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## Development of Copper Nano Crystalline Metal Matrix Composite

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**Abstract:** There has been an increasing interest in composites containing low density and low cost reinforcements. High mechanical strength and excellent electrical conductivity of copper matrix composites, along with other properties, ensure a wide application range for these materials. To fabricate metal matrix composites among the various manufacturing technologies sintering and casting are the most advantageous techniques. The objective is to develop copper nano crystalline metal matrix composite reinforced with chromium and tungsten, to make copper nano crystalline metal matrix composite by both Powder metallurgy and casting process with copper, chromium, tungsten in the ratio of 60%, 25%, 15% and to find the micro hardness value for the manufactured copper nano crystalline metal matrix composite, to analyse the microstructure using SEM and composition by XRD.

**Keywords:** Copper Nano Crystalline Metal Matrix Composite.

### Introduction

During the last decade, as a consequence of the development of highly reinforced copper alloys, numerous research work was published reporting on diverse processing and forming techniques of these composite materials. Metal matrix composites were prepared of AlSiC with varying percentile compositions of SiC at 5% 10% 20% 15% and 30% with aluminium<sup>1</sup>. These sample were tested for hardness, impact and the micrographs were examined. Measured the compact dimensional change during liquid phase sintering of W-Cu system sintered at 1250<sup>0</sup>c is reported<sup>2</sup>. Micro structural characterisation was done using optical microscopy.

The effect of space holder content on the porosity of sintered copper fabricated by powder metallurgy was studied<sup>3</sup>. Copper powder and carbamide particles were compacted by hand press and its true density were measured. Copper reinforced copper matrix composite with 2% carbon nanotubes and compacted at 80kN and sintered<sup>4</sup>. The results of the sintered and theoretical densities showed 98% of the theoretical density. Stir casting technique was used to study and optimise the stirring conditions is reported<sup>5</sup>. A computer program was used to stimulate the fluid flow in the process. Preparation of a metal matrix composite using Al7075 alloy matrix reinforced with alumina particulates was reported<sup>6</sup>. Tensile behaviour like ultimate tensile strength and percentage elongation were studied. Investigated the hardness of metal matrix composite composed of Al(6061)

as matrix and rice husk and copper as reinforcement<sup>7</sup>. The results showed that the hardness increased as the percentage weight of reinforcing particles.

Fine ceramic particles, based on metal oxides, nitrides, borides and silicates are most commonly used as composite reinforcements. Typically reinforcing material are strong with low density while the matrix is usually ductile or tough material. If the composite is designed and fabricated correctly, it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material. To fabricate metal matrix composites among the various manufacturing technologies powder metallurgy is one of the most advantageous technique.

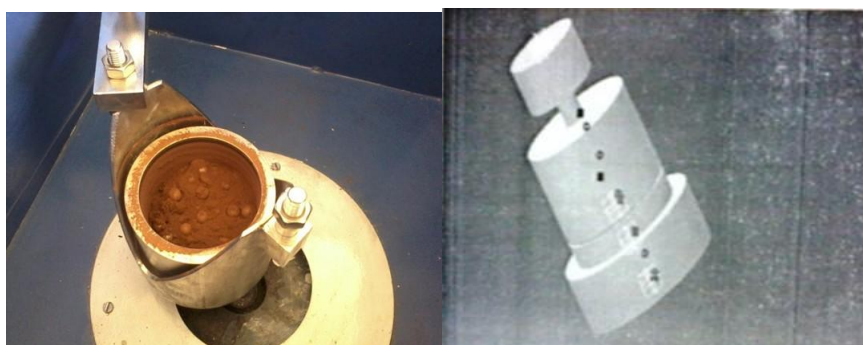
The objective is to develop copper nano crystalline metal matrix composite reinforced with chromium and tungsten, to make copper nano crystalline metal matrix composite by both P/M and casting methods and to find the micro hardness value for the manufactured copper nano crystalline metal matrix composite, to analyze the microstructure using SEM.

## Experimentation

The metal matrix composite consisting of copper, chromium, tungsten at 60%, 25%, 15% of weight respectively was formed. The powders were first ball milled (planetary ball milling) individually for 12 hours and combined for 8 hours. The purpose of ball milling is to convert the metal powders into nano size. The ball milling machine used is VBCC/PM/250/7 model with a maximum load of 10 to 100 grams and optimum speed is 650 rpm. A die was prepared for compacting these powders with die internal diameter of 20 mm and die length of 100mm with clearance of 1mm, the material used is hardened alloy steel. The die is machined in a lathe machine with T-30 and K-20 carbide insert and the 20 mm hole is made by carbide drill tool. The die was treated at a temperature of 800° c in a blast furnace to increase its hardness.

