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# Microstructural Characteristics of Aluminum Based Composites Developed By Liquid Metallurgy Route: An Overview

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## ABSTRACT

The extensive potential engineering applications of Aluminium Metal Matrix Composites (AMCs) are strong motivations for researchers renewed efforts in the development and characterisation of this class of material. The importance of microstructures for AMCs characterisation is enormous for reliable interpretations of its physical, mechanical, corrosion and thermal properties. Hence, a comprehensive review is quintessential in order to have a general overview of the influence and implications of microstructural characteristics on AMCs material properties. The review shows that an improved stir casting setup provides a reliable platform for effective and efficient stirring mechanism in the production of AMCs. This improved system is capable of reducing agglomerations to the barest minimum and thus promotes homogeneous dispersion of ceramic reinforcement particles in the matrix. The nature of AMCs microstructures have specific implications to its mechanical, corrosion and wear properties. The formation of pores, pits, rough surface and ceramics particles agglomerations in AMCs microstructures are manifestations of severe corrosion of the composites in different environments**.** The microstructural characteristics of corroded composite samples are aggravated by the harshness of the corrosion environments and increase in the percentage weight fractions of most ceramic reinforcement particles. The type of ceramic reinforcement particles used in AMCs has been well reported in the literature to have immense influence on its microstructural characteristics. Further, the review was able to show that heat treatment is a reliable process that can be explored in enhancing the homogeneous dispersion of reinforcement particles in AMCs matrix and its overall microstructural features. This review has enriched researchers' understanding on immense benefits of AMCs microstructural examinations and its numerous implications. It is hopeful that this will be an illuminating platform for intensifying research activities on the microstructural characterisation of AMCs. The conclusion that can be drawn from this in-depth overview is that microstructural examinations will remain one of the leading techniques for AMCs materials properties characterisation. Optical Microscopy (OM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Energy Dispersive Spectroscopy (EDS), X-ray Diffraction (XRD) and X-ray Fluorescence (XRF) will continue to be the domineering microstructural examinations techniques for characterising the material properties of AMCs.

**Keywords**: *AMCS, Microstructures, Stir Casting Technique, Material Properties and Heat Treatment*

## 1. INTRODUCTION

Aluminium Metal Matrix Composites (AMCs) has evoked researchers' attentions in a new dimension. This is due to its numerous potential applications in aerospace, automobiles, oil and gas, construction and telecommunication industries to mention a few. Therefore, the importance of microstructural characterisation in the development of AMCs suitable for various engineering applications cannot be overemphasised. Microstructural examinations will continue to remain an integral part of materials development and characterisation. This is because it gives opportunities for in-depth observations of materials' internal structures with a view of identifying different phases, constituents, crystalline structures and grains that are present in quantities and qualities. The use of Optical Microscopy (OM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Energy Dispersive Spectroscopy (EDS), X-ray Diffraction (XRD) and X-ray Fluorescence (XRF) are among the major techniques that have been well reported in the literature for microstructural examinations of AMCs and other classes of materials (Prevey, 2000 ; Flores-Zamora *et al*., 2004; Shamusuddin *et al*.,2008; Botor-Probierz *et al*., 2011 and Wang, *et al*., 2013). Modest achievements have been made by many researchers on the microstructural examinations of AMCs. For instance, microstructural characterisation of AMCs was considered in the work of Alo *et al*. (2012) where the effects of silicon (Si) and silicon carbide (SiC) particles contents on the microstructural behaviour of Al-Si-$SiC_p$ were investigated. The optical micrographs revealed the presence of SiC, Si and aluminium carbide ($Al_4C_3$) within matrix. The micrographs showed homogeneous distribution of SiC particles in the aluminium matrix in composites with 0.5 and 1.0%SiC. On the contrary, some clustering of SiC was observed in composites with 1.5% and 2.0% volume fraction of SiC. It was concluded that varying Si and SiC contents affected the microstructural characteristics of Al-Si-SiC composites and which in turn dictated the degree of its hardness properties. Abbass *et al.* (2015) investigated the microstructural behaviour of aluminium alloy 6061/SiC composites and the obtained optical micrograph of Al6061 revealed α-Al grains and fine particles of phase $Mg_2Si$ dispersed uniformly in the matrix. Generally, the micrographs revealed good bond between the matrix alloy and SiC particles. The uniform microstructures manifested were due to the presence of magnesium as the wetting agent in the AMCs.

Researchers have made commendable efforts on studies concerning the influence of modified stir casting techniques (Alaneme and Aluko (2012); Alaneme and Bodunrin (2013); Koli(2013) and Selvam *et al.*(2013)). The use of manual stirring technique and other varieties of stir casting techniques configurations have been found to impact AMCs properties. Meena *et al.* (2013) investigated the microstructural features of AMCs from stir casting technique. The microstructures of the developed composites were examined on inverted metallurgical microscope (Model: Nikon, Range-X50-X1500). The optical micrographs showed reasonably uniform distribution of SiC particles. The authors reported that the degree of homogeneous dispersion of SiC particles in the aluminium matrix was observed to be highly influenced by the extent of stirring. A modest attempt had been made by Singla *et al.* (2009) to develop a conventional low cost method of producing Metal Matrix Composites (MMCs) with the aim of obtaining homogeneous dispersion of ceramic material in the aluminium matrix. The authors adopted two steps stir casting at varying percentage fractions (5%, 15%,20% and 30%). The results of the two steps stir casting were compared with that of those without stirring and manual stirring techniques. The micrographs shown in plates 1(a, b and c) showed the microstructural features of the developed composite samples in the three techniques. It is evident in these micrographs that plate 1a exhibited a high density of clusters and agglomerations due to non-stirring of the mix. Some places were even identified without the presence of SiC while in other regions, it was found domineering. This perhaps was due to floating of SiC particles on the surface. This could be attributed to lack of stirring the melt for homogeneous dispersion. Plate 1b shows a better dispersion due to introduction of manual stirring. Plate 1c shows the best microstructural characteristics where there was impacting homogeneous distribution of the reinforcement SiC particles in the matrix. The high improvement in the general hardness, impact strength and normalised displacement properties could be attributed to the homogeneous distribution of the reinforcement particles in the matrix. This interesting features and improvement in mechanical properties are evidences of significant impact and enormous success of two steps stir casting technique.

