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Complete List of Authors:	C, MATHALAI SUNDARAM; Nadar Saraswathi College of Engineering and Technology, Mechanical Engineering B, Radha Krishnan; Nadar Saraswathi College of Engineering and Technology, Mechanical Engineering S, HARIKISHORE; Nadar Saraswathi College of Engineering and Technology Vijayan, V.; K Ramakrishnan College of Technology, MECHANICAL
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Wear Behavior of B_4C reinforced Al6063 matrix composites electrode fabricated by stir casting method

[1]C.Mathalai Sundaram, [2*]B.Radha Krishnan, [3]S.Harikishore, [4]V.Vijayan

[1]Principal, Nadar Saraswathi College of Engineering and Technology, Theni, India

[2*]Assistant Professor, Nadar Saraswathi College of Engineering and Technology, Theni, India

[3]Assistant Professor, Nadar Saraswathi College of Engineering and Technology, Theni, India

[4]Professor, K.Ramakrishnan College of Technology, Trichy, Tamilnadu, India

Corresponding Author mail ID: radhakrishnankrce@gmail.com

Abstract

The aim of the study is to predict the surface topological characteristics of Al-B_4C composite electrodes and the OHNS Die steel in the Electrical Discharge Machining (EDM) Process. The surface characteristics of Composite electrodes are evaluated by using Scanning Electron Microscopy (SEM) and EDAX Analytical Method. Surface roughness and hardness of the OHNS die steel was measured by the Stylus probe and Brinnel hardness. The composite electrodes prepared by the Aluminium 6063 and B_4C materials. Both elements are mixed at molten state in the stir casting process at different compositions. The chemical composition properties of the Composite electrode is analyzed by the SEM and EDAX testing. The surface Roughness of the OHNS steel measured by the Brinell hardness tester. Based on the SEM and EDAX results, the 92% Al 8% B_4C was producing the good surface roughness in OHNS die steel.

Key Words: Composite Electrode; Electrical Discharge Machining; Scanning Electron Microscopy; EDAX Analysis.

1. Introduction

EDM is a widely used unconventional machining process by thermoelectric energy sources. During the machining process, the spark occurs between the tool and work material. So the electrode tool and workpiece should be the electrically conductive materials. OHNS steel used as the workpiece in the EDM process for its high industrial usage. Normally the Brass, Copper, Copper alloy, Molybdenum, Silver, Graphite, and Tungsten used as the electrode in the EDM process. In this research, Al6063 as the major component of a composite electrode. B_4C is added with Aluminium to improve the hardness of the electrode. Industries are expected the high strength Temperature resistance materials for the EDM process. The copper and copper-based materials electrodes are one of the high-performance electrodes in the EDM process (Mahajan R et al 2018).

Fig 1. Work Piece OHNS Die Steel

Ti-6Al-4V materials carried out in the micromachining process are very difficult. So this study has been recognized the micro Electrical Discharge Machining is the most suitable method for Ti-6Al-4V (Tiwary A.P et al 2018). The composite electrode prepared by Pseudo-alloy for the EDM machining process, especially for the dissimilar materials. After the machining process, the workpiece surface roughness and tool conditions are evaluated (Grisharin A.O et al 2019). The experiments were conducted on EDM Milling at various peak current, pulse duration, pulse interval, speed, and diameter of the electrode (Dhakry N.S et al 2014). There is more number of fabrication techniques adopted for Al MMCs. One of them will be mechanical alloying through powder metallurgy. During alloying, some agents like methanol shall be added to improve the bonding nature of the reinforcing elements (Canakci A et al 2012). During the production of Al-MMCs, through powder metallurgy milling time, compaction pressure, sintering temperature and sintering time play a vital role in deciding microstructure, mechanical properties, even distribution of reinforcing materials (Canakci A et al 2012). The volume fraction of the addition of reinforcements in the Al matrix shall be varied from 5 to 15% (Canakci A et al 2015). Liquid state processing is one of the old and easiest methods for the manufacturing of Al-based MMCs. B_4C of different sizes shall be incorporated into commercial aluminium alloys with varying volume percentages. The result revealed that the dispersion of boron carbide particles with larger size was good, which improves the hardness along with porosity but decreases the yield strength when compared with smaller sized particles (Canakci A et al 2014) . The problem with fine particles is that they will lead to agglomeration. So finally, to optimize the size, the volume of the B_4C particles ANN shall be successfully utilized (Canakci A et al 2013, Canakci A et al 2014).

2. Experimental Methodology

In this process, the Al6063 and B_4C selected as the base material to produce the electrode. The Al 6063 was Pre-heated at 450°C, and B_4C powder was heated up to 900oC. Aluminum and B_4C mixed at Different proportions are 100% Al, 98% Al 2% B_4C, 96% Al 4% B_4C, 94% Al 6% B_4C, 92% Al 8% B_4C.

Fig 2. Stir casting setup used to fabricate the composite samples

After that, Al 6063 and B_4C mixed mechanically. After that, the Al-B_4C composite heated up to the melting temperature (1200°C) in Electric Furnace. The molten composite mixed properly with a stir at 400rpm, while the temperature of the furnace controlled at 760°C. Finally, the molten metal poured into the mould cavity and allowed it solidified.

