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Open Air Exploding Arc Synthesis of Nano Cu and Cu_2O

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Low cost Cu and Cu_2O nanoparticles are prepared through explosion of copper wires in a current range of 50-200 amperes, at 220 volts, in the open air. Nanomaterials are characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM) and Raman spectra. Nano sizes between 20-100 nm are detected by SEM. XRD results show face-centered cubic (fcc) crystals with an average particle size of 25 nm.

Key Words: Synthesis, Nano, Arc, Nanoparticles, Copper, Copper oxide, Exploding wire.

INTRODUCTION

Simple quantitative syntheses of low cost, pure nanoparticles are of interest to many workers[1-10]. Major synthetic pathways developed include gas-phase chemical reaction[1], spray pyrolysis[2], water-heating reaction[3], laser ablation[4], flame processing[5], vapour deposition[6], microwave plasma[7], sol-gel[8], anodic arc plasma[9] and the exploding wire in dense media[10].

The latter two relatively more recent methods appear rather promising. Anodic arc plasma is reported to be a convenient and inexpensive method for giving high yields of Cu nanoparticles in inert atmospheres of helium, nitrogen and argon[9]. Similarly, exploding wire method is employed in a dense medium, typically water or some heavy alcohols, where Cu, Ag, Fe and Al nanoparticles are obtained[10]. Notably, strong explosions occur through electro explosion of wires (EEW), under water, with pulse current amplitudes of a few hundred amperes[11].

The explosions are driven by electrodynamic axial forces (F), generated in different parts of the element, which appear proportional to the square of current (I^2) and the logarithm of length of the wire (L) over its thickness (D)[12].

$$F = I^2 \log (L/D) \tag{1}$$

In fact the choice of the medium is one of the most important key factors for the control of the quality of nano particles produced through electro explosion of wires. In this present work, an attempt is made to produce uniform, low cost nanoparticles of copper and copper oxide, through exploding arc synthesis in the open air, as the medium of choice.

EXPERIMENTAL

Experimental conditions employed have the relative advantages of being economical and clear-cut. All tests are conveniently carried out in the open air, requiring very short times (0.001-1 s). Simply, currents of 50-200 amperes at 220 volts, are passed through thin copper wires-with different diameters (0.001-0.01 cm) until visible explosions occur. The nano-structures, produced in high yields, are characterized by a Holland Philips Xpert X-ray powder diffraction (XRD) diffractometer using monochromatic high intensity Cu K, radiation (λ = 0.154056 nm), at a scanning speed of 2"/min from 10" to 60" (2 θ). The particle size and morphology shape are investigated by scanning electron microscopy (SEM) of a Holland Philips XL30 microscope with an accelerating voltage of 25 kV. Micro Raman spectroscopy is preformed at room temperature using a thermo Nicolet almega dispersive Raman spectrometer equipped with a second harmonic 532 nm laser line in a back scattering configuration. The slit width is set to 20 μm and Raman spectrum resolution of about 4 cm^{-1}.

RESULTS AND DISCUSSION

Fairly uniform, chickpeas shaped copper and copper oxide nanoparticles are produced in high yields, using exploding arc method in the open air (Fig. 1). Specifically, a copper wire is driven through a wire guide across which a current is applied until a visible explosion takes place. The times required for the occurrence of explosions appear proportional to the square of current (I^2) and the logarithm of the length of the wire (L) over its thickness (D) (eqn. 1.)[12]. The SEM picture shows a uniform distribution of the nanoparticles, separated from each other and there is no clustering seen as such, at 100 amperes. A typical particle is chosen for the size measurement by drawing a line across it and the diameter measured. Several particles are investigated to infer particle sizes in the range 20-100 nm. The XRD pattern recorded for as a θ-2θ plot scanning from 10°-60° show the lines (111) and (200), at 2θ = 43.68° and 50.73°, respectively for Cu and lines (110), (111) and (200) at 2θ = 29.69°, 36.71° and 42.61°, respectively for Cu_2O (Fig. 2). The observation of a diffraction peak for the copper nanoparticles indicates that these are still crystalline (fcc) in this size range while its broadening is related to the altered particle size. However, the predominance of the (111) and (200) lines in XRD indicate reorientation of the nanoparticle grains preferentially in two directions against the random orientation of grains in the bulk material. Cu_2O nanoparticles have the predominance of the (110), (111) and (200) lines in XRD indicate reorientation of the nanoparticle grains preferentially in three direction. From the full width at half maximum, the average crystalline size can be estimated with the maximum peak in the XRD spectra according to the