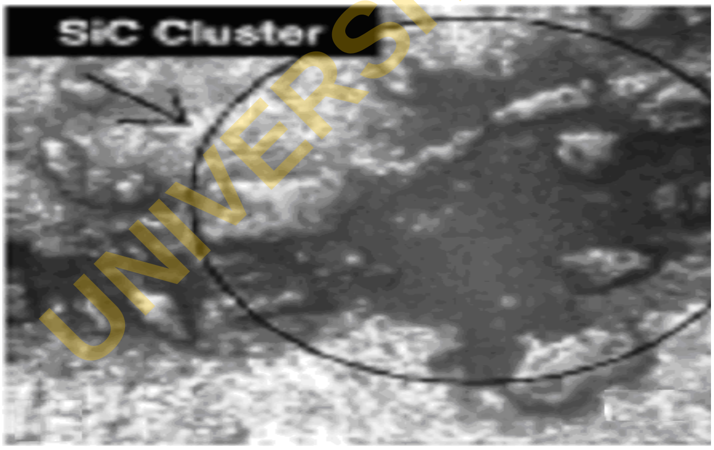


**Plate 1a: Micrograph of AMCs Without stirring (100microns) (Source: Singla *et al.*(2009))**

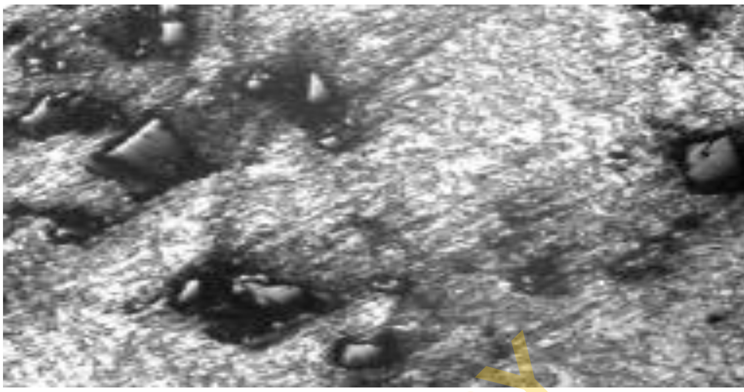

**Plate 1b : Micrograph of AMCs With Manual stirring (100microns) (Source: Singla *et al.*(2009))**

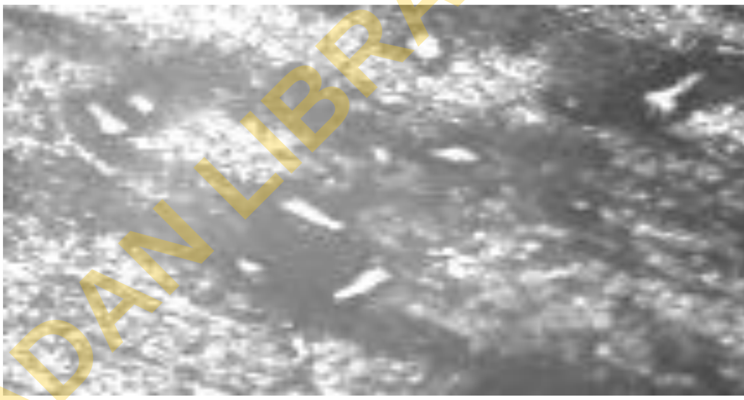

**Plate 1c: Micrograph of AMCs With two steps stirring (100microns) (Source: Singla *et al.* (2009))**

Samal *et al.*, 2013 investigated the extent of the influence of using modified stir casting approach on the microstructural and mechanical properties of AMCs. By improving upon the usual basic laboratory stir casting set up through replacing the common impeller solid shaft with hollow mild steel as the spindle. The modified approach was adopted for introducing the ceramic reinforcement particles into the aluminium matrix melt capsule containing the reinforcement particulates and then pushed inside the melt directly by means of steel plunger rod. The steel plunger rod contained silicon carbide (SiC) particles or magnesium wrapped with aluminium foil in capsules made of perforated mild steel. The composite constituents were dispersed into the melt with satisfactory evenly distributions in the melt due to vigorous stirring effect of the rotating spindle. The XRD analysis of the produced composite as shown in fig.1 manifested the presence of Al, MgO and $MgAl_2O_4$. The results of the XRD implied that some magnesium got oxidized leading to the formation of MgO. Plate 2 shows the microstructure of the produced AMCs (Al-3%-10%SiC). It can be seen from the micrograph that there is high degree of dispersion composite reinforcement constituents in the AMCs. The dark areas which implied SiC were well distributed in the microstructure. This uniform structure could be attributed to the significant enhancement in the yield strength, ultimate tensile strength and elastic modulus. The outcome of the study showed that the modified casting technique was quite successful. The authors work has provided a satisfactory stir casting clue for the enhancement of AMCs microstructural and mechanical microstructural characteristics.

