the bending characteristics evaluation using an Instron 1122 Series universal testing machine at a testing speed of 2 mm/min and a distance between supports of 55.88 mm, in accordance with the ISO 2740:2007 standard for sintered materials. Mechanical characteristics determined by tensile testing of components manufactured in the 00 orientation; supplied values are means with 95% confidence intervals. Results from conventional casting and as-built printing of AlSi10Mg were used as a point of reference by the properties. During the as building condition, Mg2Si precipitates are formed, resulting in SLM-AlSi10Mg printed objects with exceptional hardness and strength. Even in their "as-built" (i.e., unheated) form, SLM components achieve far better hardness and strengths. Table 4 shows the findings from the tensile experimental test, and Figure 6 shows the plotted results. The ultimate tensile strength is 340 MPa, the yield strength is 130 MPa, and the elongation is 5.2%.

Figure 4: UTM experimental setup.

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Fig 5: UTM L9 samples after experimental braked samples.

Table 4: Tensile test results

Specimen ID	Maximum Load (kN)	Ultimate Tensile Stress (Peak Stress)	0.2% offset (Yield stress) in MPa	Elongation in % GL 4D	% Reduction Area
S - 1	15.037	328.680MPa	233.190MPa	4.24	6.95
S - 2	16.392	326.857MPa	218.960MPa	4.08	13.06
S - 3	16.529	357.562MPa	250.047MPa	5.08	8.67
S - 4	14.911	322.681MPa	205.348MPa	5.04	5.65
S - 5	15.694	341.376MPa	230.400MPa	5.56	5.92
S - 6	15.708	342.655MPa	227.194MPa	5.20	8.70
S - 7	14.650	321.242MPa	210.349MPa	5.80	8.22
S - 8	14.747	316.564MPa	206.248MPa	7.20	8.88
S - 9	16.116	350.565MPa	236.787MPa	6.40	5.16

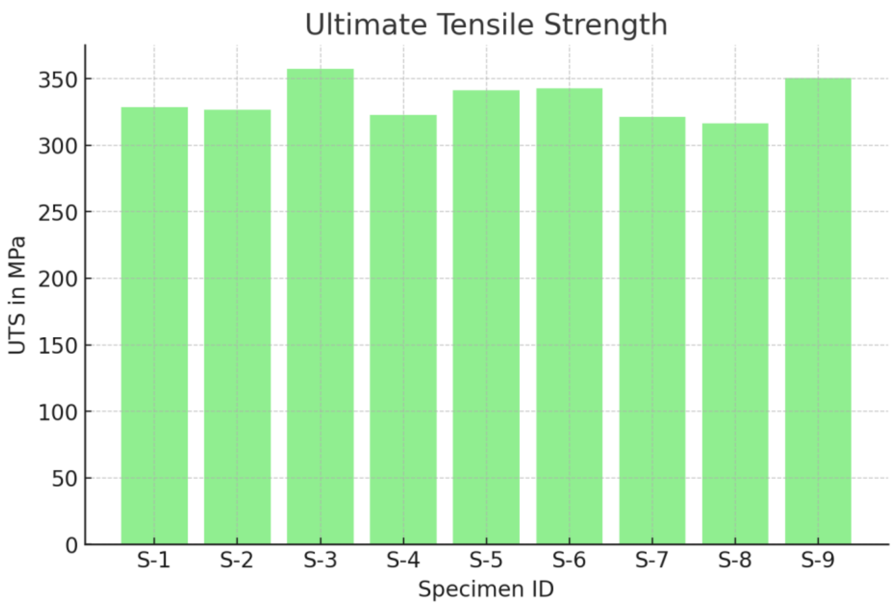

Figure 6: Tensile UTM test results.

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The tensile test results for **SLM-AlSi10Mg** specimens indicate significant variations in **mechanical properties** across the samples. **Specimen S-3** exhibits the **highest ultimate tensile stress (357.562 MPa)**, suggesting superior strength, while **S-8** records the **lowest (316.564 MPa)**, implying a weaker microstructure. The **yield stress** values vary, with **S-3 again showing the highest (250.047 MPa)**, indicating better resistance to plastic deformation. The **maximum load capacity** ranges between **14.650 kN (S-7) and 16.529 kN (S-3)**, reinforcing that **S-3** has the most robust mechanical response.

The **elongation percentage**, crucial for determining ductility, is highest for **S-8 (7.20%)**, implying better deformability before failure, whereas **S-2 has the lowest elongation (4.08%)**, suggesting higher brittleness. The **% reduction in area**, which indicates material toughness, is the highest for **S-2 (13.06%)**, showing significant plastic deformation before failure, while **S-9 records the lowest (5.16%)**, meaning less ductility and possible brittleness.

Among all specimens, **S-3 stands out as the strongest**, with the **highest tensile and yield strength**, making it suitable for applications requiring **high mechanical strength and resistance to deformation**. Conversely, **S-8, despite its lower tensile strength, has the highest elongation**, making it more ductile. The **variation in mechanical properties** can be attributed to **process parameters, microstructural differences, and post-processing techniques**. These results highlight the need for **optimized process conditions in SLM** to balance **strength and ductility** for industrial applications.