Fig 3. AL6063, B_4C Electrodes

In this work, the OHNS die steel chooses at the workpiece. Normally the OHNS die steel used for milling cutter and gauging tools. It contain the carbon rate is 0.9% - 1.3%, Tungsten rate is 0.4% - 0.8% and chromium rate is 0.5%. The B_4C particles were purchased from Alfa Aesar Private Limited, London, with 44 microns and approximately 325 mesh. The experimental density was taken and listed in Table 2. Experimental density was taken by the Archimedes principle. We can see that due to the increase in the addition of B_4C, the density of the samples decreased. The experimental densities were close to theoretical due to the smaller size of the particles, which removes the formation of porous in the sample. The same is shown in fig. 4.

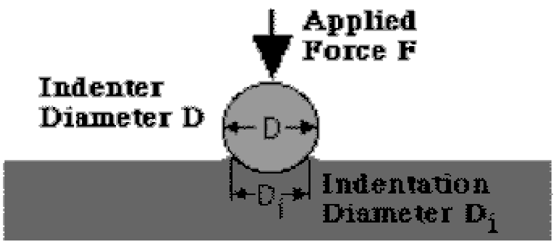
Table 1.Chemical Composition of OHNS Die Steel

Table 2.Theoritical and Experimental Density

Fig 4. SEM image of formed AL6063, B_4C Electrodes

3. Result and Discussion

After the machining process, the workpiece OHNS die steel hardness value predicted by using Brinell hardness tester. The test carried out to various proportions electrode listed out in the table



$$BHN = \frac{F}{\frac{\pi}{2} D \cdot (D - \sqrt{D^2 - D_i^2})}$$

Where

F – Load applied on the indenter in kg

D – Diameter of steel ball indenter in mm

d – Diameter of ball impression in mm

Fig 5. Brinell Hardness Test on OHNS machining surface

Table 3. Brinell hardness test for Al-B_4C Electrodes

Table 4. Brinell hardness Test

Table 3 shows the Brinell Hardness Number of the casted MMCs. The increase in the hardness of the samples was due to the addition of reinforcements of B_4C. It reaches maximum according to the volumetric increase of the reinforcements, and the increment saturates at 10% additions. Table 4 results show the 100% Aluminum electrode was low hardness value, and it may be broke during the high machining process. 98 % Al 2 % B_4C contains the good hardness value compare with the other composition electrodes.

The surface roughness value is one of the major parameters to decide the quality of the product. In the present paper, the OHNS steel was machined by the different chemical composition electrodes in Electrical Discharge Machining. The OHNS steel materials surface quality measures by the Mitutoyo Stylus probe equipment. The surface roughness value is shown in table 5. The surface roughness increases with the reinforcements. This is due to the agglomeration of smaller sized particles. The accumulation of these reinforcements at grain boundaries and uneven distribution. This non-homogeneous mixture was the reason for unusual roughness in the metal matrix composites. Table 6 shows the mass loss during the sliding wear test for different percentages of B_4C.

Table 5. Surface Roughness Test

Table 6. Wear Rate of the MMCs at 600 rpm

a) SEM analysis

Scanning Electron Microscopy used to analyze the surface topology and defects in Aluminum composite electrodes. X-ray is the major source of the SEM, which is used to predict the machining surface quality. The range of the SEM is 200 micrometers.

Fig 6. AL 6063 100 % (Pure Aluminum)

Al 6063 100% electrode purely made with only aluminum material. The SEM image 6 shows the Chemical Composition of the composite electrode (Al6063 100% electrode). The surface analysis shows some micro-cracks over the electrode surfaces.

Fig 7. 98 % AL 6063 2% B_4C

In figure 7 shows the SEM analysis of the AL 6063 98 % B_4C 2% composite electrode. More micro-cracks and improper surface irregularities are present in the composite electrode, so it leads the poor machining surface on the OHNS steel.

Fig 8. 96 % AL 6063 4% B_4C

Figure 8 shows the SEM analysis of 96 % AL 6063, 4% B_4C composite electrode. Blowholes and major cracks are present over the composite surfaces. Those defects affected the machining accuracy in the EDM process.

Fig 9. 94 % AL 6063 6% B_4C

Figure 9 shows the SEM analysis of the AL 6063, 94 %, B_4C 6%composite electrode. SEM images the B_4C materials have not mixed properly; it was indicated by the SEM analysis.

Fig 10. 92 % AL 6063 8% B_4C

The above SEM images results show the bonding compositions of Al and B_4C. Figure 10 represents the Composite electrode 92 % Al and 8% B_4C was good chemical composition, which is shown in the SEM image. This composite electrode produces the minimum surface defects on OHNS steel. Based on the above testing images, the good surface characteristics achieved through the 92% Al, 8% B_4C.

b) EDAX Testing

EDAX method used to identify the elemental compositions of the materials. The composition of the materials calculated based on the number of emitted x-rays versus their energy. EDAX test carried out for different composition electrodes, which used to predict the materials percentage distribution in the electrode. Figure 11 to 15 shows the compositions of the materials in different composite electrodes. B_4C mixed with Al for improving the strength of the electrode, which withstands the machining process in EDM.

Fig 11. EDAX images 100% Al 6063

Fig 12.EDAX images 98 % Al 6063, 2% B_4C

Fig. 13. EDAX images Al 6063 96 %, B_4C 4%

Fig 14. EDAX images 94 % Al 6063, 6% B_4C

Fig 15. EDAX images Al 6063 92 %, B_4C 8%

From the above results, the 92% Al, 8% B_4C electrode produces the good surface morphological in OHNS steel.

4. Conclusion

The EDM process induces surface damage in the electrode; hence, the electrode lifetime is reduced. We have to check the testing of the electrode for the following tests. The following results are obtained as follows in this result, and we can choose the best electrode.

