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Study of grain size variation and thermal oxidation of nanocrystalline copper produced by exploding wire method

Rashmita Das*, Basanta. K.Das, Anurag Shyam

Energetics and Electromagnetics Division, Bhabha Atomic Research Centre, Autonagar, Visakhapatnam - 530012, (INDIA)

E-mail : rashmita78@gmail.com

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ABSTRACT

Heat generation in the process of formation of nanoparticles plays important role. Copper wire exploded by current pulse undergoes many intermediate stages, whose detailed study is required for formation of desired size, shape as well as of the possibility of generation of new material. In this paper we will discuss about those intermediate stages of copper oxide by varying overheating of wire, which occurs due to variation of the energy injection into the wire. Sample was characterized by X-ray Diffraction for composition and grain size variation. The result shows the systematic increase of oxidation of copper with decrease of grain size.

KEYWORDS

Oxidation;
Nano powder;
XRD;
Exploding wire.

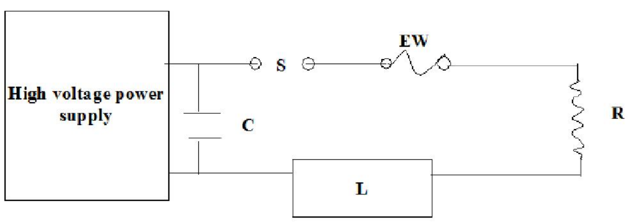
INTRODUCTION

In recent years, there are many evolving experiments emphasizing the synthesis and fabrication of different size and shape of metal nanoparticles Metal nanoparticles display many significant application in optics, nano electronics, information storage etc[1]. Copper powder are interest of many researchers due to its application in gas testing facilities, lubrication bearings, electrical connections, cutting tools and copper oxide have applications in a p type semiconductor[2]. Considerable experimental studies were carried out on generation of nanoparticles of oxides by the wire explosion process[3-5]. Therefore, it is almost desirable to characterize intermediate stages of the formation of copper oxide during the processing of copper nanoparticles in wire explosion method. In this study; the thermal oxidation of copper nano particles by wire explosion technique has been reported.

EXPERIMENTAL TECHNIQUE

It is difficult to clearly understand the process involved in nanoparticles formation by exploding wire method as it undergoes multiphase phenomena. The entire process initiate around the amount of energy deposited into the wire. Understanding of formation of nanoparticles of particular composition, morphology requires a methodical experimental study, which is very time consuming but necessary to determine many high temperature phenomena and material behaviour where high temperature and shock involved.

The basic circuit involved is a capacitor discharging LCR circuit figure 1. In the present work, the experiments were carried out by imparting different levels of electrical energy to the exploding conductor. The capacitor of 7.1 µf was charged from 7.5 kV to 11.5 kV. The energy stored in the capacitor was discharged into the wire of 0.19mm diameter and 12 cm length in short interval of time as of micro second. Maximum energy it can deposit into the wire in time period t is given by E=V×I×t[6]. The voltage developed across the wire was measured by voltage probe and current through the wire was measured by current transformer. The magnitude of current flow in the circuit depends on the resistance and inductance of the circuit. The current flowing in the wire causes the joules heating of the wire. That leads to the temperature rise of the conductor. Higher the energy of deposition, higher the increase of temperature. Due to vaporization of the wire, the resistivity increases, this leads to sudden drop in the current. Voltage and current waveform of different charging voltage are shown in figure 2-5. Re striking occurs when we go to



S: Spark gap
EW:Exploding wire
R: Resistance of circuit
L: Inductance of the circuit
C: Capacitor

Figure 1: Circuit diagram of exploding wire experiment.