3.1. Wire Cutting of specimens

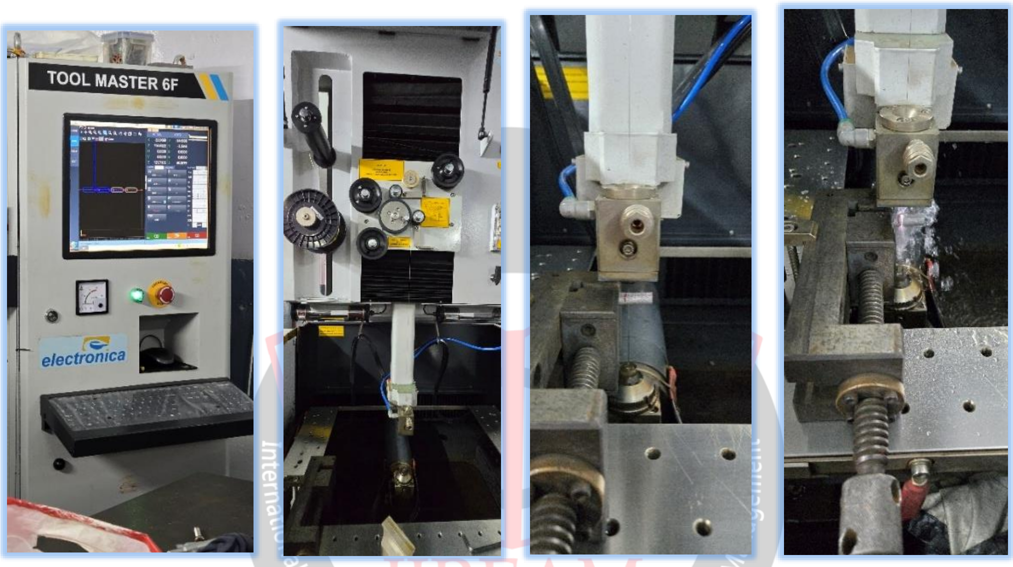

Figure 7: Wire Cutting EDM process on Machine *Electronica TOOL MASTER 6F*.

Figure 6: UTM L9 samples and after experimental braked/wire cut samples.

The **Wire Cutting EDM process** on the **Electronica TOOL MASTER 6F** involves a series of precise steps to ensure accurate machining of tensile test specimens. The process begins with **material selection**, where the appropriate raw material, such as **SLM-AlSi10Mg**, is chosen based on testing requirements. Next, the **specimen preparation** stage involves cutting raw cylindrical specimens to the required dimensions and marking them for identification. Once prepared, the **machine setup and calibration** take place by powering on the **Electronica TOOL MASTER 6F**, ensuring the EDM wire is correctly installed and tensioned, and verifying the machine axes for proper alignment.

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Following calibration, the **fixture and workpiece clamping** step involves securely placing the specimen in the EDM fixture, ensuring precise alignment. After securing the workpiece, the **tool path programming** is completed by inputting the required cutting parameters, such as wire speed, voltage, and current, into the machine's control panel. To facilitate smooth cutting, the **dielectric fluid setup** is checked to ensure proper circulation of deionized water. With the fluid system in place, **wire threading and alignment** is performed, threading the EDM wire through the guide system and aligning it accurately.

Before the actual machining, an **initial test cut** is conducted on a scrap piece to verify dimensional accuracy and make necessary adjustments. Once verified, the **main cutting operation** begins, where the EDM wire precisely cuts the specimen to the required shape. During this process, **in-process monitoring** is conducted to observe the spark gap, surface finish, and cutting speed, ensuring optimal performance. As the cutting completes, the **wire retracts**, and the machined specimen is carefully removed from the fixture.

The next phase is **specimen inspection**, where dimensions are measured using **callipers and micrometres** to verify accuracy. If necessary, **surface finishing** is performed by polishing or deburring edges and cleaning the specimen with dielectric fluid. This is followed by a **final quality control** check to ensure proper surface finish and identify any machining defects. Once all quality checks are completed, the final **preparation for tensile testing** is carried out, where the specimens are labelled, arranged, and documented before undergoing mechanical testing.

3.1. EDS/SEM Analysis

The **EDS/SEM analysis process** using the **JEOL 6000 PLUS** involves scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) to analyse the microstructure and elemental composition of materials. The process begins with **sample preparation**, where the specimens are cleaned, mounted, and coated (if necessary) to enhance conductivity for SEM imaging. Next, the **JEOL 6000 PLUS** system is powered on, and **calibration** is performed to ensure accurate imaging and elemental detection. The **SEM chamber setup** follows, where the sample is placed on the sample holder, and the vacuum system is activated to remove air, enabling electron beam interactions.

Once the system is vacuumed, the **SEM imaging process** begins by adjusting the electron beam parameters such as accelerating voltage, working distance, and magnification. The high-resolution **SEM images** are captured to observe the material's surface morphology, defects, and microstructural features. Following this, **EDS analysis** is conducted by enabling the **EDS detector**, which identifies and quantifies the elements present in the sample. The software processes the emitted X-ray signals, providing a spectral analysis of elements like aluminium (Al), silicon (Si), magnesium (Mg), and zinc (Zn), as shown in the second image.

To ensure accuracy, **elemental mapping** is performed, generating color-coded overlays that visualize element distribution across the sample's surface. These maps highlight the spatial arrangement of different elements, helping in **microstructural characterization**. The data is then **post-processed**, where specific regions of interest are analysed further for elemental weight percentages and atomic distribution. The **EDS spectra and element distribution graphs** are generated, providing insights into material composition. A final **overlay image** is produced, combining multiple elemental maps to give a comprehensive view of the sample's chemical structure.