## Specification

Model	: VBCC/PM/250/7
Sample quantity:	200 to 300 grams
Maximum load	: 10 to 100 grams
Input size	: up to 5mm
Output size	: 0.1 – 1 micron
RPM	: 650 RPM (optimum speed – 250 to 300 RPM)
Grinding jar	: tungsten carbide 250 ML
Grinding Media	: tungsten carbide – 10 mm balls



**Fig.1 During ball milling of Cu Fig.2 Catia Model of die**

## composite powders

Next the powders are compacted to get it into a shape and also give densification. A hydraulic press of 400bar capacity is used for this process, the die with powder are placed in the hydraulic press and pressed to make it to a shape. This is called green compact. Next stage is the sintering of the compact, it increases the density and improves hardness and toughness. Pellet of 20mm in diameter and 5mm in height is compacted at the pressure of 372 bar and another pellet of 10mm in diameter and 2mm in height is compacted at the pressure of 400 bar is compacted.

By using the box furnace the 20mm diameter pellet was sintered at a temperature of 710°C. It took 2 hours and 20 minutes to reach the temperature of 710°C and it is kept at this temperature for 1 hour and then cooled within the furnace for another 2 hours. The 10mm diameter pellet was sintered at a temperature of 950°C. It took 3 hours to reach the temperature of 950°C and it is kept at this temperature for 2 hours and then cooled within the furnace for another 3 hours.

Finally, the composite powder was filled in an alumina crucible and it was placed in the box furnace and heated up to a temperature of 1300°C. It took 4 hours to reach the temperature of 1300°C and it was cooled within the box furnace for another 2 hours.



**Fig. 3 Cast material in ingots**

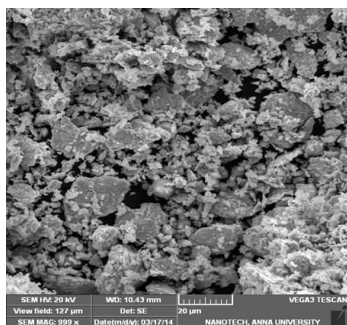
## Results and Discussion

### Hardness test

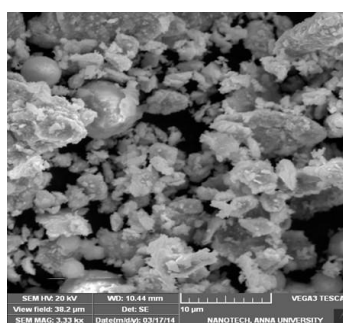
Vickers hardness test was done to measure the micro hardness of the specimen prepared which has a square-based diamond-pyramid indenter with angle of 136° between opposite faces. A load of 0.5kg was applied. The Vickers hardness number being expressed in terms of load and area of impression. The average hardness of sintered sample is 53.776HV and for casting it is 68.4HV.

### SEM Analysis

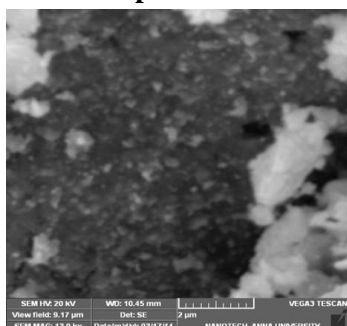
By comparing these SEM images it is inferred that as the temperature for sintering increases, the agglomeration formed is more which implies that the possibility of finding nano particles at the same magnification in a material sintered at high temperature is lesser than the material sintered at lower temperature.



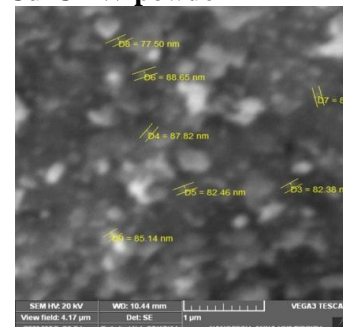
**Fig.4. 20μm magnification Cu-Cr-W powder**



**Fig. 5 10μm magnification of Cu-Cr-W powder**

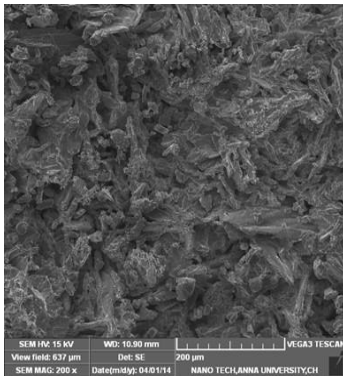


**Fig.6. 2μm magnification of Cu-Cr-W powder**

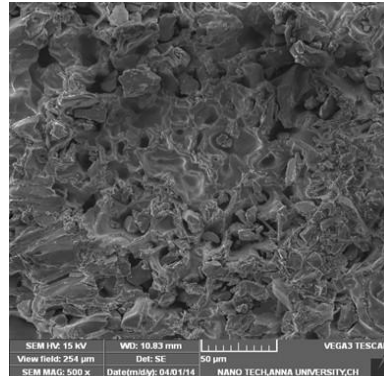


**Fig. 7 1μm magnification of Cu-Cr-W powder**

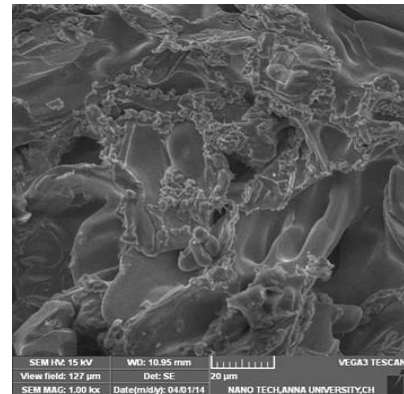
Fig.4, Fig.5, Fig.6, Fig.7 shows the SEM image of copper metal matrix composite powder at various magnification. The SEM images shows the homogenous mixture of copper and reinforcement