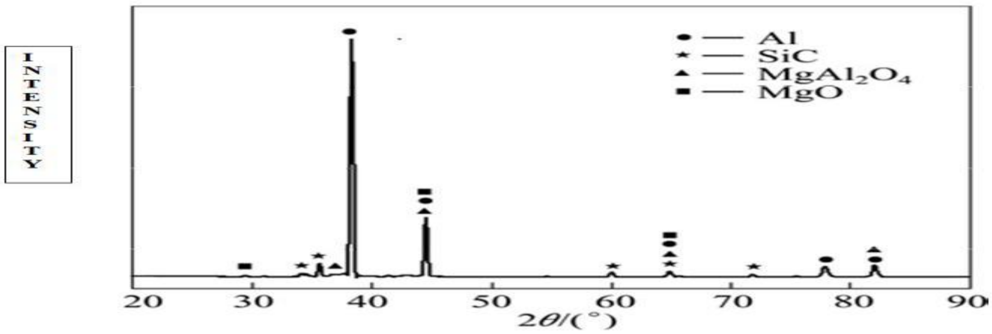


**Fig.1 : XRD Pattern of Al-3%Mg-10%SiC (Source : Samal *et al.* , 2013)**

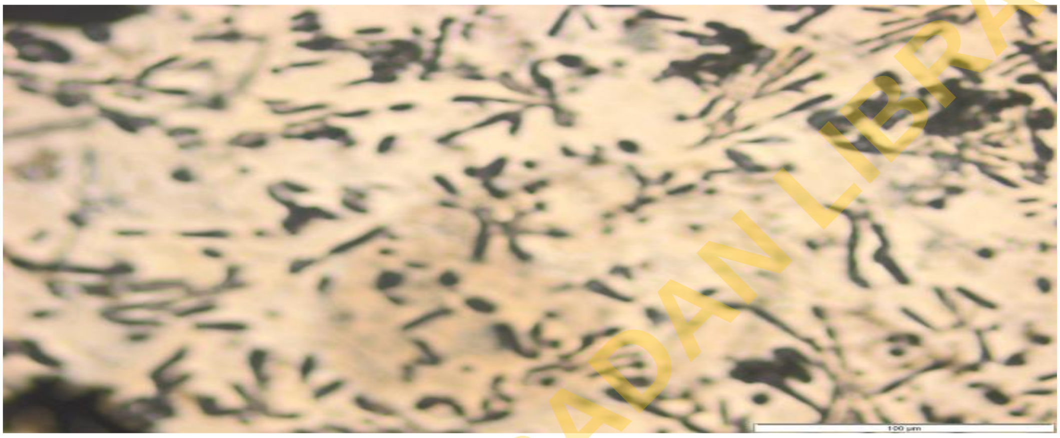

**Plate 2: Micrograph of Al-3%Mg-10%SiC Produced from Modified Casting (Source: Samal *et al.* 2013)**

Similar studies have been carried out by Alaneme and Aluko (2012); Alaneme and Bodunrin(2013) ; Koli (2013) and Selvam *et al.*, 2013. It was extensively reported by the authors that the enormous benefits of stir casting in production of AMCs could not be overemphasised. The open access literature has shown that modified versions of stir casting techniques which provides opportunity for effective and efficient stirring are more favoured in the recent times for the production of AMCs with no or minimal agglomerations. Numerous works (some of which are Adeosun *et al.*, 2012; Alaneme and Aluko (2012); Nandam, *et al.* (2012);;Kini *et al.*,2013; Hossein-Zadeh *et al.*,2014; Hamed *et al.*,2014 and Omran (2014)) had been carried out by researchers in this field on how variations of certain factors could remarkably alter the microstructural characteristics of AMCs and its implications on the mechanical, corrosion and wear properties. The general overview of the implications of different microstructures on the mechanical, corrosion and wear properties of AMCs produced from stir casting (as well as the influence of heat treatment process technique and ceramic reinforcement types) are presented in this extensive literature review.

## 2. INFLUENCE OF MICROSTRUCTURES ON MECHANICAL PROPERTIES

Nandam *et al.* (2012) carried out a study on the microstructural examination of two aluminium in situ composite foams. The authors employed XRD, OM and SEM techniques in the foaming characteristics study of Al-7Si-0.3Mg-10$TiB_2$ and Al-4Cu-10$TiB_2$ composites. The XRD revealed significant intensity of aluminium metal and $TiB_2$. This is a reflection of the grade of aluminium and type of reinforcement materials used in the composites production. In addition, the XRD showed peaks corresponding to silicon (Si) and $Al_2Cu$ precipitates of Al-7Si-0.3Mg-10$TiB_2$ and Al-4Cu-10$TiB_2$ respectively. Satisfactory homogeneous dispersion in the developed composites could be partly attributed to the absence of $Al_3Ti$ peaks in the XRD pattern. This is because $Al_3Ti$ has been extensively reported to impact brittleness and promotes agglomerations in the developed composites. The SEM micrographs of the developed composites showed a significant grain refinement and have a very strong potential in the enhancement of composites mechanical properties. This work has provided useful information on the nature of microstructures formed when $TiB_2$ is used as reinforcement particles in Al-7Si-0.3Mg and Al-4Cu based composites. An attempt had been made by Thangarasu *et al.* (2012) to produce AA1050/10wt%TiC composites and studied the microstructural influence on its hardness properties. The etching was done with Keller's reagent. The microstructures of the as received AA1050/10wt%TiC alloy, AMCs and TiC reinforcement particles were observed using optical microscope and scanning electron microscope (JEOL-JSM-6390 model). Plate 3 shows optical micrograph of monolithic alloy AA1050 while the plate 4 illustrates the SEM micrograph of TiC ceramic particles powders. According to the authors, plate 5 is an illustration of SEM micrographs of the interface zone at the retreading side between the composite surface and aluminium alloy substrate. The micrograph clearly showed a well-bonded surface composite layer to the aluminium substrate without visible defects at the interface. Plate 6 shows that TiC particles were uniformly dispersed in the composite matrix and this significantly improved the level of grain refinement.