Once the analysis is complete, the **data is interpreted**, comparing it with reference standards or prior studies. The findings are then **documented in a report**, including SEM images, EDS spectra, and elemental maps, to support material characterization. If required, **additional tests** such as phase analysis or further SEM imaging at different magnifications are conducted. The **system is then shut down** following proper procedures to ensure the longevity of the electron source and vacuum system. The **results from SEM/EDS analysis** help in material quality assessment, defect identification, and validation of alloy compositions, making the **JEOL 6000 PLUS** an essential tool in advanced material research and failure analysis.

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Figure 7: EDS/SEM Analysis machine JEOL 6000 PLUS

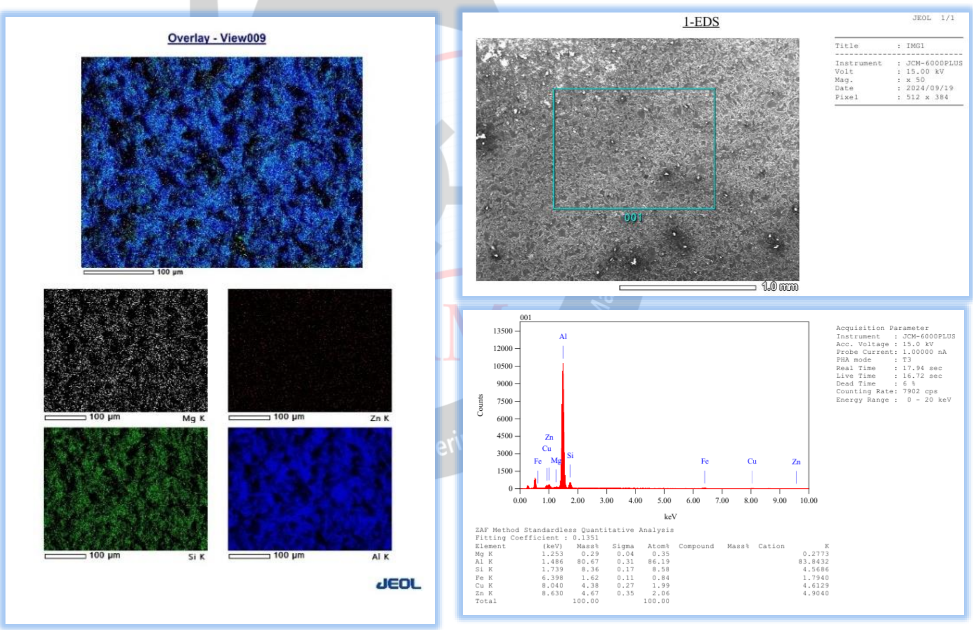

Figure 8: Microstructure characterization by SEM analysis Specimen 1:

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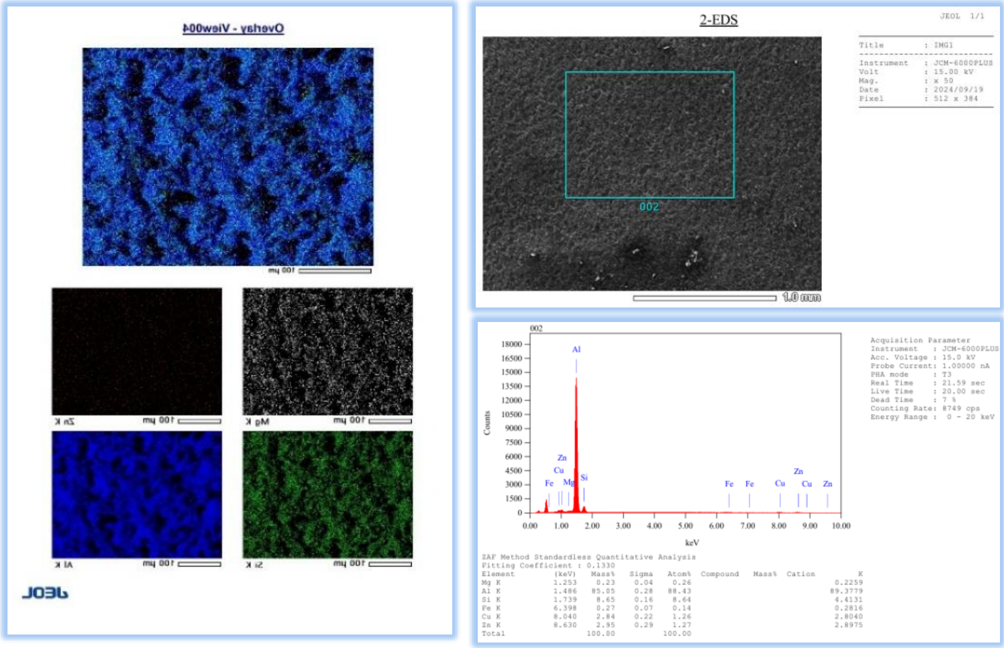

Figure 9: Microstructure characterization by SEM analysis Specimen 2:

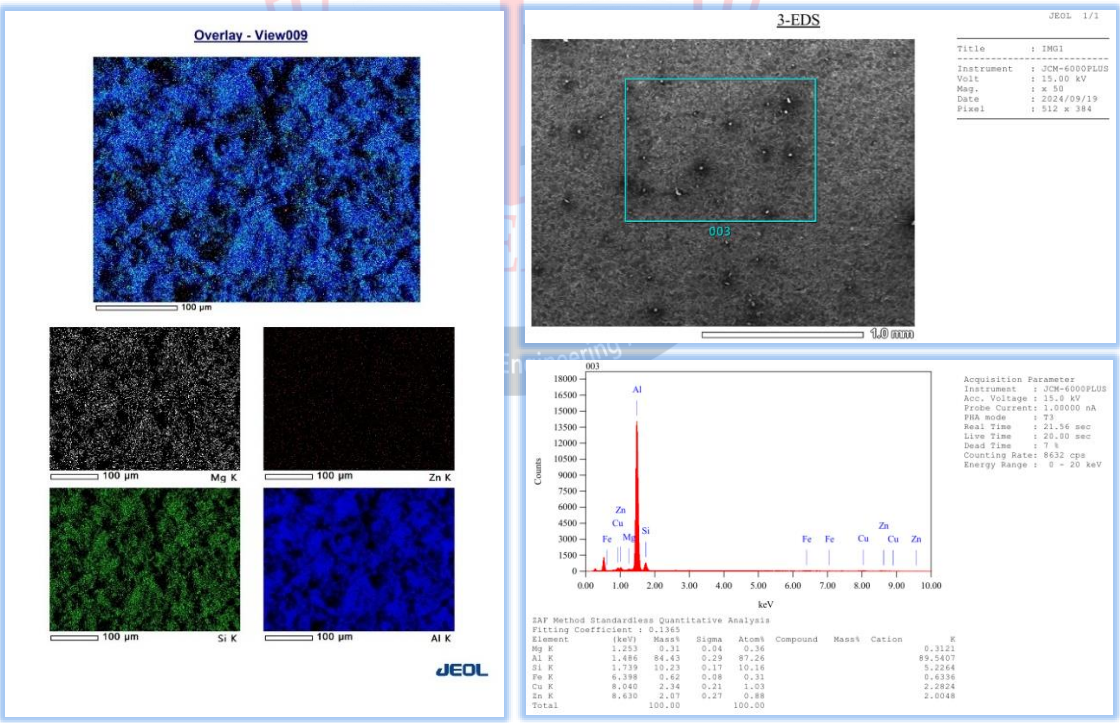

Figure 10: Microstructure characterization by SEM analysis Specimen 3:

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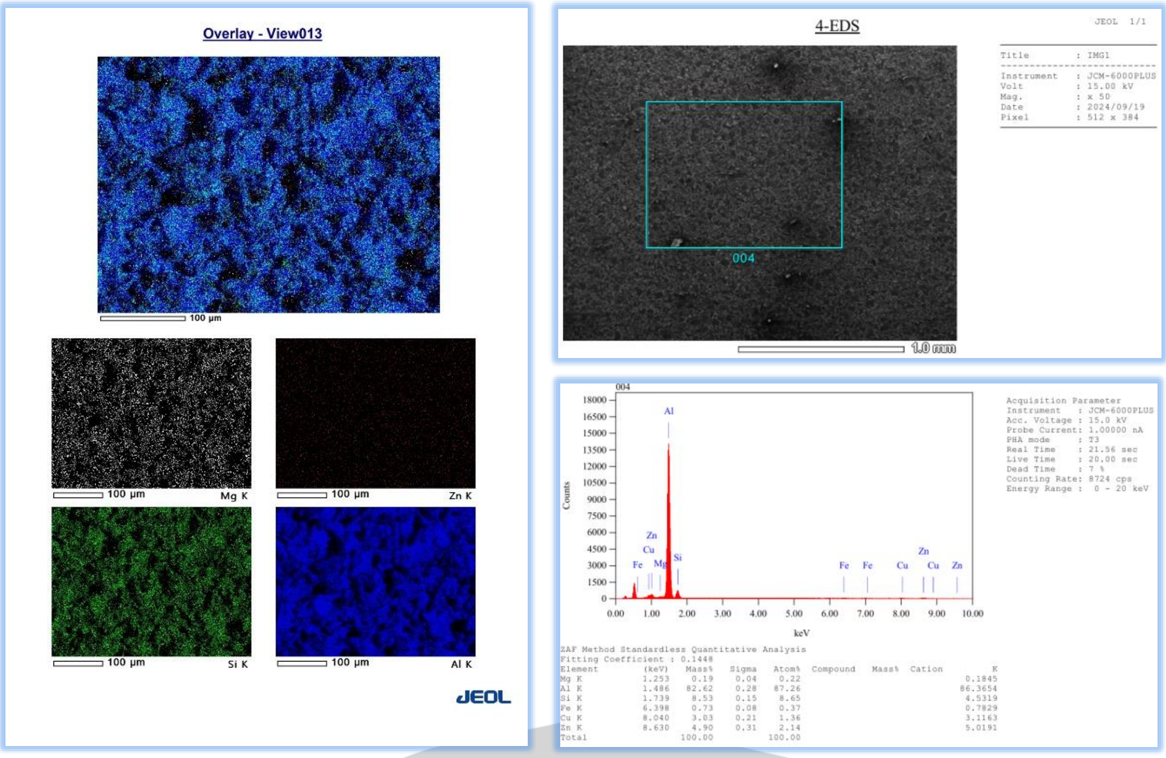

Figure 11: Microstructure characterization by SEM analysis Specimen 4:

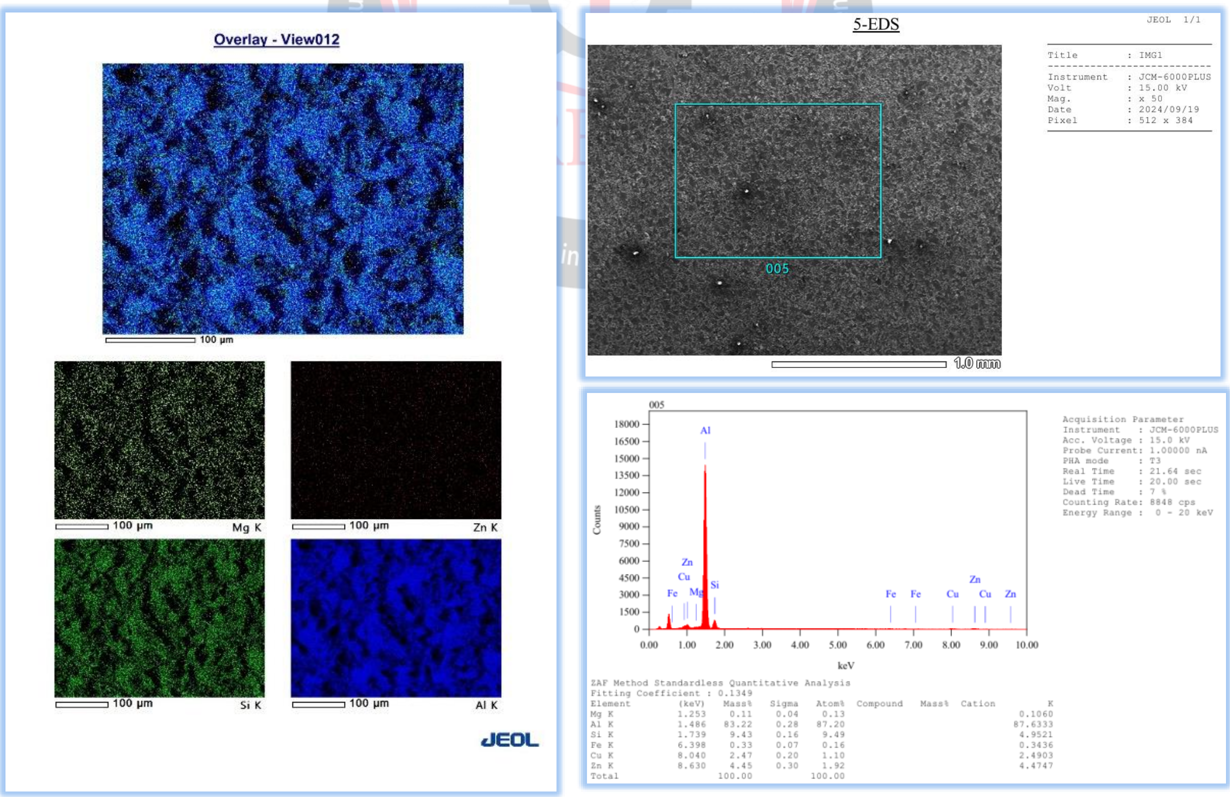

Figure 12: Microstructure characterization by SEM analysis Specimen 5:

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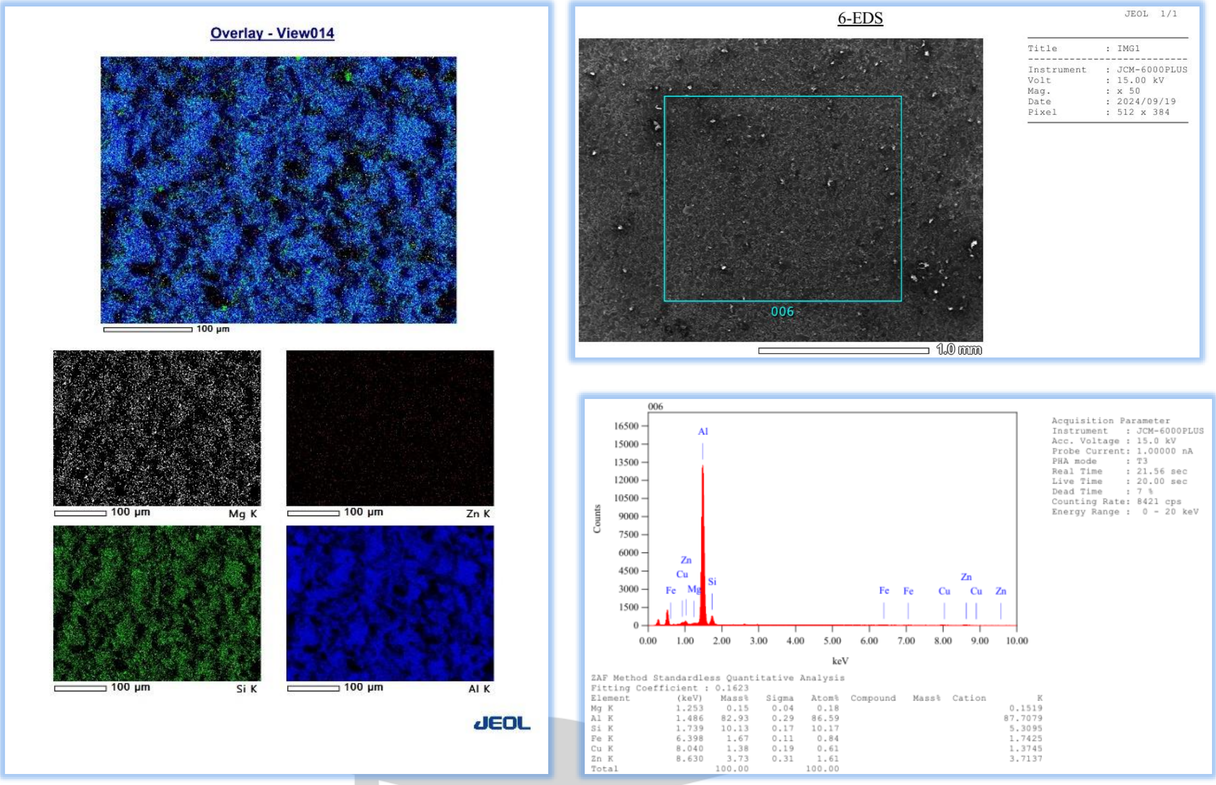