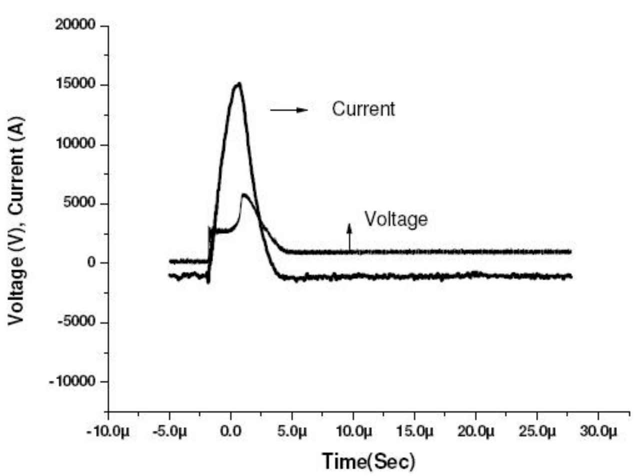


Figure 2 : Current and voltage waveform for the charging voltage 7.5 kv

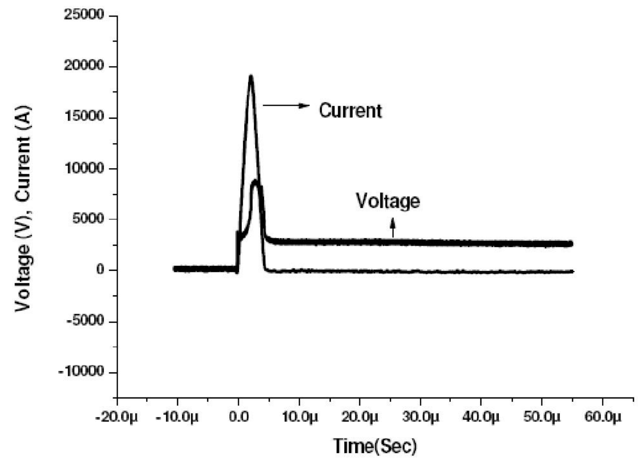


Figure 3 : Current and voltage waveform for the charging voltage 9.5 kv

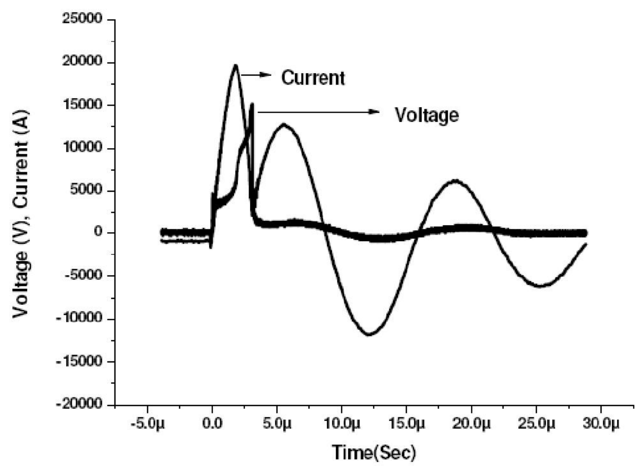


Figure 4 : Current and voltage waveform for the charging voltage 10.5 kv

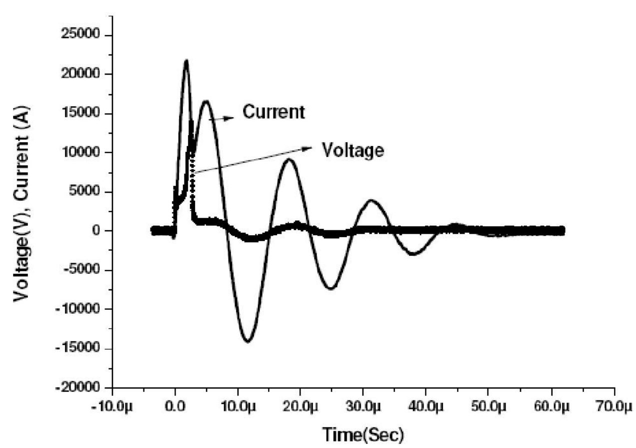


Figure 5 : Current and voltage waveform for the charging voltage 11.5 kv

higher voltage. Energy deposited in the wire for respective charging voltages are shown in figure 6.

