International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

Effect of Nickel and Molybdenum on the Mechanical Properties of Aluminium- 4%Copper Alloy

Oghenekowho P. A.
Mechanical Engineering Department
Federal University of Petroleum Resources
Effurun, Nigeria

Odo J. U., Nnuka E. E.
Metallurgical/Materials Engineering
Nnamdi Azikiwe University
Awka, Nigeria

***Abstract*-- The effect of nickel and molybdenum on the mechanical properties of aluminium-4% copper alloy was studied using standard techniques. The dopants (nickel and molybdenum) were added in concentrations of 0.5%, 1%, 1.5% and 2% by weight, stirred and cast by gravity die casting. The specimens were then machined to standard sizes for ultimate tensile strength, hardness and impact strength tests. The microstructures of the samples were also studied using a reflected light metallurgical microscope. The results obtained showed that the mechanical properties tested improved with increase in the concentration of the dopants. 18.5% and 6.2% increase in ultimate tensile strength and hardness respectively was achieved when specimen was doped with nickel while 31.1% and 24.4% increase in ultimate tensile strength and hardness respectively was achieved when specimen was doped with molybdenum.**

Keywords-- Nickel, molybdenum, properties, aluminium, copper, alloy.

INTRODUCTION

Aluminium, a non-ferrous metal, has a unique combination of properties which makes it one of the most versatile, economical, and attractive metallic elements for a broad range of uses - from soft, highly ductile wrapping foil to the most demanding engineering applications (Davis, 2001). Aluminium excels among other non-ferrous metals because of its high specific weight, resistance to corrosion etc. (Nnuka, 1985). Pure aluminium easily forms alloys with many elements such as copper, zinc, magnesium, manganese and silicon. Aluminium alloys have light weight and high strength which make them suitable for designing and construction of aircraft and space vehicles. The major setback in the use of most aluminium alloys in structural and automotive applications is the presence of brittle intermetallic particles which reduce the formability of these alloys (Adeosun et al, 2011).

Dopants are usually added to improve the mechanical properties of alloys and their effect depends on the concentration of the alloying elements (Nnuka et al, 2001). The most effective dopant for aluminium alloys is scandium (Royset, 2005) but because of its high cost the effect of other elements like magnesium, manganese, ytterbium, zinc, chromium etc are being investigated. Salihu et al (2012) worked on the effect of magnesium on the microstructure and mechanical properties of Al-Cu-Mg alloy. Magnesium of 0.5 to 2.5 % in the interval of 0.5% was added to the base alloy and melting was done in an electrical resistance furnace, using graphite crucible and the molten composition was poured into a permanent cylindrical die of diameter 25 mm and 200 mm long. Test specimens for tensile and Brinnell hardness tests were prepared and the tests carried out. It was discovered that the tensile strength increased progressively from 101.89MPa for the control sample to 172.06MPa for the sample containing 2.5 wt% Mg and that the Brinnell hardness number increased also from BHN72.20 for the control sample to BHN94.20 for the sample containing 2.5 wt.% Mg. Nafsin and Rashed (2013) also concluded that magnesium addition increased the hardness of aluminium copper alloys when they alloyed Al-6%Cu with varying magnesium content from 0.1-2%. Mahasneh and Al-Qawabah (2011) investigated the effect of vanadium addition at a rate of 0.1% on the microstructure and hardness of Al-9%Cu. Samples of Al-9%Cu and Al-9%Cu-0.1%V were prepared and specimen for microstructure and hardness tests were machined out. From the result obtained, it was concluded that the addition of a transition element such as vanadium followed by cold working process caused a reduction in the average grain size of the Al-9%Cu alloy from 124-134μm to 34-45μm and hence increased the hardness. The effect of microalloying on the structure and properties of Al-Zn-Mg-Cu alloys was studied by Friedlander et al (1986). Transition metals like zirconium and hafnium were added to the Al-Zn-Mg-Cu alloy system containing 0.1% iron and then aged. The result obtained showed that the introduction of zirconium and hafnium to the alloy led to an increase in both the ultimate tensile strength and the plasticity after aging. Nnuka and Ette (1990) worked on the texture, composition-sensitive structure and mechanical properties of Al-Cu and Al-Zn alloy system. Binary alloys of Al-Cu and Al-Zn were inoculated with Mg, V, Ca, Mn, Fe, Nb and Ta. The dopants were varied by adding 0.1%, 0.5% and1.0% by weight and the samples produced were analysed for changes in structure and mechanical properties. It was concluded that the addition of the third element (dopant) caused an increase in strength and decrease in plasticity.

MATERIALS AND METHOD

Materials sourcing and preparation

Aluminium 6063 ingots from Nigeria Aluminum Extrusion Company, Lagos State, and copper rod, nickel and molybdenum powder from chemical market, bridge head,

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

Onitsha, Nigeria were used for the work. Weight percent calculation was used to obtain the mass by weight needed for each material and weighing out was done using a digital electronic weighing balance.