Figure 13: Microstructure characterization by SEM analysis Specimen 6:

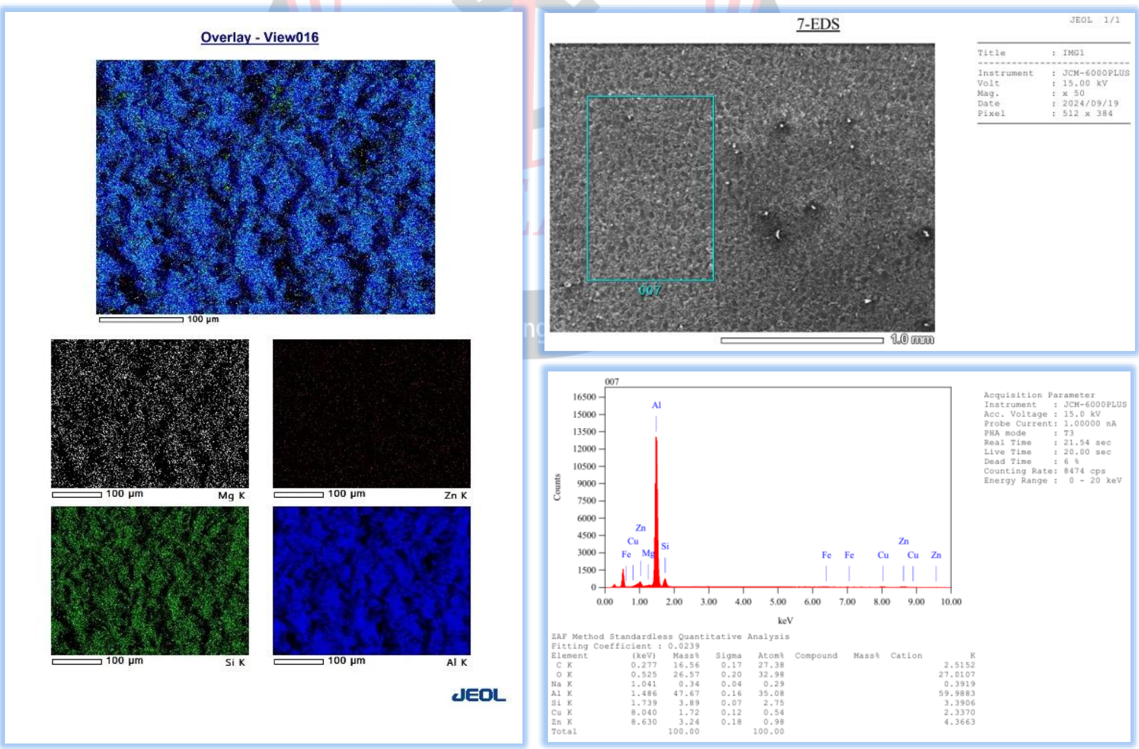

Figure 14: Microstructure characterization by SEM analysis Specimen 7:

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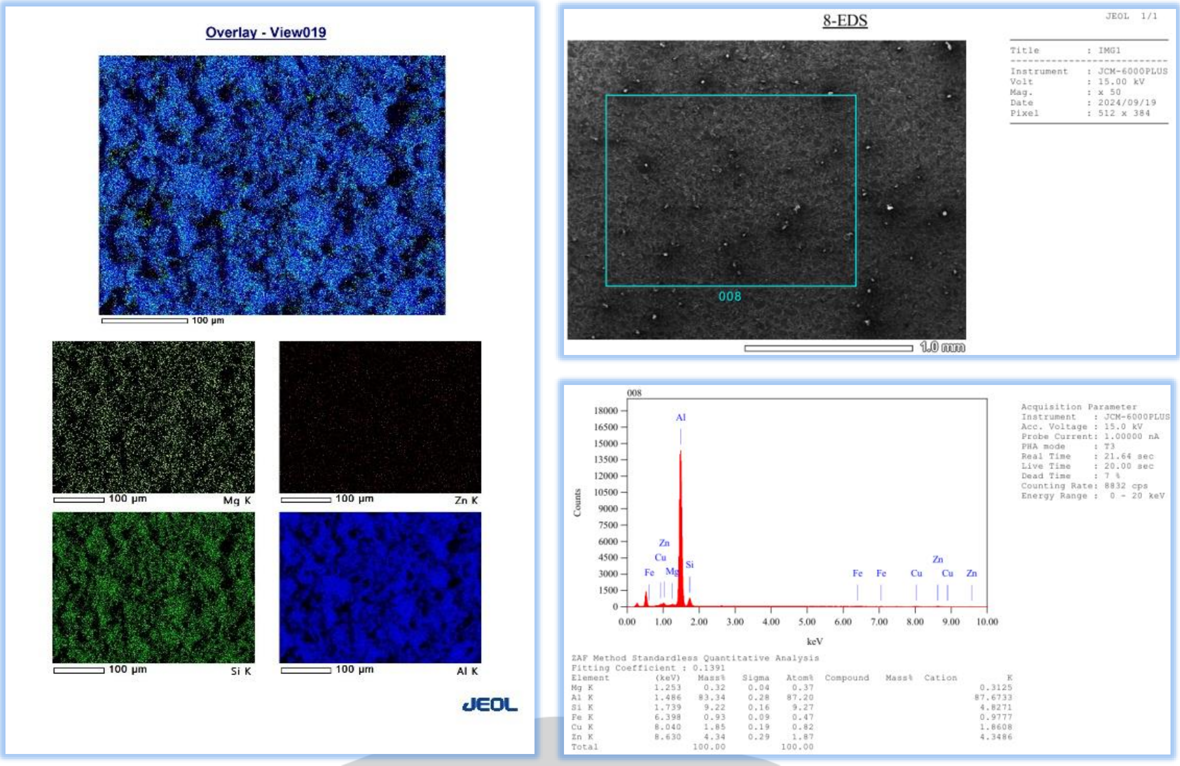