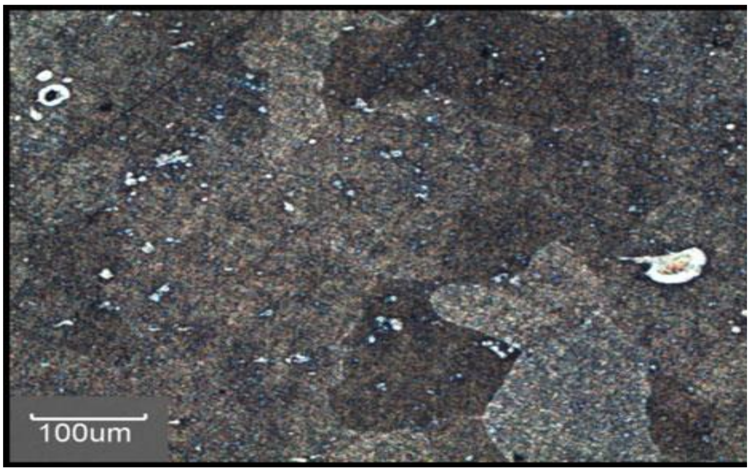


**Plate 3: Optical micrograph of AA1050 ( Source: Thangarasu *et al.* 2012)**

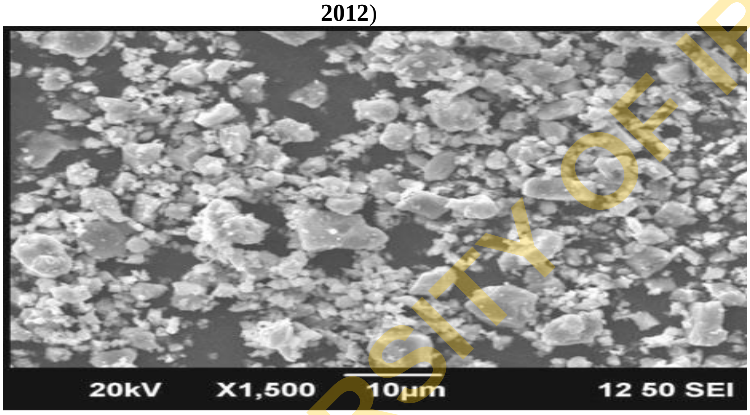


**Plate 4: SEM Photomicrograph of TiC Powders (Source: Thangarasu *et al.*, 2012)**


**Plate 5: SEM Photomicrograph of Interphase Zone ( Source: Thangarasu *et al.*, 2012)**

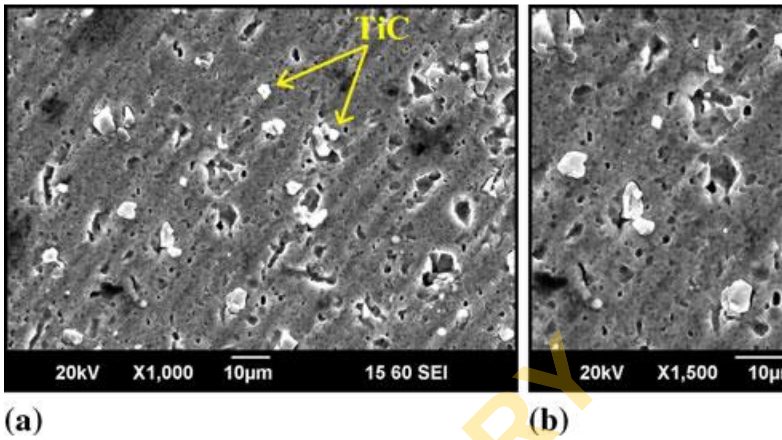


**Plate 6: SEM Photomicrograph of AA 1050/TiC Composite (Source: Thangarasu *et al.*, 2012)**

On the whole, it was reported by the authors that a 45% improvement in microhardness was achieved in the developed composites when compared to the AA1050 monolithic alloy. In the work of Rino *et al.* (2013), mechanical properties of Al6063 based composites reinforced with zircon sand alumina were investigated. Zircon sand with varying volume fractions (0%, 2%,4%,6% and 8%) and alumina with percentage fractions (8%, 6%, 4%,2% and 0%) were reinforced with Al6063 alloy. The SEM images showed uniform distribution of the reinforcement in the matrix alloy. The micrographs manifested pore formation in the 8% alumina reinforced composite is more than that of the other samples. The nature of microstructures obtained was attributed to the optimum hardness and tensile strength properties achieved when hybrid reinforcement of 4% alumina and 4% zircon sand were reinforced with the aluminium matrix alloy.

The interesting use of Al-V alloys in Ti-Al-V alloy based material and their numerous applications in aerospace missiles and air frame structures are strong motivations for some researchers in the recent time. A novel approach for production of Al-V composites reinforced by $Al_3V$ intermetallic compounds by mixing the $V_2O_5$ and Aluminium using ball mill had been attempted (Omran, 2014). A 30 g $V_2O_5$ was mixed with aluminium powder at different weights (7.5 g, 15 g and 22.5 g). The powders were homogeneously dispersed in cylindrical polyethylene bottle using a $ZrO_2$ ball with ball-to-ball powder ratio of 6:1. Microscopic examinations were carried out using optical microscope with image analyzer, Scanning Electron Microscope (JSM 6400 model) equipped with an energy dispersive X-ray spectroscopy (EDS) and X-ray diffractometer. The XRD results of the produced Al-$Al_3V$ composite showed that only two phases were present (Al and $Al_3V$). The SEM micrographs of the prepared composites contain 8.3%V. The microstructures revealed homogeneous distribution phase from nodule like dispersed with dispersed gray matrix. This study has shown extensively the usefulness of microstructural techniques in AMCs characterisation. The XRD, SEM and EDS results showed clearly that $Al_3V$ intermetallic compounds were formed in the AMCs. The presence of this intermetallic compounds in the AMCs was attributed to the significant hardness of the produced Al-$Al_3V$ composite. The microstructural characteristics and improvement in the hardness of the composite had shown that the developed novel approach was highly successful and attested to the relevance of more research attentions in this direction. No doubt, the authors work has shown extensively the usefulness of microstructural techniques in the characterisation of AMCs developed using novel stir casting techniques. A novel approach for dispersion of multi-walled carbon nanotubes (MWCNTs) in AMCs had been studied (Hamed *et al.*, 2014). The microstructure of nano-composites and the interface between A536 monolithic aluminium alloy and MWCNTs were investigated using optical microscope and scanning electron microscope equipped with energy dispersive X-ray analysis. The results of the microstructural examinations showed a great deal of homogeneous dispersion of the nanotubes within the A356 aluminium alloy matrix. This has led to the significant grain size refinement and improvement in the mechanical properties (ultimate tensile strength and Rockwell hardness) of the developed composites. The work had shown how microstructural examinations could be used to evaluate the effectiveness of this casting technique in the enhancement of the mechanical properties of the produced composites.