1. Hardness is the property of the material. All the electrodes are tested in the Brinell Hardness Machine. AL6063 98%, B_4C 2% holds more Hardness number than all other electrode Machining.

2. Surface roughness is the type of material property it is done by surface roughness testing machine. Here we check the in OHNS steel material the shows the good surface roughness.

3. SEM is one type of testing to know the detailed view of the cross-sectional view of the electrode. Here the electrode is zoomed up to 200 µm. The AL6063 92%, B_4C 8%, is the best surface image on the magnification image.

4. EDAX is the one type of test here X-ray is used to find the various types of materials inside into it. Here the AL6063 92%, B_4C 8%**,** is the best electrode in this test.

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List of Tables

Table 1.Chemical Composition of OHNS Die Steel

Carbon	Chromium	Tungsten	Iron
0.9 - 1.3%	0.5%	0.4 - 0.8%	Rest

Table 2.Theoritical and Experimental Density

Type of Specimen	2	4	6	8
Theoretical	2.696	2.692	2.688	2.684
Experimental	2.59	2.56	2.52	2.45

Table 3. Brinell hardness test for Al-B_4C Electrodes

Type of specimen	Diameter of ball	Diameter of indentation in mm	Load (p) N	Hardness BHN
0	10	5.2	300	26.02
2	10	4.9	300	29.16
4	10	4.6	300	34.06
6	10	4.41	300	35.13
8	10	4.54	300	36.02

Table 4. Brinell hardness Test

Type of specimen	Diameter of ball	Diameter of indentation in mm	Load (p) N	Hardness BHN
0	10	4.5	300	35.70
2	10	3.2	300	72.64
4	10	3.8	300	50.92
6	10	3.7	300	53.85
8	10	3.8	300	50.92

Table 5. Surface Roughness Test

Percentage	Ra	Rq	Rz
0	3.537	4.146	14.705
2	3.655	4.604	18.022
4	4.048	4.779	17.245
6	3.987	4.971	20.490
8	3.764	4.433	15.337