Method

The aluminium ingots and copper rod were melted in a bailout crucible furnace and stirred to obtain a homogenous melt. The dopants were added in concentration of 0.5% - 2% by weight in intervals of 0.5%, stirred thoroughly and cast by gravity die casting method using a gravity die mould with cylindrical cavity. The specimens were then machined to the required dimensions for the brinnel hardness, ultimate tensile strength and impact tests respectively. Tensile strength was determined using the testrometric universal testing machine model M500-25KN, impact strength was also determined using the Birmingham impact testing machine: striking velocity 220ft.lb. Brinnell hardness test was carried out using the Gunt Brinnell hardness tester and the microstructure of the specimens were examined using the Reflected light metallurgical microscope model: L2003A. The test pieces for microstructural examination were successively ground using 80, 220, 320, 400, 600 and 1200 microns grade of emery paper mounted on a rotating circular disc grinding machine, polished using aluminium oxide (Al2O3) and etched in Keller's reagent made up of 2.5cm3 trioxonitrate (V) acid, 1cm3 hydrofluoric acid and 1.5cm3 hydrochloric acid in 95cm3 of water.

RESULTS AND DISCUSSION

Mechanical Properties

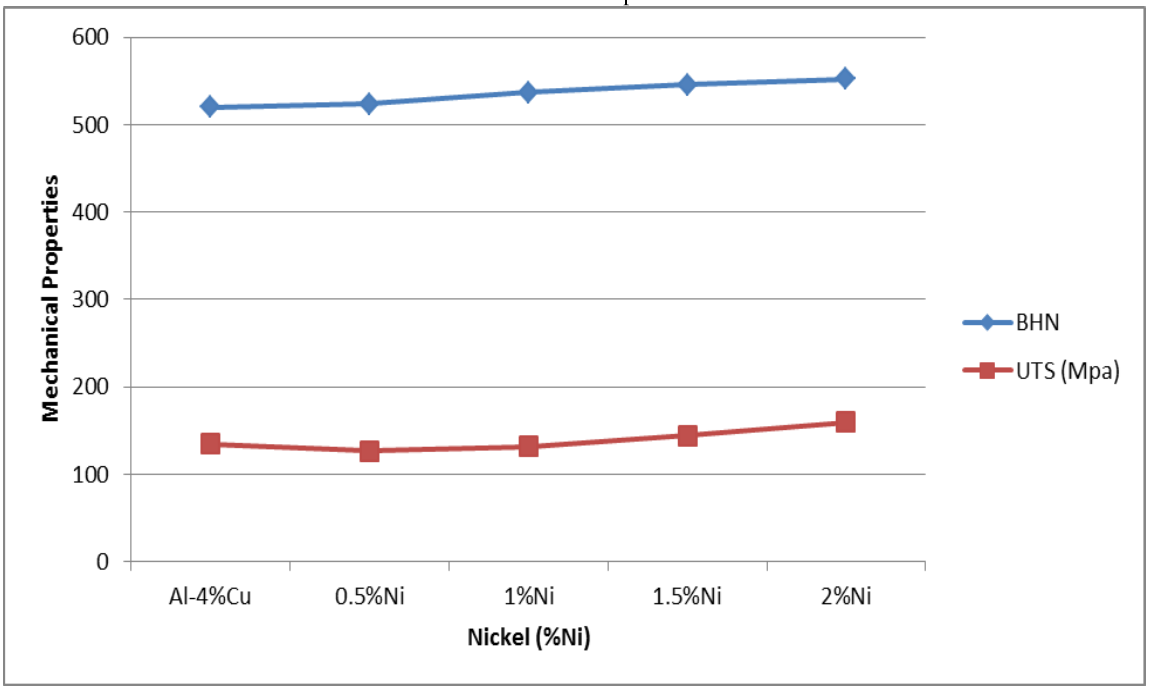

Figure 1.1: Effect of nickel concentration on ultimate tensile strength (UTS) and hardness of Al-4%Cu alloy