## 3. IMPLICATIONS OF MICROSTRUCTURES ON CORROSION AND WEAR CHARACTERISTICS

The corrosion behaviour of Al-Mg alloy A537 and its composites containing varying percentage weight fractions of fly ash in selected media were partly investigated by means of microstructural techniques (Obi, 2008). The hybrid reinforcement of the composites contained 5wt% fly ash and 5wt% SiC. The corrosion tests were performed in 3.5wt% NaCl and fresh water sourced from the South Saskatchewan River. The results of OM and SEM revealed that $Mg_2Si$ phase and Al-Mg intermetallics corroded preferentially to the matrix. Plates 7 and 8 respectively shows the optical micrographs of the hybrid composites (A535/hybrid/$10_p$) when immersed in 3.5% NaCl solution and river water both for exposure time of 14 days.


**Plate 7: Optical Micrograph of A535/Hybrid/$10_p$ immersed in 3.5% NaCl for 14 days( Source: Obi, 2008)**

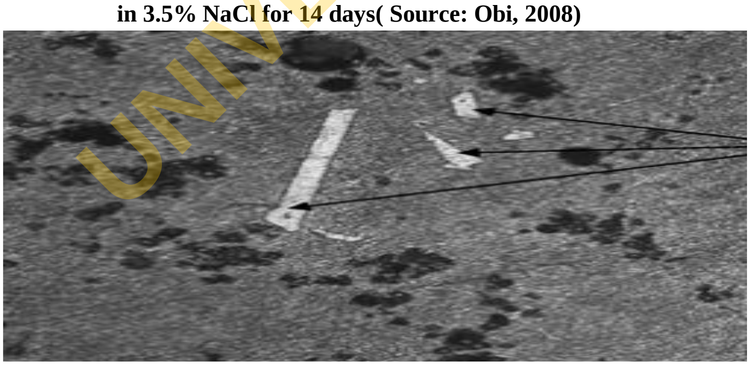

**Plate 8: Optical Micrograph of A535/Hybrid/$10_p$ immersed in river water for 14 days (Source: Obi, 2008)**

The nature of micrographs obtained showed that the composites experienced severe corrosion in 3.5% NaCl solution when compared to that of fresh water South Saskatchewan River water. The morphologies have enriched researchers' understanding on the corrosion characteristics features in fresh and salt solutions. A study on microstructural characteristics of Al7075/Zircon metal matrix composites in seawater was investigated by Nagaswarupa *et al.* (2012). The results of the SEM micrographs showed the formation of pits on the composite surface and reported to be more intense as the percentage weight fraction of zircon increases. It was evident from the authors' work that the matrix alloy with 6wt% of zircon showed evidence of more pit formation on the surface of the composites than that of the matrix alloy. The implication of this microstructural features is that zircon has high tendency in promoting corrosion of AMCs. Singh *et al.* (2012) carried out a comparative study of the corrosion behaviours of AMCs and cast iron in 3.5% NaCl solution. The surface morphology of the corroded specimens was examined by scanning electron microscope after 24 hours exposure of LM13-10% SiC composite in the solution. The micrograph showed the presence of Si containing dendrites and aluminium matrix in separate phases. The corroded surface of the composite indicated the presence of SiC particles in agglomerated form. This was due to the preferential corrosion of the surrounding aluminium matrix. On the other hand, the micrograph showed that the corroded surfaces of the cast iron manifested the presence of graphite flakes which were surrounded by deeply corroded grain boundaries. Furthermore, microstructural analysis of the corroded surface demonstrated the occurrence of galvanic type of corrosion in the substrates of all samples investigated. Its XRD analysis established the manifestation of aluminium oxide film in the AMCs samples. This explains why the AMCs exhibited a better corrosion resistance when compared to cast iron. The corrosion and wear behaviour of Al-Mg-Si alloy matrix hybrid composites using agro-based reinforcement materials have been studied by Alaneme *et al.* (2013). The corrosion and wear mechanisms microstructures were examined using SEM (Model: JSM 7600F JEOL). The SEM photomicrograph of the hybrid reinforced agro-based particles exhibited better microstructural characteristics when compared to the non-hybrid reinforced Al-Mg-Si based composites. The authors concluded that the production of low cost Al-Mg-Si matrix hybrid composites using RHA as a complementing reinforcement to SiC had immense assurance for improved corrosion and wear resistance behaviours. A study that focused on the tribological behaviour of Al6061 metal matrix composites and its microstructural characteristics have been carried by Suresh and Kumar (2013). The composite containing varying percentage fractions of $Al_2O_3$ particles at fixed 2wt% of graphite were produced using a stir casting technique. The SEM results showed a satisfactory uniform distribution of graphite and $Al_2O_3$ particles in the metal matrix. The SEM micrographs of the worn surfaces of the aluminium 6061 composites showed that the worn surface of the composite alloy was generally much rougher than that of unreinforced alloy. The microstructural characteristics implied an absence of wear mechanism which was essentially due to hard $Al_2O_3$ particles expressed on the worn surface. Microstructural examination had been used by Srinivasa *et al.* (2014) to study the wear characteristics of AMCs. In the authors' work, aluminium was heated to a temperature of 900 °C and thereafter reinforced with SiC particles. The molten matrix, wetting agent and SiC particles mixing were done with the help of mechanical stirrer. It was thoroughly stirred for 5 minutes at 250 rpm. Fig. 2(a-d) shows the XRD graphs obtained as the percentage weight fraction of SiC increases.