The powder samples were characterized by x- ray diffraction (XRD) to determine the grain size variation and evolution of thermal oxidation of copper at higher temperature. XRD pattern of different phases of copper and copper oxide nanoparticles with the variation

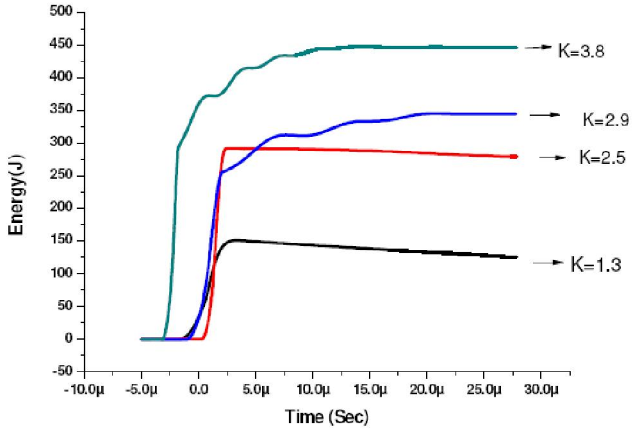


Figure 6 : Energy deposited into the wire with variation of overheating factor

TABLE 1 : Grain size variation with overheating factor

Sample No	Over heating factor	Grain size (nm) XRD
1	1.3	59.68
2	2.5	51.13
3	2.9	45.9
4	3.8	39.61