**Fig.8. 200µm magnification of sintered material**

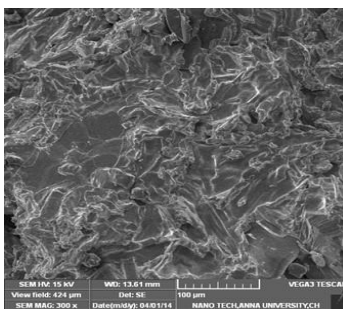


**Fig. 9 50µm magnification of sintered material**

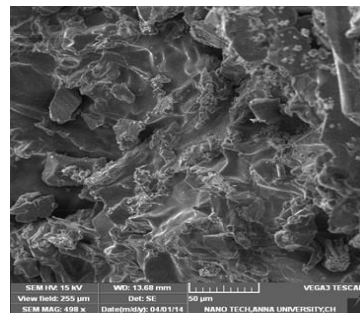


**Fig.10 20µm magnification of sintered Material**

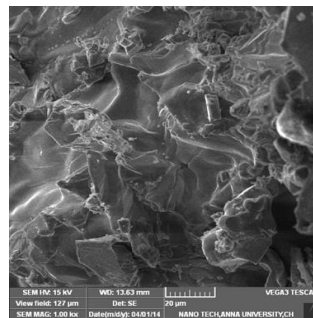
Fig.8, Fig.9, Fig.10 shows the SEM image of sintered copper metal matrix composite at various magnification. The copper metal matrix composite shows the cluster formation in the structure. Due to increased sintering temperature and cluster formation on the composite there is reduction in the hardness value



**Fig.11. 100µm magnification of cast material**



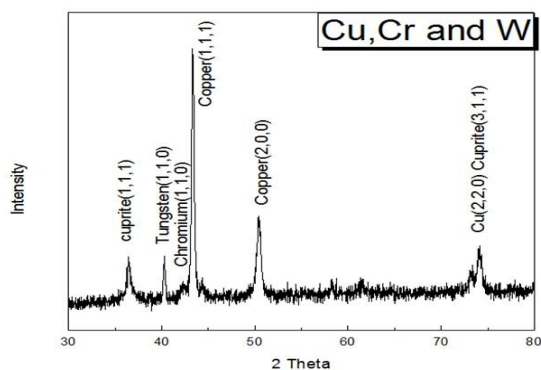
**Fig. 12 50µm magnification of cast material**



**Fig 13 20µm magnification of cast material**

## XRD Test

Fig.4 illustrates the XRD patterns of Cu-Cr-W powder in which the copper occupies the peak position. The peak position indicates that the majority of the constituents is copper in the metal matrix composite. The pattern also shows the presence of chromium and tungsten.



**Fig.4 XRD of Cu-Cr-W powder**



## Conclusion

The SEM images of cast metal matrix and sintered metal matrix reveals that a clustered structure is formed in both the types. The clustered structure is more prevalent in cast material due to its high temperature. Due to this more densification is obtained in cast matrix which results in a higher hardness. The micro hardness test showed that the casted copper nano crystalline metal matrix composite has higher hardness than sintered copper nano crystalline metal matrix composite. Future work can be carried out by varying the temperature for both casting and sintering and also by varying the Chromium and tungsten percentage of weight.

## References

1. Bözkal, O., Anish, U., Öveçolu, M.L. and Randall M.German, Realtime Sintering Observations in W-Cu system: Accelerated Rearrangement Densification via Copper Coated Tungsten Powders Approach, Sintering, 1-5, Euro PM, 2004
2. Shamsul, B.J., Chong, X. Y., AlidaAbdullah, KamarudinHussin, Effect of Space Holder and Compaction Pressure on the Porosity of Sintered Copper, Advanced Materials Research, 795, 82-86, 2013.
3. Gehad, G., Faiz, A., Mamat, O.,Microstructural Studies Of Sintered Carbon Nanotubes Reinforced Copper Matrix Composite, Journal of Engineering Science and Technology, 5, 272-283, 2010.
4. Indumati, B.D., Purohit, G.K., Modelling Tensile Behavior of Stir-cast Aluminium Matrix Composites (AMCs) Using Factorial Design of Experiments, Chemistry and Materials Research, 2, 1-8, 2012.
5. Ankit, M. and Ramnarayan, M., Fabrication and characterization of Mechanical Properties of Al-RHA-Cu Hybrid Metal Matrix Composites, International Journal of Current Engineering and Technology, 3, 1779-1783.

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