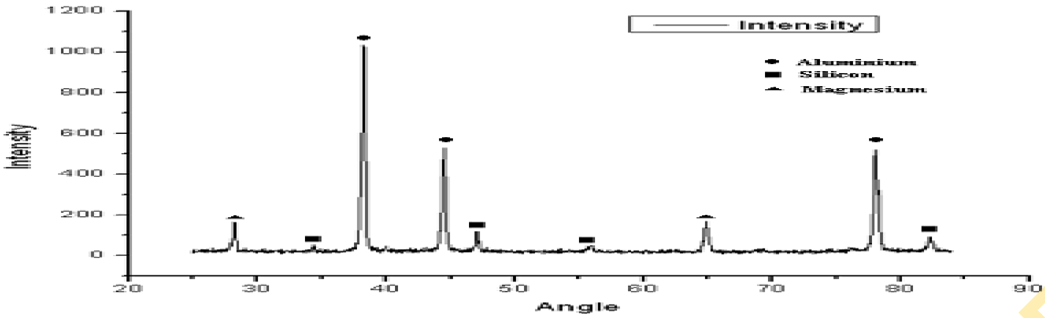


**Fig. 2a : XRD of Based Metal ( Source : Srinivasa *et al.*,2014)**

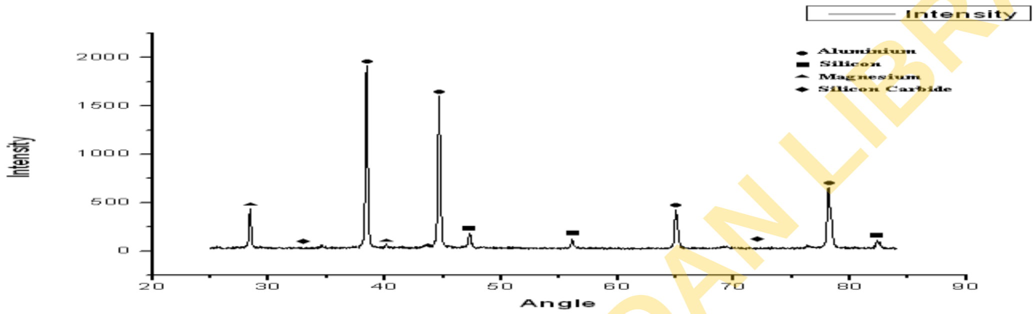


**Fig.2b: XRD Pattern of AMCs at 5% SiC (Source : Srinivasa *et al.*,2014)**

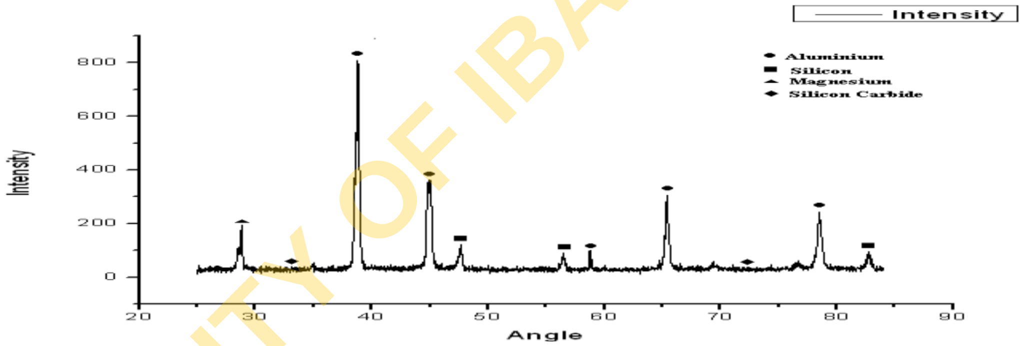


**Fig.2(c): XRD Pattern of AMCs at 10% SiC (Source : Srinivasa *et al.*,2014)**

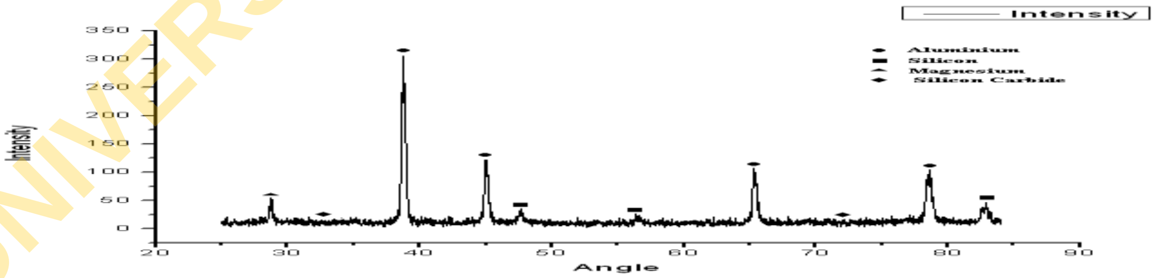


**Fig. 2(d): XRD Pattern of AMCs at 15% SiC (Source : Srinivasa *et al.*, 2014)**

It was deduced from the XRD analysis that the intensity of aluminium decreases as the volume fraction of SiC increases. Furthermore, the micrographs obtained from microstructural examinations showed the presence of uniform distribution of SiC in the matrix. The uniformity of microstructure was responsible for improved hardness and wear characteristics of the composites.

Suresh *et al.* (2014) studied the wear prediction of stir cast Al-$TiB_2$ composites using response surface methodology (RSM). In their study, Al6061 was reinforced with various percentages of $TiB_2$. The microstructural examinations were carried out using XRD, EDS and SEM methods. The XRD and EDS graphs established the presence of Al, $TiB_2$ , $TiO_2$ , CuO and other elemental or constituents at different peaks. The micrograph showed the microstructure of the worn surface of the composites for 10wt% of $TiB_2$ at an applied load of 5 N and constant sliding velocity of 2.61 m/s. The microstructural grooves features obtained were due to the reinforcing particles of $TiB_2$.