Table 6. Wear Rate of the MMCs at 600 rpm

Percentage	Mass Loss in grams
0	0.44
2	0.41
4	0.37
6	0.36
8	0.35

List of Figures

Fig 1. Work Piece OHNS Die Steel

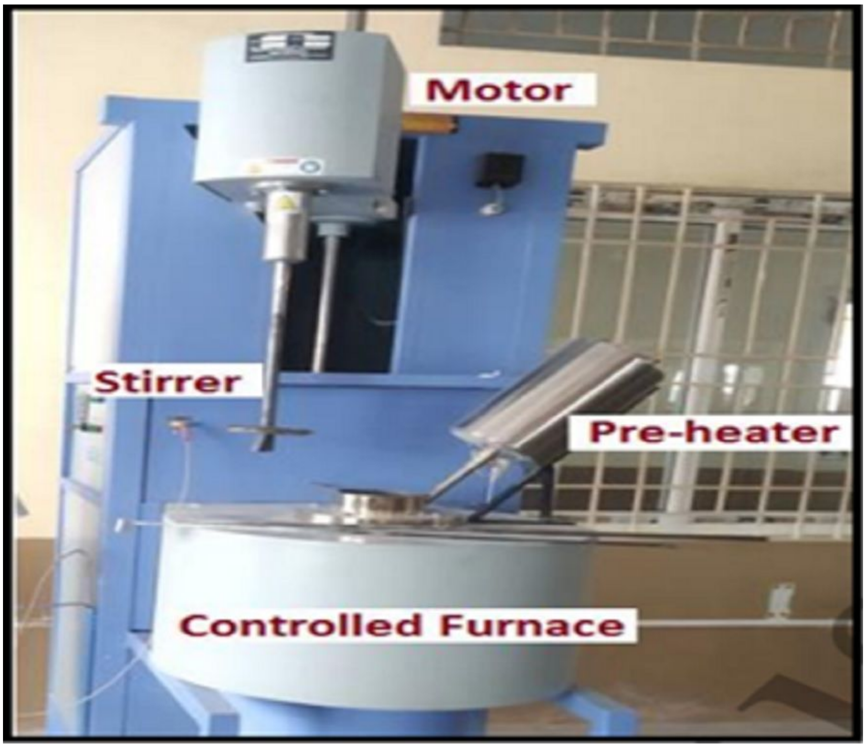


Fig 2. Stir casting setup used to fabricate the composite samples

Fig 3. AL6063, B_4C Electrodes

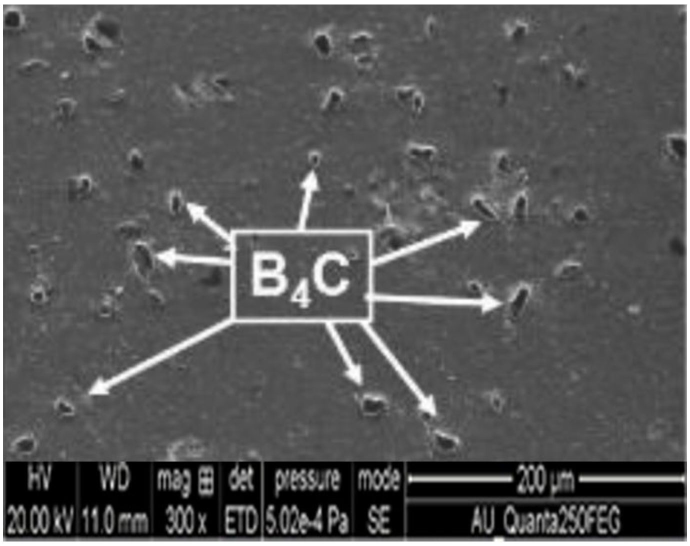


Fig 4. SEM image of formed AL6063, B_4C Electrodes

Fig 5. Brinell Hardness Test on OHNS machining surface

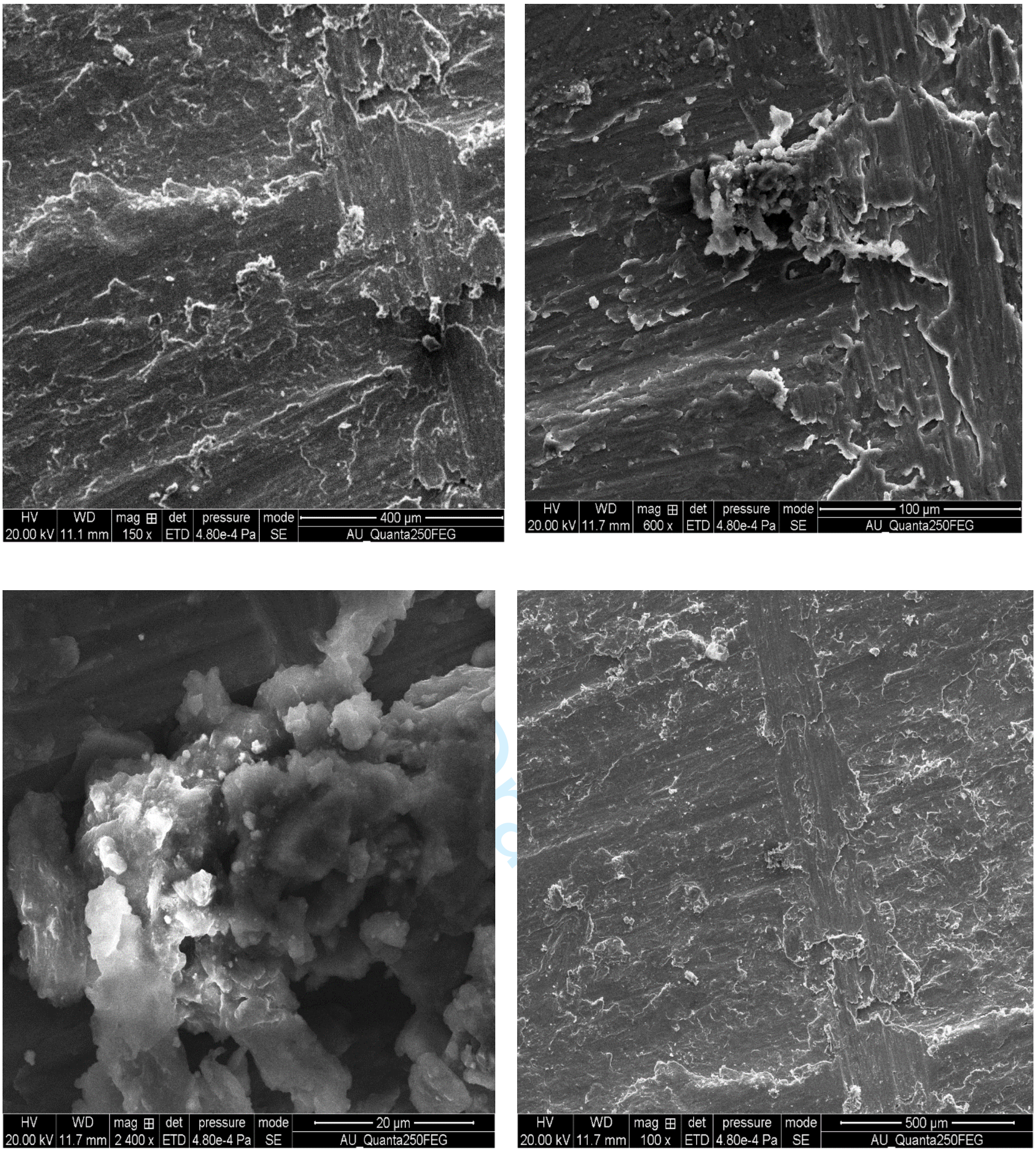


Fig 6. AL 6063 100 % (Pure Aluminum)