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

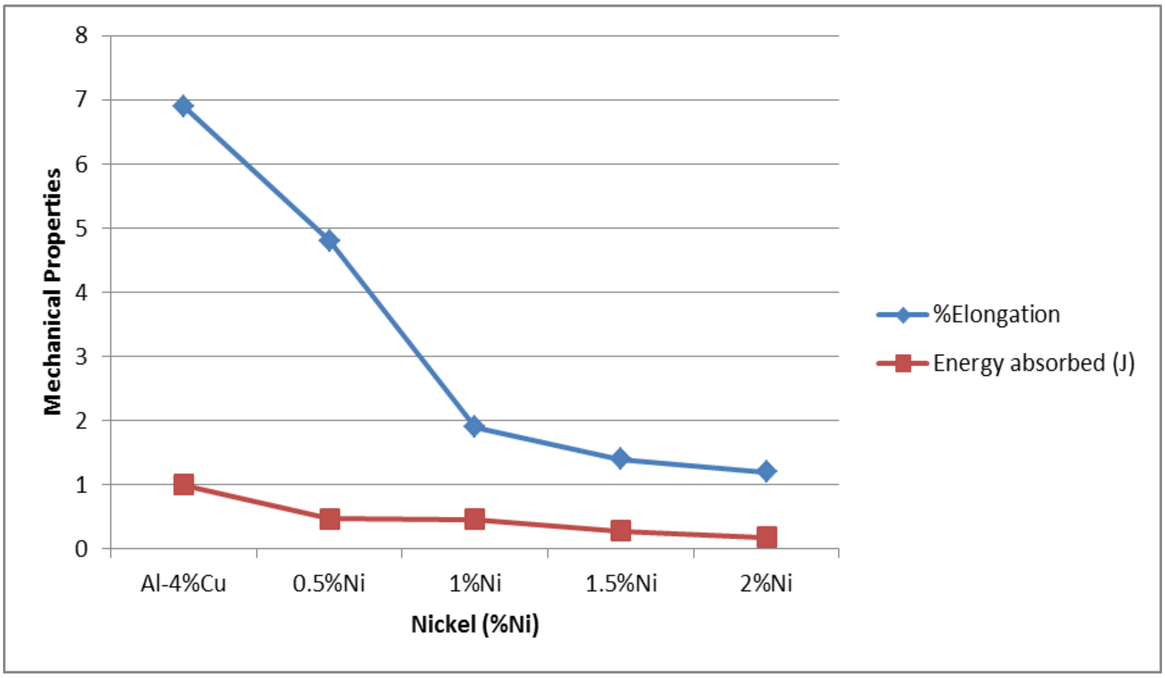

Figure 1.2: Effect of nickel concentration on impact strength (energy absorbed) and percentage elongation of Al-4%Cu alloy

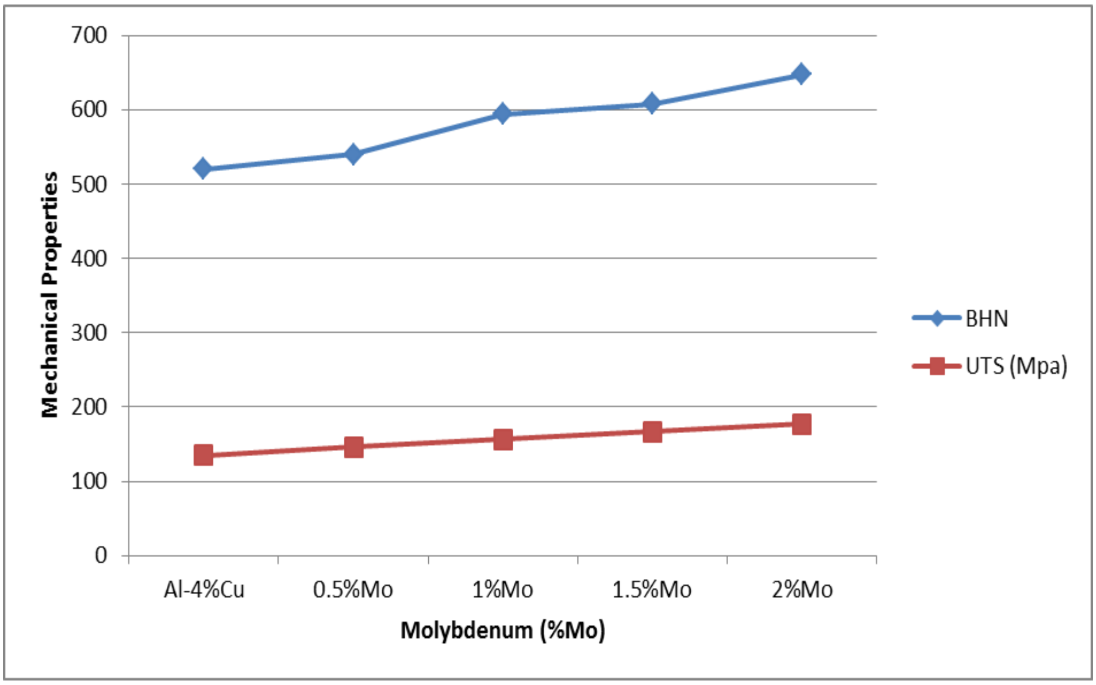

Figure 1.3: Effect of molybdenum concentration on ultimate tensile strength (UTS) and hardness of Al-4%Cu alloy