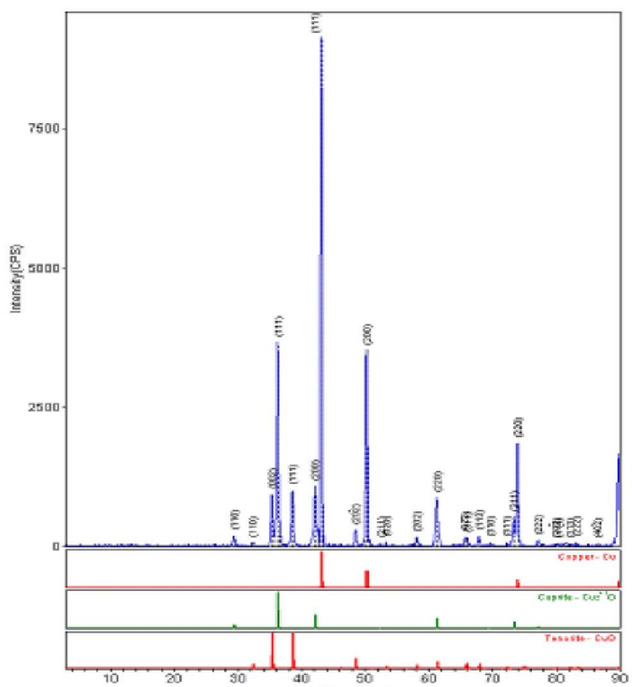


Figure 7 : X-ray diffraction pattern of the sample for overheating factor 1.3

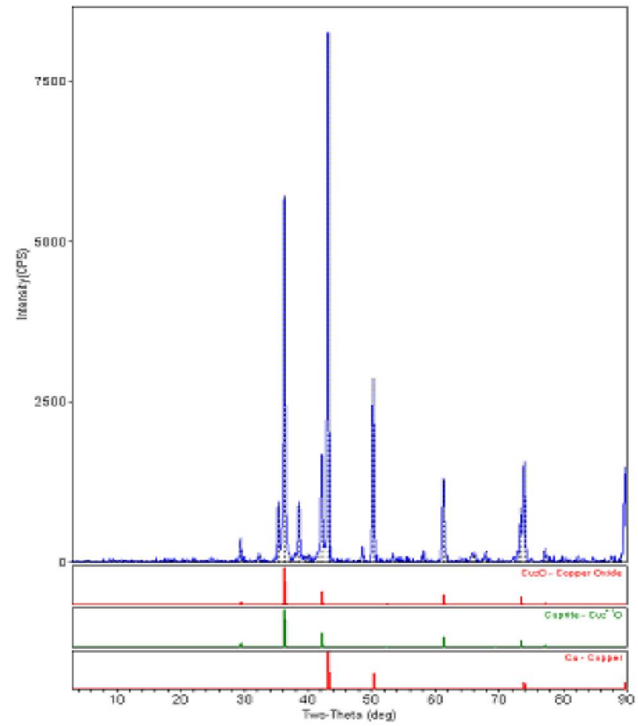


Figure 8 : X-ray diffraction pattern of the sample for overheating factor 2.5

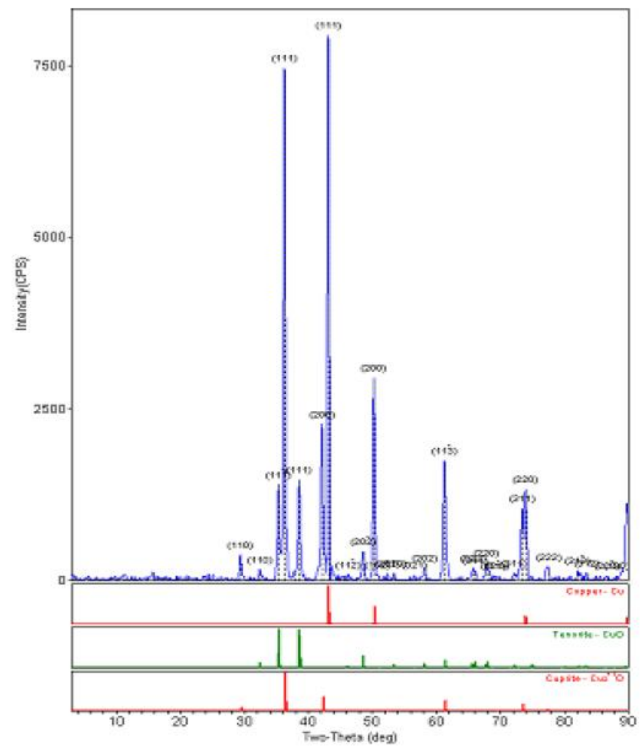


Figure 9 : X-ray diffraction pattern of the sample for overheating factor 2.9

of overheating factor, which is defined as the ratio of energy deposited into the wire to sublimation energy are shown in figure 7-10. Sublimation energy required

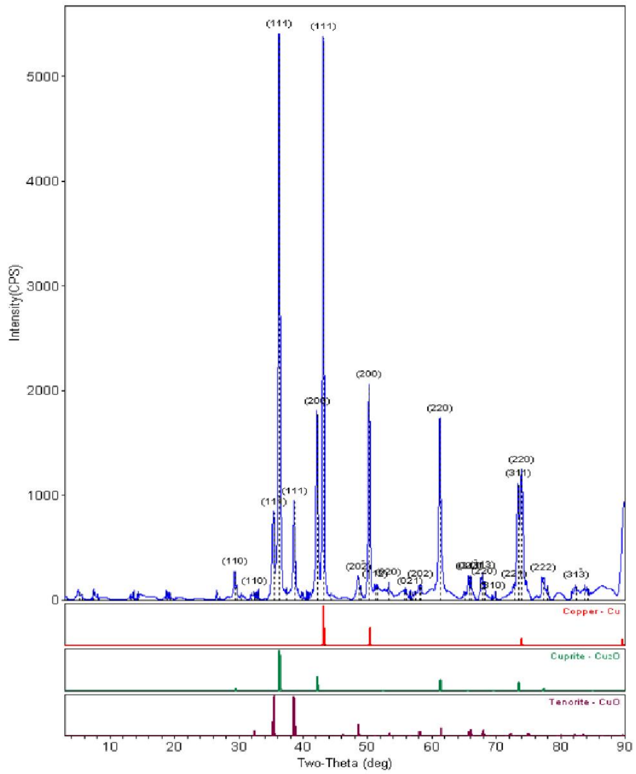


Figure 10 : X-ray diffraction pattern of the sample for overheating factor 3.8

for the wire in our case is 113 Joule. The grain size was measured by Scherrer's equation. Variation of grain size with overheating factor is shown in TABLE 1.

CONCLUSION

In the exploding wire experiment, nanoparticles form by Brownian coagulation of the explosion material. Here the explosion was carried out in atmosphere air. It is observed that for the overheating factor 1.3, core of nanoparticles is copper with very little oxidation of Cu_2O on the surface. But with the increase of overheating factor surface oxidation of copper increases in the same ambient condition. Grain size measured shows decreasing trend with increase of overheating factor. This indicates for higher temperature of vapour molecules and small size of the particles, rate of coagulation is very small.

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