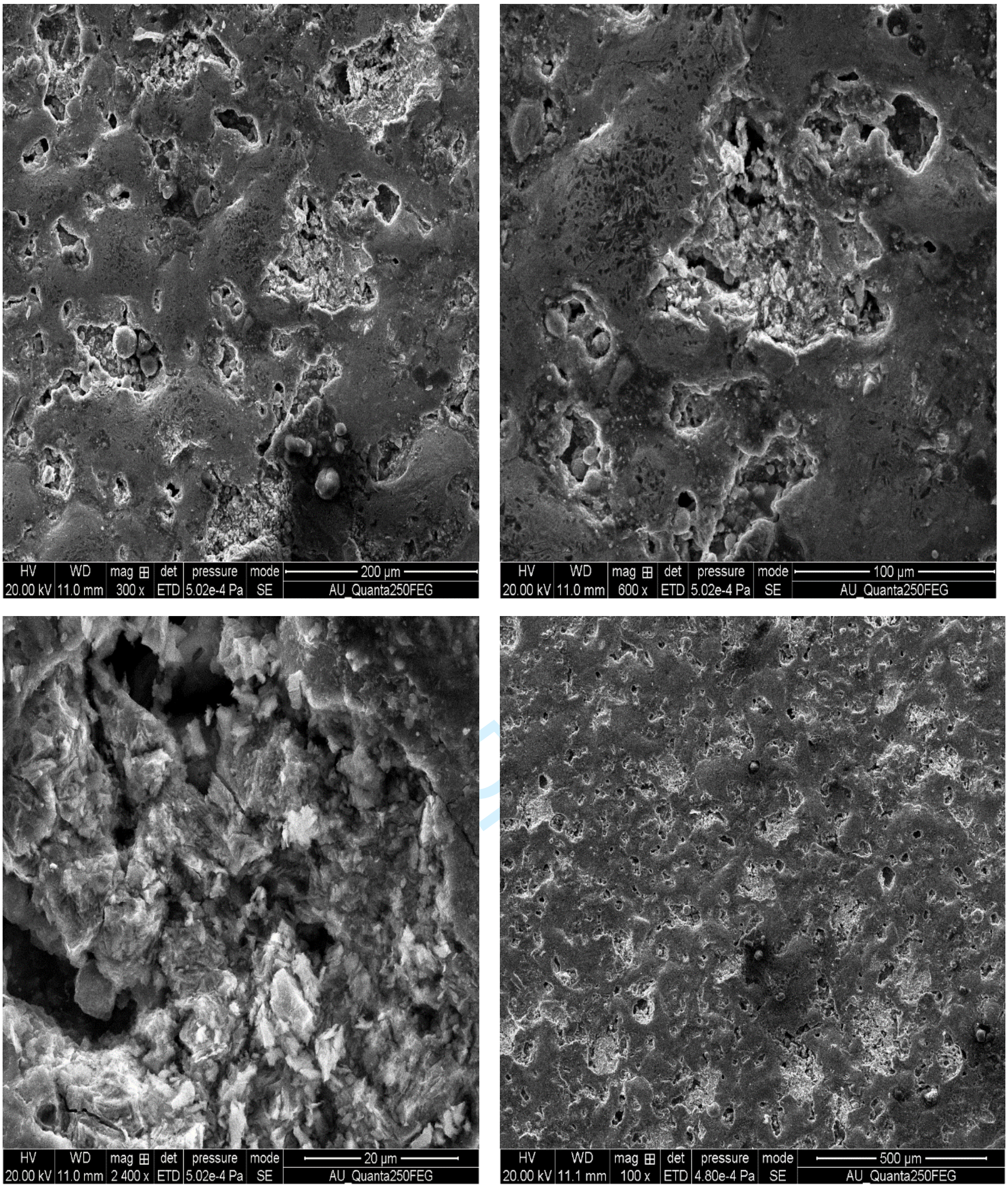


Fig 7. 98 % AL 6063 2% B_4C

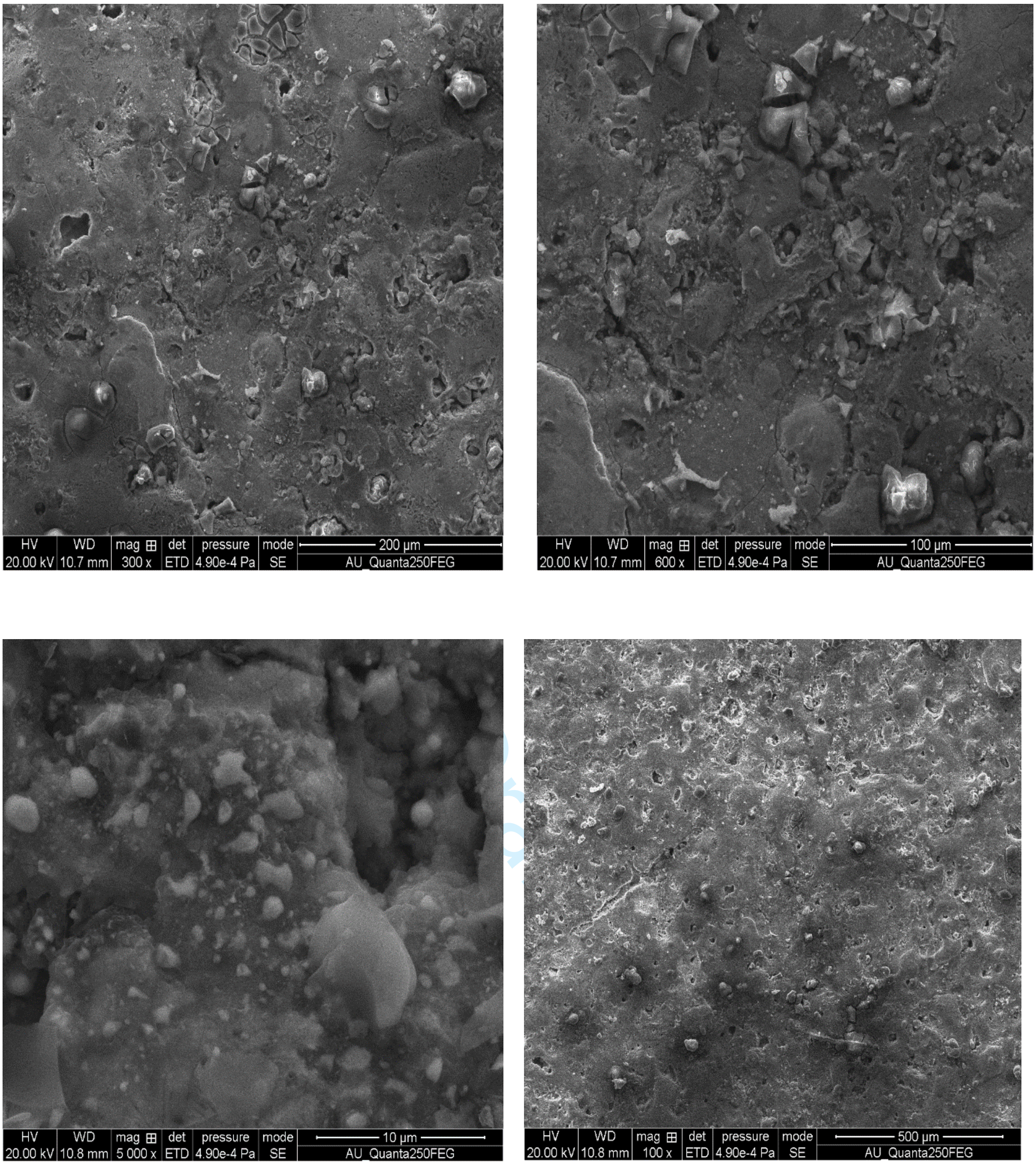