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

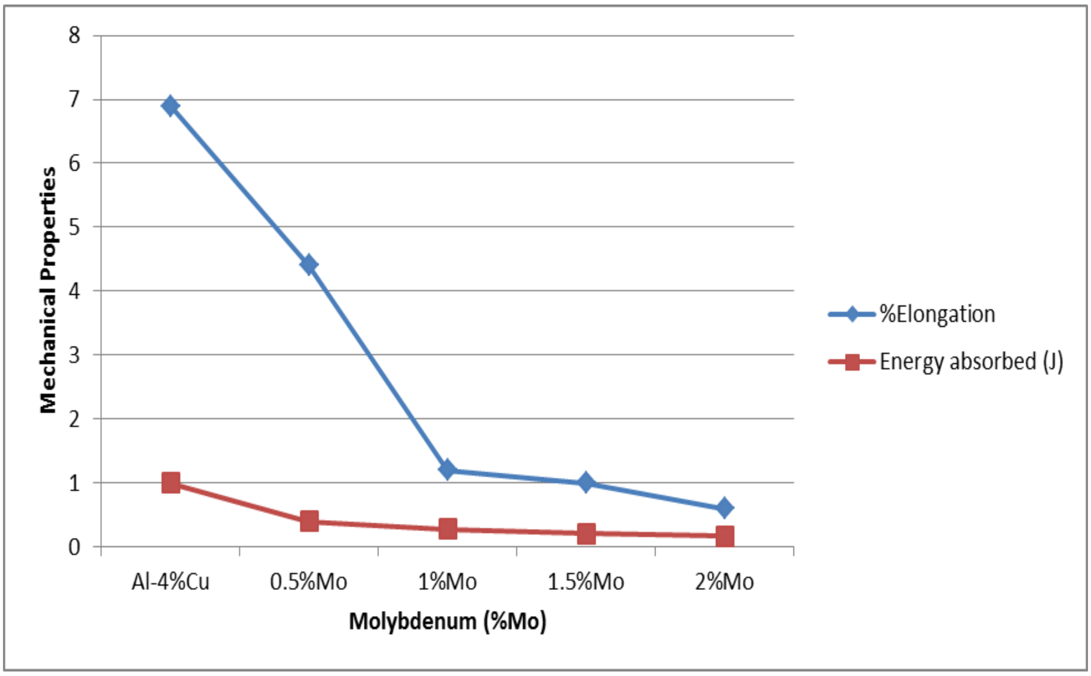

Figure 1.4: Effect of molybdenum concentration on impact strength (energy absorbed) and percentage elongation of Al-4%Cu alloy

Figures 1.1-1.4 above represent the mechanical properties of aluminium-4% copper alloy doped with nickel and molybdenum. It was observed that the hardness and ultimate tensile strength for samples doped with nickel and molybdenum increased non-linearly as the concentration of the dopants increased while the ductility and impact energy (energy absorbed) decreased in similar manner. The increase in the hardness and ultimate tensile strength as the concentration of the dopant increased was gentle throughout while a sharp drop in the ductility of the Al-4%Cu alloy was observed as the concentration of dopants increased to 1%. As more dopants were added, the drop in ductility was gentle and the impact energy was also observed decrease gently as the percentage dopants added increased.

Microstructural examination

Plates 1–9 represent the micrographs of aluminium-4% copper alloy doped with different alloying elements in different concentration at X400 magnification.

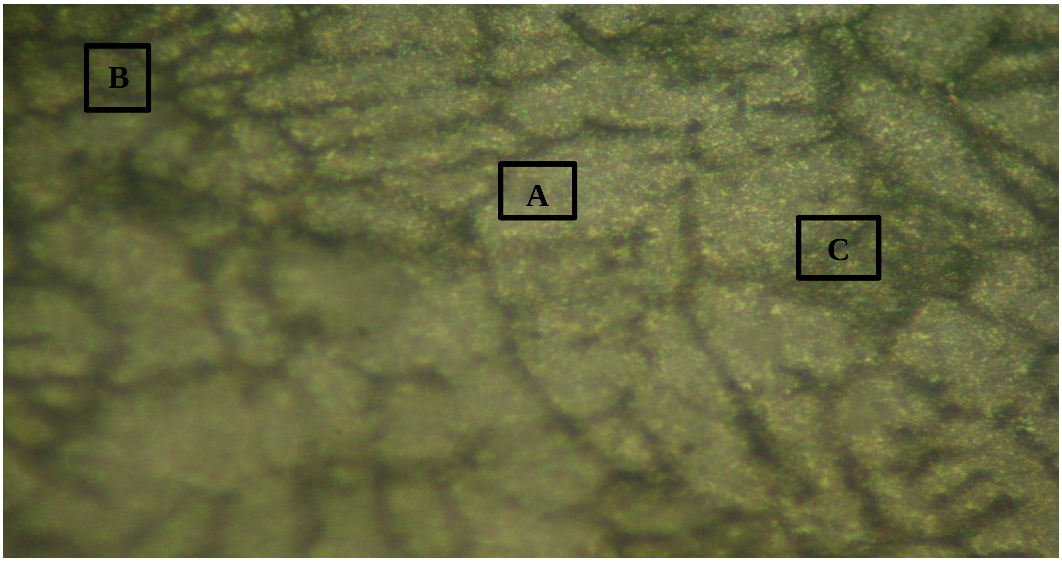

Plate 1: Micrograph of Al-4%Cu
A- Intermetallic compound; B – grain boundary; C –α-solid solution