## 4. IMPACT OF REINFORCEMENT TYPES ON MICROSTRUCTURES

The influence of agro-based Rice Husk Ash (RHA) particles on the microstructural features and mechanical properties of AlSi10Mg matrix based composites has been investigated (Saravanan and Kumar, 2013). RHA with varying percentage weight fractions (3wt%, 6wt%, 9wt% and 12wt%) were used as reinforcement particles in order to develop AMCs using a liquid metallurgy route. The surface morphology was examined using SEM. The SEM micrographs manifested a uniform distribution of RHA particles without voids and discontinuities. The results suggest good bonding between aluminium matrix and RHA particles. This work has further enriched the literature on the effect of agro-based reinforcement on the microstructural characteristics of AMCs. The exploitation of waste fly ash in the production of AMCs was attempted by Senapati et al. *(*2014). Waste fly ash from different sources (identified as type A and type B) were utilised as reinforcement materials. In order to have a better understanding of the difference in particle distribution between type A and type B in the matrix, SEM micrograph were taken for the three classes of material samples LM6 alloy, fly ash type A reinforced AMCs and fly ash type B reinforced AMCs). Experimental results showed that the highest strength value for the produced AMCs was obtained with type B fly ash. The maximum compression test value obtained under static and dynamic conditions for type B fly ash reinforced AMCs was attributed to the microstructural differences, presence of carbon and general change in morphology of the microstructures. The authors' work is indeed one of the open access literature providing satisfactory explanations on how the use of different ceramic reinforcement particles can markedly exhibit diverse microstructural morphologies. As reported in a critical review carried out by Casati and Vedani (2014), nanoparticles ceramic reinforcement materials had been shown to have satisfactory potential for improving homogeneous dispersion and reducing agglomeration in AMCs. This outcome has potential for enhancing the microstructural characteristics and its general material properties. In their review, the authors reported interesting outcome of TEM examination of the AMCs using 10wt% $Al_2O_3$ nanoparticles (50 nm in sizes) in the matrix. The TEM micrograph in plate 9 shows an impactful homogeneous dispersion of $Al_2O_3$ nanoparticles in the matrix. Buntan et al., 2011; Alaneme et al.,2012; Damesh et al.,2012;Alaneme et al.,2013 and Gopi et al.,2013 have also studied the effects of ceramic reinforcement type on the microstructural features of AMCs. It is inferred from the literature that the effects of selecting different ceramic reinforcement particles on the microstructures and mechanical properties of AMCs is enormous.

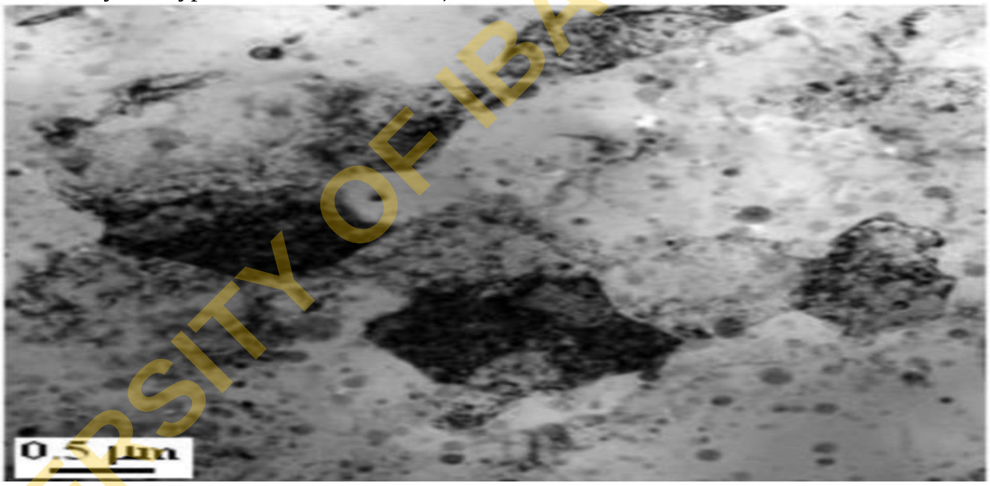


**Plate 9: TEM micrograph nanoparticles reinforced Al-10wt%$Al_2O_3$ Composite**

**(Source : Casati and Vedani, 2014)**

Prakash and Jaswin (2015) developed aluminium hybrid metal matrix composites using casting technique and thereafter studied its microstructural characteristics. Aluminium rods were preheated at 850 °C for 3 to 4 hours. This was followed by mixing the SiC (5%, 6.5% and 8%) and $B_4C$ (5%,3.5% and 2%) with the molten form of Al6061 monolithic alloy. The reinforcement morphology and its dispersion in metal matrix were examined in a scanning electron microscope (with model JEOL JSM 3.5). The microstructures showed that there was an enhancement in the particles clustering as temperature and reinforcement volume fraction increases. It could be deduced from plates 10, 11 and 12 that more clustering was formed as percentage weight fraction of SiC increases and that of $B_4C$ reduces in Al6061 based composites.