Fig 8. 96 % AL 6063 4% B_4C

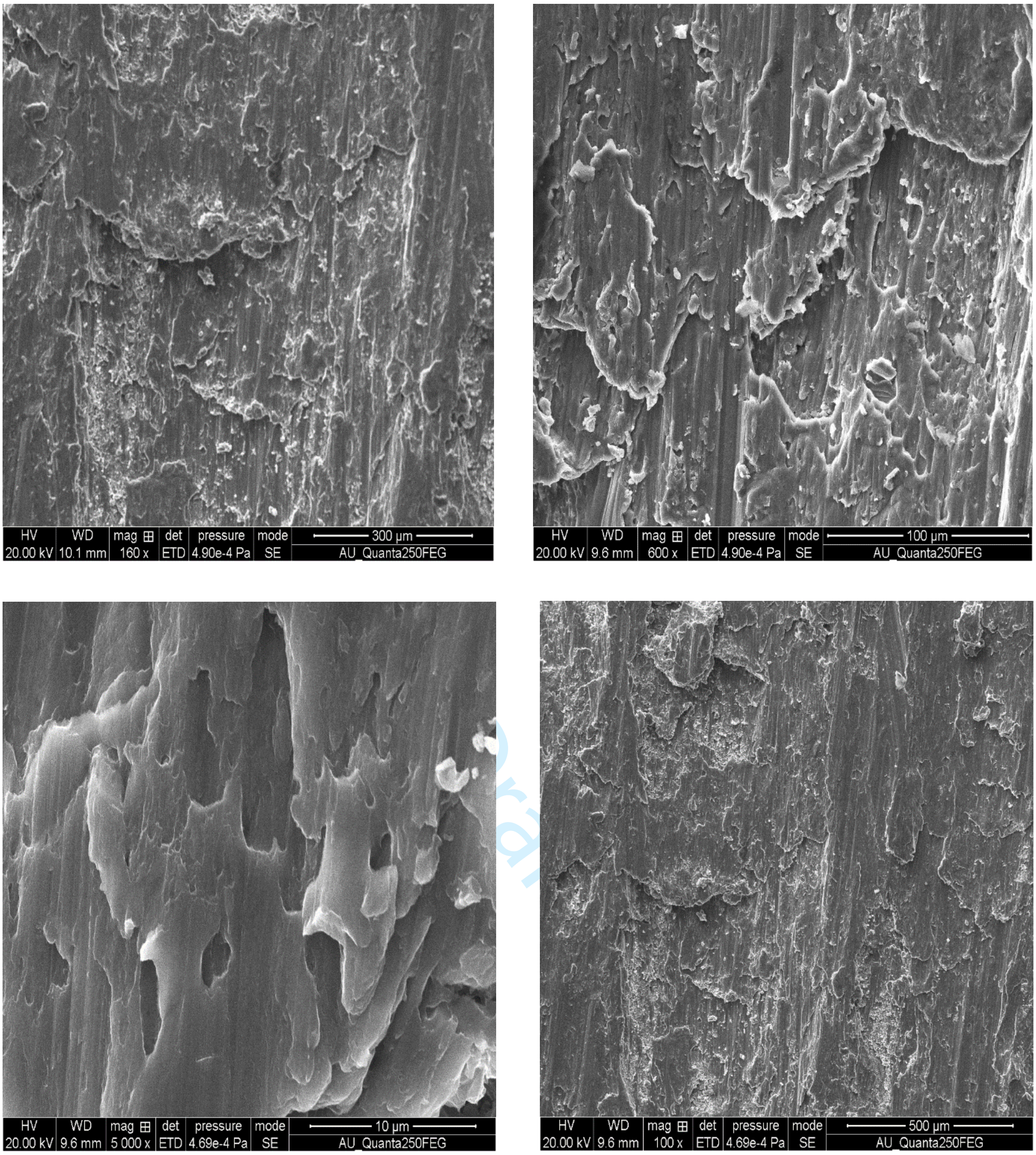


Fig 9. 94 % AL 6063 6% B_4C