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

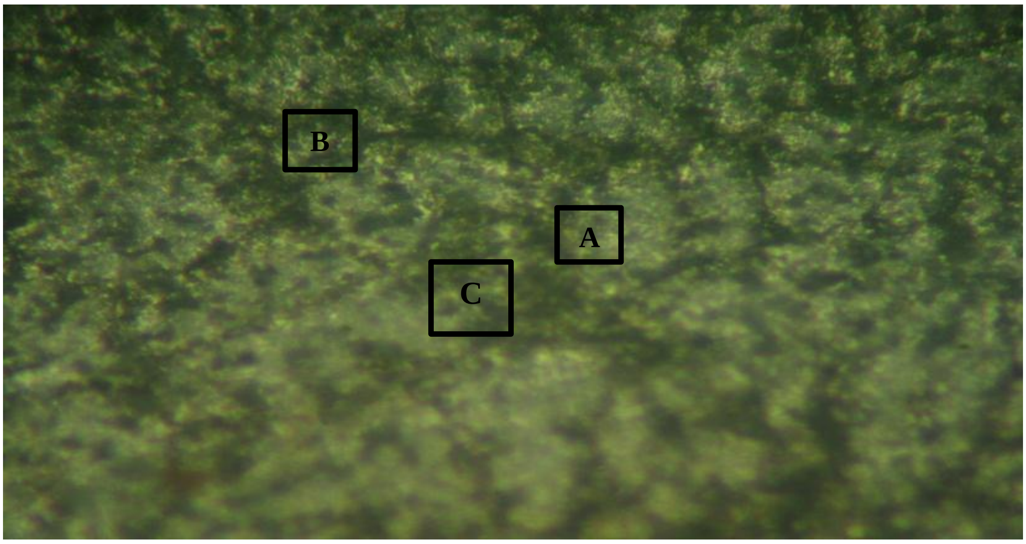

Plate 2: Micrograph of Al-4%Cu-0.5%Ni

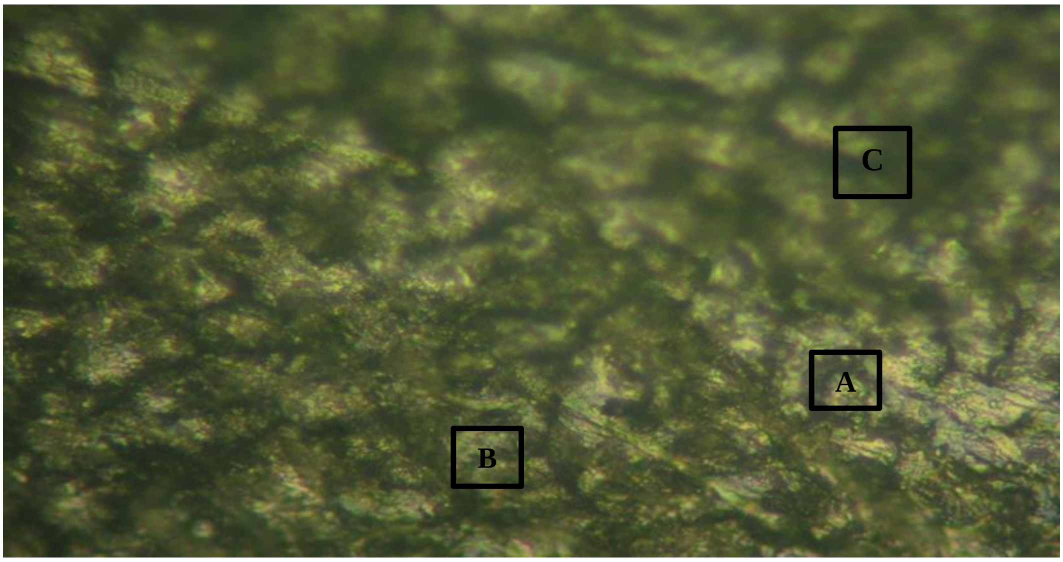

Plate 3: Micrograph of Al-4%Cu-1.0%Ni

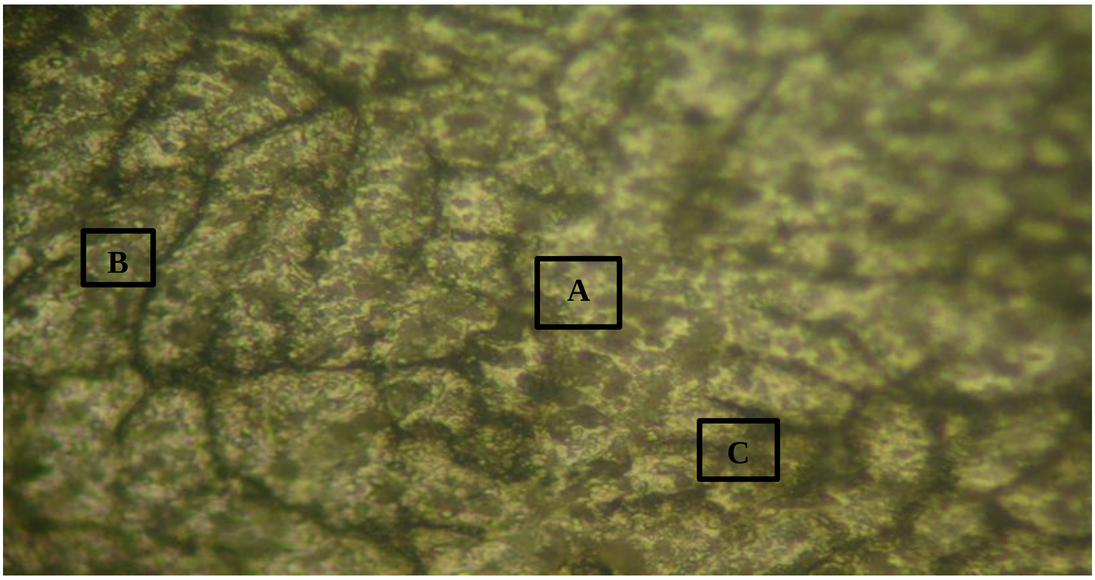

Plate 4: Micrograph of Al-4%Cu-1.5%Ni

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