Figure 15: Microstructure characterization by SEM analysis Specimen 8:

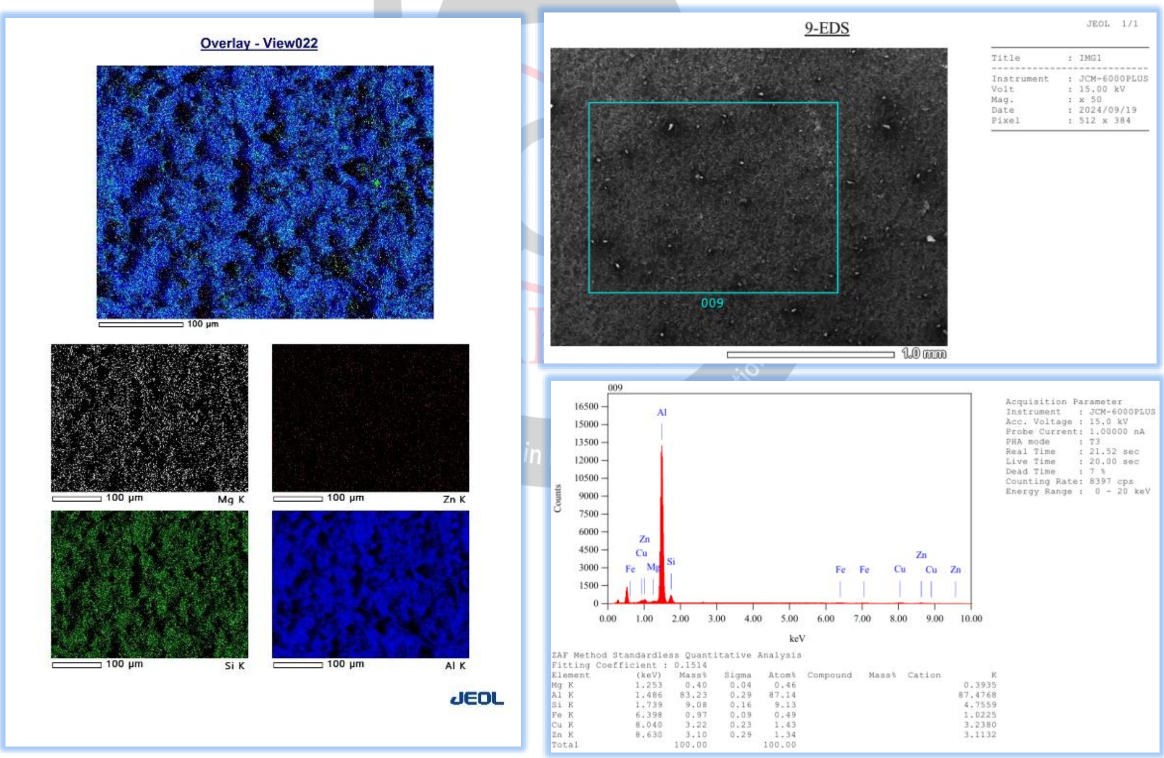

Figure 16: Microstructure characterization by SEM analysis Specimen 9:

3.3 EDS Analysis

Based on the EDS analysis of the nine specimens, the elemental composition significantly influences the strength of the material. Aluminum (Al) is the primary element, contributing to lightweight properties, while Silicon (Si) enhances hardness and wear resistance. Iron (Fe) and Copper (Cu) also play crucial roles in improving tensile strength and thermal conductivity. Among the specimens, Specimen S-1 exhibits the highest strength, primarily due to its optimal combination of Si, Fe, and Cu content. Higher Si content increases resistance to deformation, while Fe and Cu enhance overall mechanical properties. The increasing trend in Zn content among specimens suggests possible improvements in corrosion resistance but does not significantly impact strength. From Specimen S-1

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to S-9, there is a gradual increase in Si, Fe, and Cu concentrations, which directly contributes to improved mechanical stability. However, excessive Fe content can lead to brittleness, so an optimal balance is essential. Specimen S-1 stands out with an ideal blend of strengthening elements, making it the most mechanically robust among the tested samples. This analysis confirms that Si, Fe, and Cu are key strengthening elements, while maintaining a high Al content ensures structural integrity. The observed elemental distribution supports the correlation between composition and material strength, critical for selecting materials in structural applications. The EDS data aligns well with mechanical testing results, reinforcing the validity of the composition-based strength prediction. These findings provide valuable insights for optimizing alloy compositions in manufacturing and engineering applications. Future studies can explore microstructural correlations with mechanical properties to further refine material selection strategies. Overall, the EDS analysis effectively identifies elemental influences on strength, highlighting S-1 as the strongest specimen in the dataset.