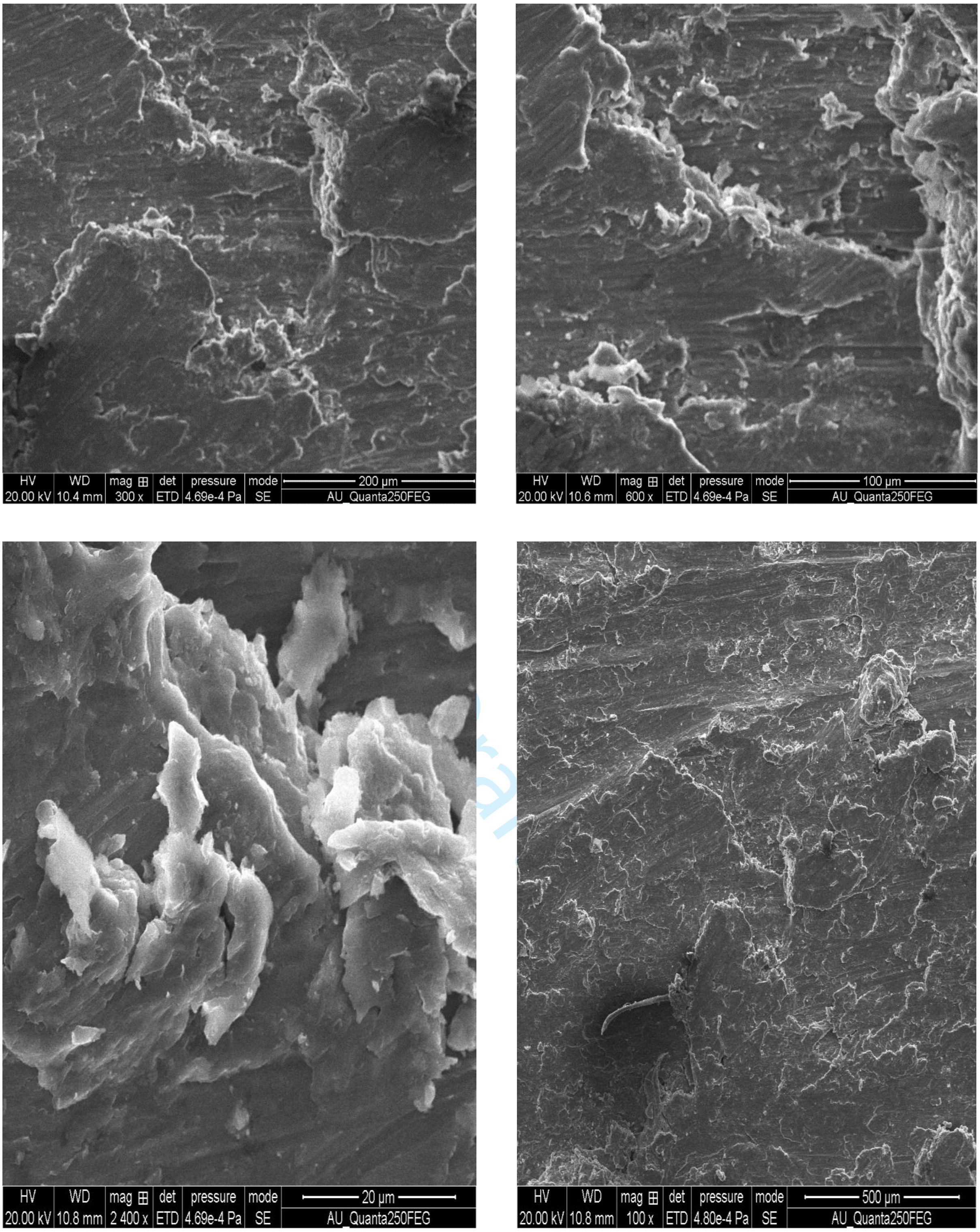
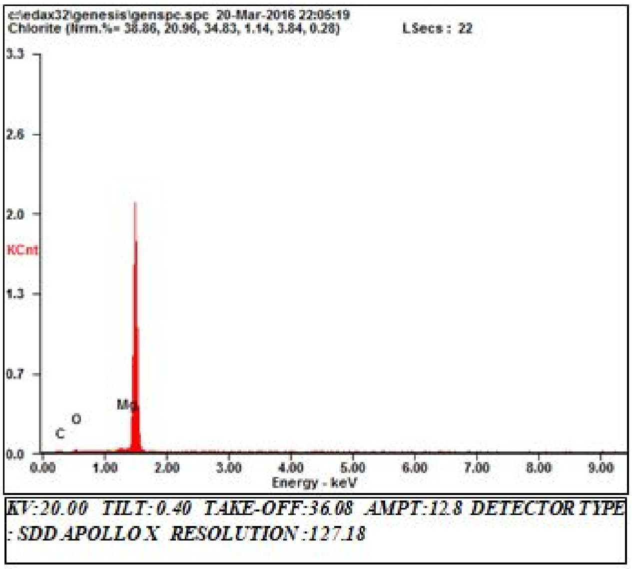
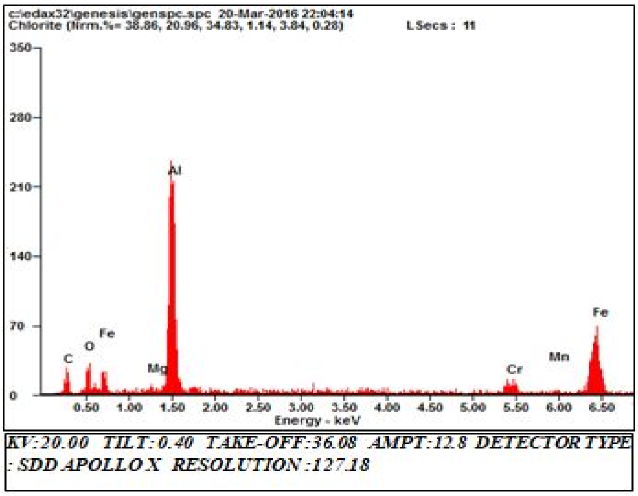