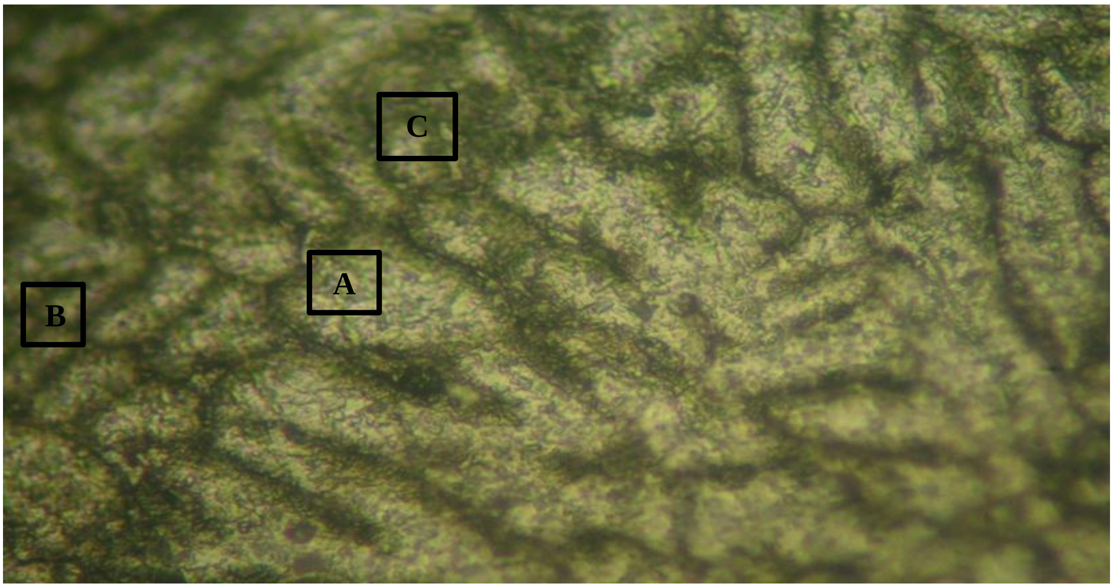

Plate 5: Micrograph of Al-4%Cu-2.0%Ni

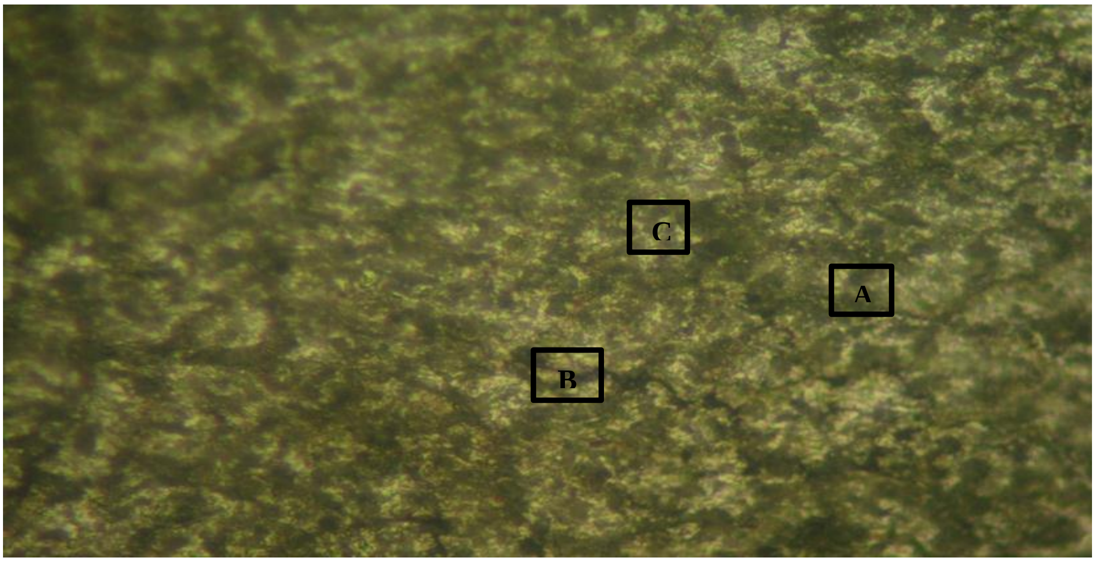

Plate 6: Micrograph of Al-4%Cu-0.5%Mo

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

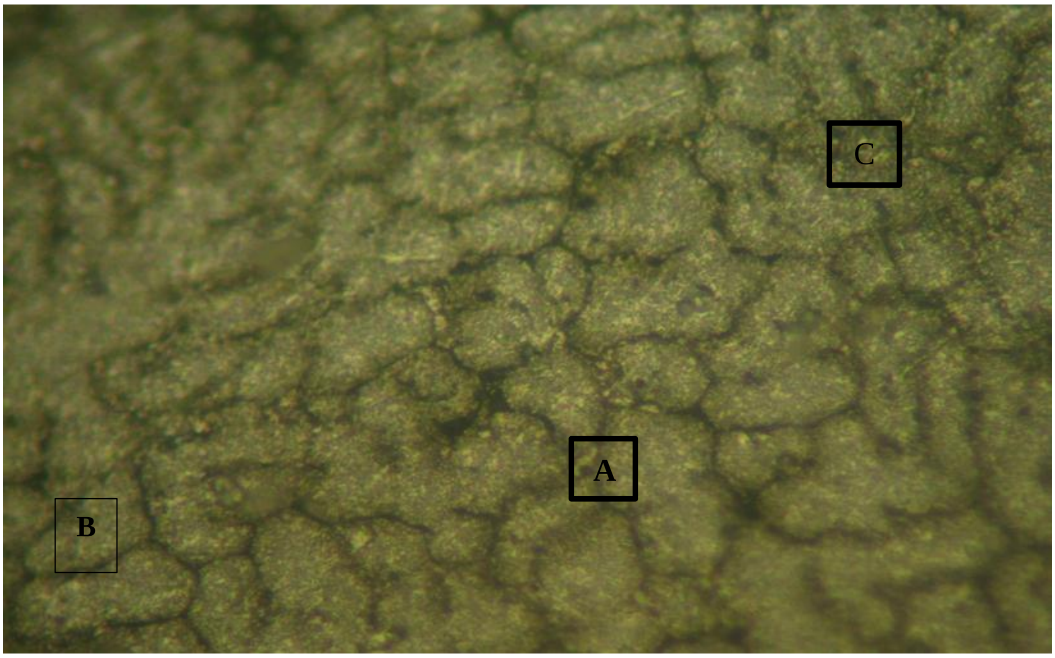

Plate 7: Micrograph of Al-4%Cu-1.0%Mo

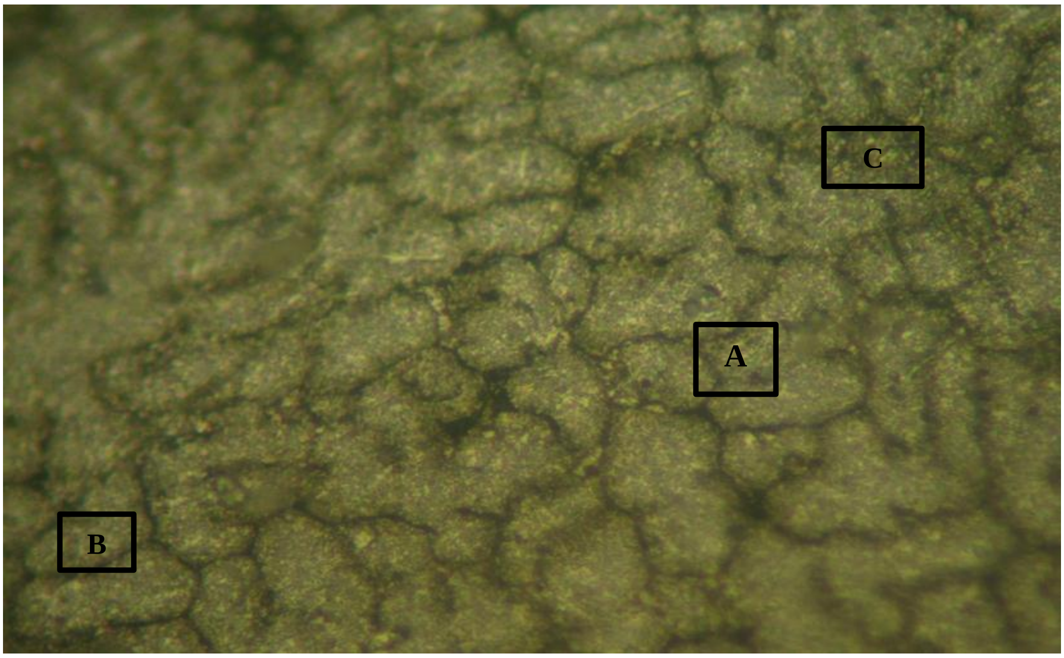

Plate 8: Micrograph of Al-4%Cu-1.5%Mo