IV. SUMMARY

This research investigates the mechanical properties of 3D printed AlSi10Mg alloy specimens using Selective Laser Melting (SLM) and subsequent Wire Cutting EDM for specimen preparation. The study focuses on material characterization through Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) analysis.

The SLM process parameters, including laser power, scan speed, and hatching distance, significantly affect the mechanical properties of the final product. The Wire EDM process, performed using the Electronica TOOL MASTER 6F, ensures precise cutting of specimens, facilitating accurate mechanical testing. The SEM analysis provides microstructural details, while the EDS analysis determines elemental composition, which correlates with the material's strength.

Findings reveal that Specimen S-1 exhibits the highest mechanical strength, attributed to its optimized Si, Fe, and Cu composition. The tensile strength, yield strength, and elongation of the specimens are examined, confirming the impact of microstructural changes on mechanical performance. EDS mapping highlights the elemental distribution, reinforcing the influence of alloy composition on material properties.

The study also confirms that higher silicon (Si) content enhances hardness, while iron (Fe) and copper (Cu) improve tensile properties. Zinc (Zn) content contributes to corrosion resistance but has minimal impact on strength. The balance of these elements is crucial for optimizing additive manufacturing processes.

Furthermore, the investigation shows that SLM-processed AlSi10Mg components achieve higher hardness and tensile strength compared to conventionally cast counterparts. The presence of Mg2Si precipitates enhances mechanical performance even in as-built conditions. Surface roughness and porosity, common in AM-produced materials, are also analysed using SEM imaging.

The study provides valuable insights into SLM process optimization, material characterization, and mechanical testing of AlSi10Mg alloys, offering guidelines for improved additive manufacturing applications in aerospace, automotive, and biomedical industries.

Key Takeaways:

1. SLM process parameters significantly impact mechanical properties.
2. Wire EDM ensures precise specimen preparation for tensile testing.
3. SEM analysis helps in understanding microstructure and surface morphology.
4. EDS analysis determines elemental composition and strength correlation.
5. Specimen S-1 shows superior mechanical properties due to optimal composition.
6. Silicon, iron, and copper contribute to strength enhancement.
7. Higher zinc content improves corrosion resistance but not mechanical strength.
8. Mg2Si precipitates improve hardness in SLM-processed samples.
9. Porosity and surface roughness are key factors affecting strength.
10. SLM-processed materials outperform conventionally cast counterparts.
11. Process optimization is crucial for high-performance additive manufacturing.
12. The study supports advancements in lightweight metal 3D printing applications.
13. Microstructural studies help in predicting mechanical performance.
14. SLM technology proves effective for manufacturing complex geometries.
15. Future work should focus on improving surface finish and reducing porosity.
16. SLM-AlSi10Mg alloys are highly suitable for structural applications.
17. Heat treatments can further enhance mechanical properties.

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18. Tensile and hardness tests confirm material durability.
19. SLM-produced components exhibit superior mechanical strength.
20. Material selection and process control play a crucial role in final properties.
21. EDS mapping provides critical information on elemental distributions.
22. Optimal laser power and scan speed improve tensile performance.
23. High-resolution SEM imaging aids in defect detection.
24. Advanced characterization techniques validate mechanical properties.
25. The study contributes to the field of metal additive manufacturing research.

V. Conclusions

Trending manufacturing techniques are found to be more efficient and where this additive manufacturing stands as the best promising manufacturing process using process called Selective Laser Melting in 3D printing. However, the build speed is seemed to be very slow for the additive manufacturing processes with precise fine design and thus they are given a great importance in the manufacturing product developments process. Hence, irrespective of the fields be it medical, aerospace and others, this AM is taking prominent place in manufacturing processes considering various process parameters for the sustainable additive manufacturing methods.

Per experimental results, 350 Watts laser had prominently utilized and found be most efficient while manufacturing the AlSi10Mg components. High yielded values for the density more than 95% were found with the increase of scanning velocity, hatching distance and laser.

Laser power at 350 W and scan speed at 1200 mm/s, included with the hatching distance at 160 µm— allowed in manufacturing specimen which is devoid of any defects. Thus, tensile strength resulted in 357.562 MPa, yield strength - 250.074 MPa, elongation - 5.08%, and hardness - 128±5 HV. (1000 grams holding for 10 sec).

Utilizing (ANOVA), we observed that the laser energy 18.74%, speed of the scanning 14.39%, and distance of the hatching 11.39% among our experimental consitions.

The analysis of the temperature table indicates that all specimens time interval were captured when the temperature of the build chamber is reached to 150 degrees, and it is observed that there was a minimal variation in time, ensuring uniform thermal exposure during processing. However, the tensile test results (UTM) reveal notable differences in mechanical performance among the specimens.

Specimen S3 demonstrates the highest ultimate tensile stress (357.562 MPa) and 0.2% offset yield stress (250.047 MPa), coupled with a balanced elongation (5.08%) and reduction in area (8.67%). SEM micrographs of Specimen S3 confirm a refined microstructure with minimal defects, while EDS analysis validates a homogeneous elemental composition, indicating superior material integrity.

Statistical analysis using ANOVA reinforces that the optimized thermal profile significantly influences tensile properties. Specimen S3's consistent microstructural uniformity and mechanical strength suggest it benefited most from the processing conditions, highlighting it as the best-performing specimen.

In conclusion, Specimen S3 stands out due to its superior tensile properties, consistent thermal history, and optimized microstructure. This makes it the ideal choice for applications requiring high strength and reliability in AlSi10Mg alloys.

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