Figure 10. 92 % AL 6063 8% B_4C



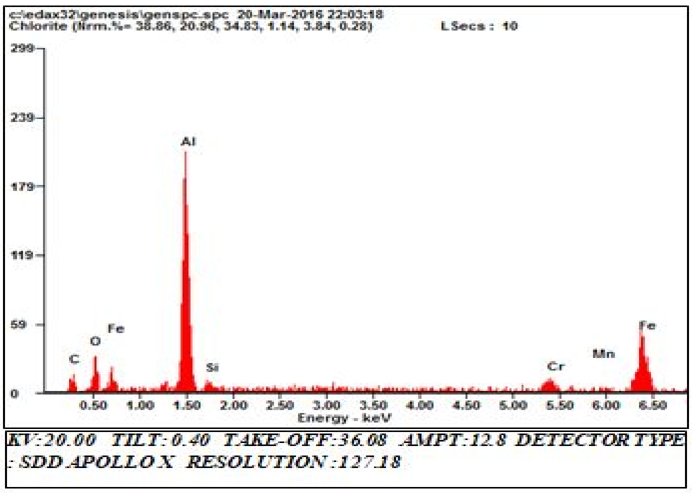
Element	Wt %	At %
C K	37.19	48.64
O K	32.14	31.56
MgK	30.66	19.81

Fig 11. EDAX images 100% Al 6063



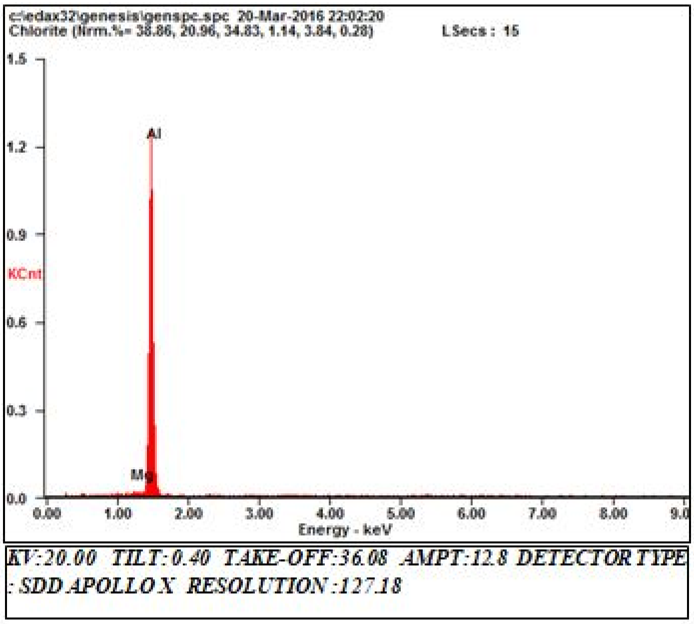
Element	Wt %	At %
C K	19.51	39.65
O K	07.81	11.92
MgK	00.83	00.83
AlK	34.30	31.03
CrK	05.11	02.40
MnK	00.68	00.30
FeK	31.76	13.88

Fig 12.EDAX images 98 % Al 6063, 2% B_4C



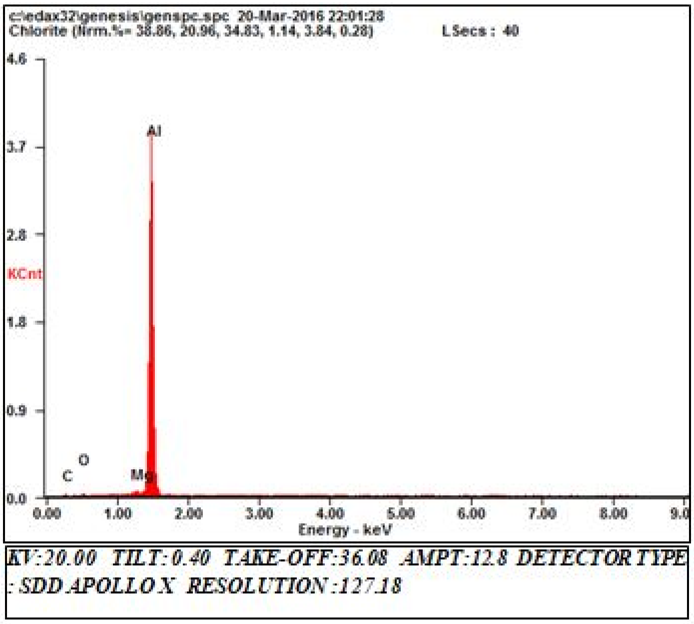
Element	Wt %	At %
C K	16.65	34.58
O K	08.92	13.92
AlK	35.95	33.24
SiK	02.01	01.79
CrK	05.32	02.55
MnK	00.46	00.21
FeK	30.69	13.71

Fig. 13. EDAX images Al 6063 96 %, B_4C 4%



Element	Wt %	At %
MgK	00.98	01.08
AlK	99.02	98.92

Fig 14. EDAX images 94 % Al 6063, 6% B_4C



Element	Wt %	At %
C K	07.41	15.07
O K	01.76	02.68
MgK	00.87	00.88
AlK	89.96	81.38

Fig 15. EDAX images Al 6063 92 %, B_4C 8%