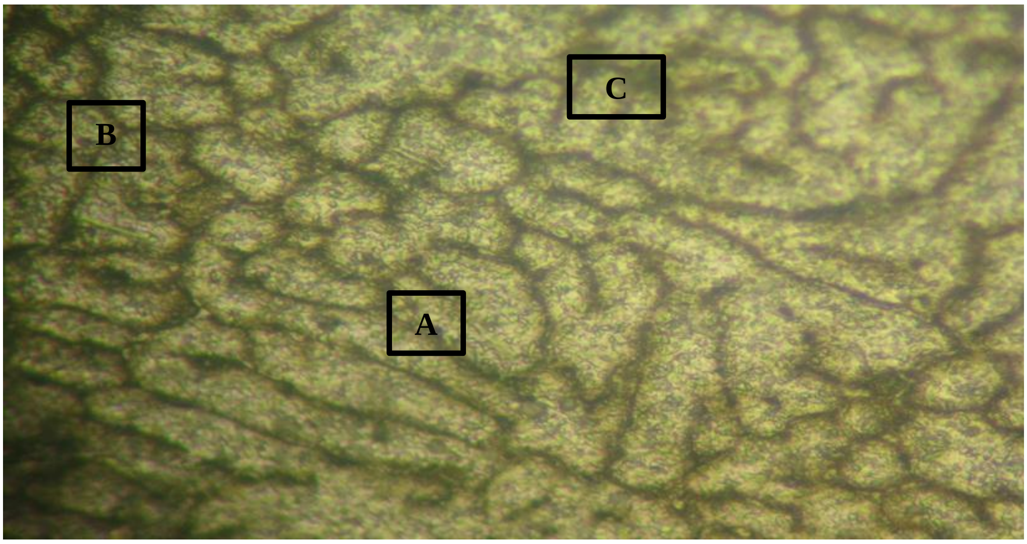

Plate 9: Micrograph of Al-4%Cu-2.0%Mo

It can be seen from plates 1 – 9 above that as the percentage weight of dopants increased, the grain boundaries increased. This explains the increase in hardness and ultimate tensile strength since grain boundaries impede movement of dislocations in the crystal lattice of the alloy.