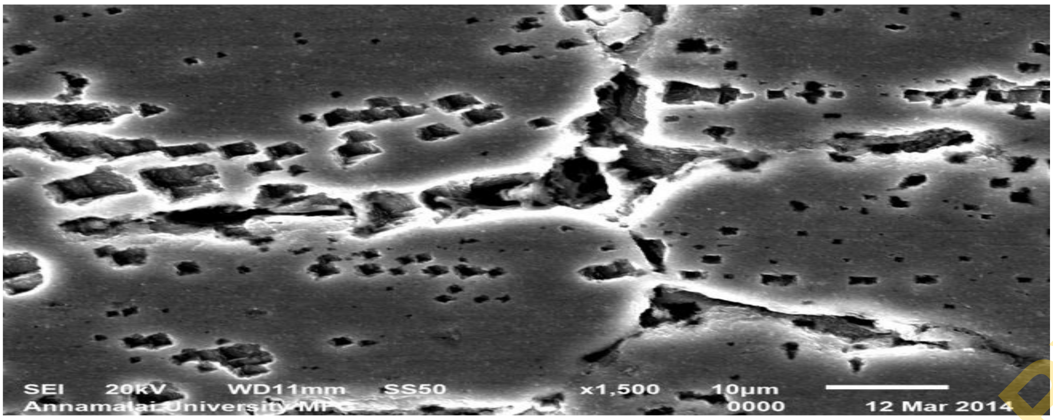


**Plate 10: SEM micrograph of Al6061-5wt%SiC-5%$B_4C$ at 1500x**
**(Source : Prakash and Jaswin ,2015)**

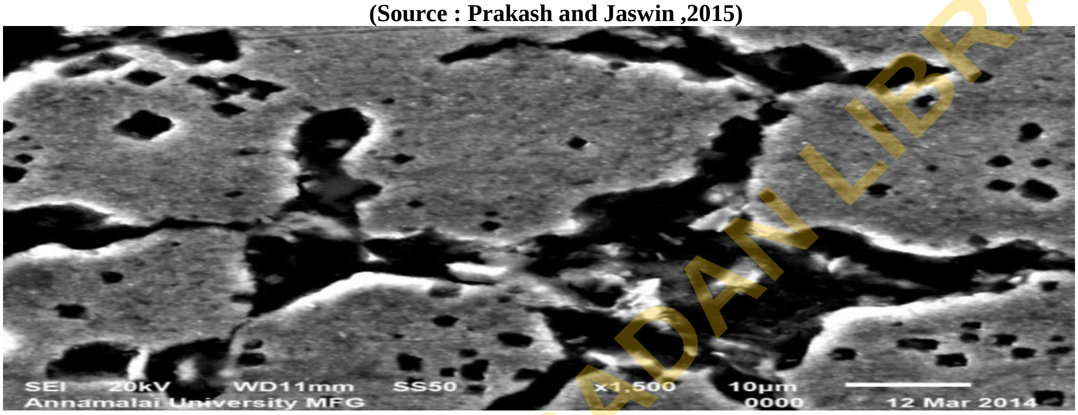


**Plate 11: SEM micrograph of Al6061-6.5wt%SiC-3.5%$B_4C$ at 1500x**
**(Source: Prakash and Jaswin ,2015)**

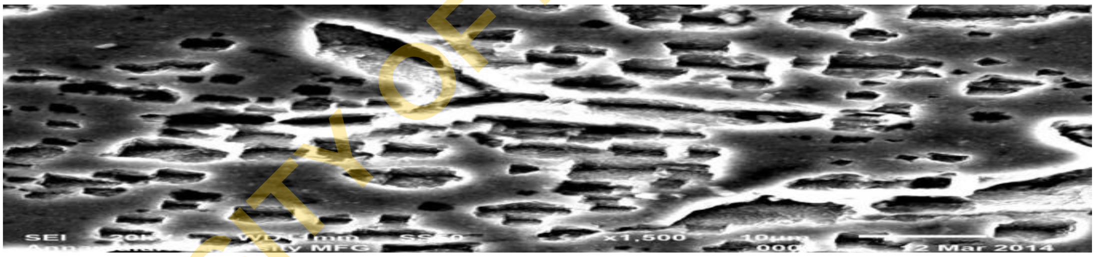

**Plate 12: SEM micrograph of Al6061-8wt%SiC-2wt%$B_4C$ at 1500x**
**(Source: Prakash and Jaswin, 2015)**

## 5. HEAT TREATMENT INFLUENCE ON MICROSTRUCTURES

The influence of thermo-mechanical treatment on the microstructures of Al6063 based composites was investigated by Alaneme (2012).The composite samples were cold rolled prior to solution heat treatment at a temperature of 550 ˚C for 1 hour and water cooled. The microstructures of the composites were examined using a Zeiss metallurgical microscope. Results showed that the microstructures of solution heat treated samples exhibited a uniform dispersion of SiC particles in Al6063 whereas the as cast samples manifested particles agglomerations in the matrix. The impact of heat treatment on the microstructural characteristics and wear regimes of Al-Cu-Mg matrix composites have been studied (Rao and Devi, 2013). The monolithic alloy and its composite were solution heat treated in a muffle furnace for 8 hours at a temperature of 490 ˚C. The samples were etched with Kellar's reagent (1%HF, 1.5%HCl, 2.5% $HNO_3$ and remaining is water) and later examined under SEM (model: JEOL, JSM-5600). The micrograph showed that the wear rate of the composite decreased due to the significant effect of heat treatment. This was reflected in the nature of microstructures obtained for the as cast and heat treated Al-Cu-Mg composites reinforced with varying volume fraction of SiC. A more uniform dispersion was observed in the micrograph of heat treated samples when compared to as cast samples. Wlodarczyk-Fligier et al.,2007;Damesh et al., 2012; Gopi et al.,2013; Soni et al.,2014 and many other researchers have carried robust studies on the impact of heat treatment on the microstructural characteristics of AMCs. It has been established in these studies that heat treatment is one of the major process techniques that can be deployed to achieve desired characteristics in the microstructures of AMCs.

## 6. REVIEW HIGHLIGHTS AND CONCLUSIONS

In this review, commendable efforts have been made by researchers in the characterisation of AMCs microstructures. Optical Microscopy (OM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Energy Dispersive Spectroscopy (EDS), X-ray Diffraction (XRD) and X-ray Fluorescence (XRF) have been found to be resourceful microstructural examination techniques.

This review has shown that modified versions of stir casting technique provides opportunity for effective and efficient stirring in the production of AMCs with minimal agglomerations and homogeneous dispersion of ceramic reinforcement particles in the matrix. The presence of pore formations, pits, rough surface and agglomerated form of ceramic reinforcement particles constituents in AMCs microstructures are manifestations of severe corrosion of the composites in different environments. Furthermore, it is inferred from this review that the microstructural characteristics of corroded composite samples are aggravated by the harshness of the corrosion environments and increase in the percentage weight fractions of most ceramic reinforcement particles. The literature has also established that the type of ceramic reinforcement particles used in AMCs markedly influences its microstructural characteristics. This review has demonstrated extensively that solution heat treatments are reliable processes that can be explored in order to enhance the homogeneous dispersion of reinforcement particles in AMCs matrix and its overall microstructural features.
In summary, this review has shown that the effectiveness of stir casting technique, type of ceramic reinforcement particles and heat treatment process play significant roles in influencing AMCs material properties (mechanical, corrosion and wear just to mention a few). It can be concluded that microstructural examinations will remain one of the leading techniques for AMCs materials properties characterisation. Therefore, researchers in this field are expected to redouble their efforts in revolutionizing the world of microstructural examinations for enhanced AMCs properties.

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