CONCLUSION

From the results of the study shown above the following conclusions can be made;

1. The hardness and ultimate tensile strength of Al-4%Cu alloy can be improved by doping with nickel and molybdenum.
2. The increase in hardness and ultimate tensile strength was achieved but ductility was sacrificed in the process.
3. The rate of increase in the hardness and ultimate tensile was lower than the rate of decrease in ductility.
4. The percentage increase in hardness and ultimate tensile strength was observed to be smaller than the percentage decrease in ductility.
5. Molybdenum is a better dopant than nickel in terms of percentage increase in hardness and ultimate tensile strength.

RECOMMENDATIONS

1. Molybdenum and nickel are recommended as good dopants for Al-4%Cu alloys to improve their mechanical properties and hence their applicability in automobile and aerospace industries.

2. Concentration of both dopants in the base alloy should be less than or equal to 1% to avoid brittleness.

3. Suitable heat treatment should be carried out to make the doped material less brittle.

REFERENCES

[1] Adeosun S. O., S. A. Balogun, L. O. Osoba, W. A. Ayoola & A. M. Oladoye (2011) Effect of Cu and Zn Addition on the Mechanical Properties of Structural Aluminum Alloy, Journal of Modern Manufacturing Technology, 3(1) January-June 2011; pp. 103-110.
[2] Davis J. R. (2001) Alloying: Understanding the basics, ASM International® Materials Park, OH 44073-0002, ISBN: 0-87170-744-6.
[3] Feidlander I. N., E. A. Tkachenko, N. A. Parkhomenko, E. N. Matveets. The effect of microalloying on the structure and properties of Al-Zn-Mg-Cu alloys, Metal Science and Heat Treatment, April 1986, Volume 28, Issue 4, pp. 285-290
[4] Mahasneh A. A., S. M. A. Al-Qawabah (2011) Effect of Vanadium Addition at a Rate of 0.1% on the Mechanical Characteristics, Microstructure, and Microhardness of Al-Cu Casted Alloys. Modern Applied Science, Vol. 5, No. 2; (April 2011) PP 92.
[5] Nafsin N., H. M. M. A. Rashed (2013) Effects of Copper and Magnesium on Microstructure and Hardness of Al-Cu-Mg Alloys, International Journal of Engineering and Advanced Technology (IJEAT), ISSN: 2249 – 8958, Volume-2, Issue-5, June 2013.
[6] Nnakwo K. C., E. E. Nnuka, J. U. Odo, S. M. Obiorah, P. A. Oghenekowho (2014) Effect of Magnesium and Manganese on the Secondary Phase and Mechanical Properties of Aluminium-4%Copper Alloy, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 3 Issue 8, August - 2014
[7] Nnuka E., A. Ette (1990) Texture, composition-sensitive structure and mechanical properties of Al-Cu and Al-Zn alloy system, The Nigerian Engineer, Vol. 25, No. 1, 1990
[8] Nnuka E., C. Onwu, A. Nwankwo (2001) The physics of the action 0f dopants in cast aluminium and some of its alloys, Journal of Science and Technology Research, Vol. 3, No. 1, 2001, ISSN 1596-9649.
[9] Royset J, N. Rynum. Scandium in aluminum alloys. International Materials Review, 2005, 50(1): 19−44.
[10] Sani A Salihu, Aliyu Isah, Polycarp Evarastics (2012) Influence of Magnesium Addition on Mechanical Properties and Microstructure of Al-Cu-Mg Alloy, IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS), ISSN: 2278-3008. Volume 4, Issue 5 (Nov. – Dec. 2012), PP 15-20.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

APPENDIX

Mechanical properties of aluminium-4% copper alloy doped with nickel and molybdenum.

S/N	Alloy Composition	UTS	BHN	Energy absorbed (J)	% Elongation
1	Al-4%Cu	135	520	1.00	6.9
2	Al-4%Cu-0.5%Ni	127	524	0.47	4.8
3	Al-4%Cu-1.0%Ni	132	537	0.46	1.9
4	Al-4%Cu-1.5%Ni	144	546	0.28	1.4
5	Al-4%Cu-2.0%Ni	160	552	0.18	1.2
6	Al-4%Cu-0.5%Mo	146	540	0.40	4.4
7	Al-4%Cu-1.0%Mo	156	594	0.28	1.2
8	Al-4%Cu-1.5%Mo	167	608	0.21	1.0
9	Al-4%Cu-2.0%Mo	177	647	0.16	0.6