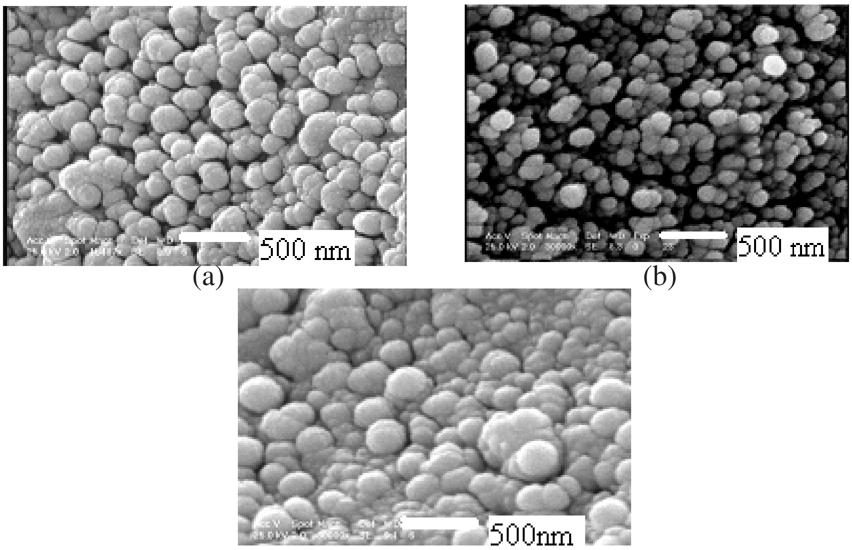

Fig. 1. Scanning electron microscopy (SEM) of the copper and copper oxide nanoparticles produced at (a) 90, (b) 100 and (c) 110 amperes in the open air

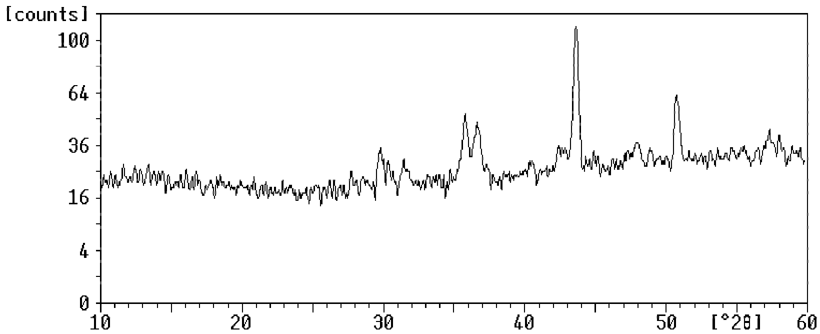

Fig. 2. XRD pattern of Cu and Cu_2O nanoparticles

Scherrer formula $d = KA/(B\cos\theta)$. d is the crystallite size, K = 0.89, which is the Scherrer approximate constant related to the shape and index (hkl) of the crystals, A is the wavelength of the X-ray (Cu Kα, 0.154056 nm), θ is the diffraction angle and B is the corrected half-width of the diffraction peak (in radians) given by $B^2 = B^2_m - B^1_s$; where B_m, is the measured half width and B_s, is the half-width of a standard sample with a known crystal size greater than 100 nm. The effect of geometric (instrumental) broadening on the reflection peaks is calibrated. The average crystallite size is calculated to be around 25 nm. Raman absorptions appear consistent with those of Cu and Cu_2O nanoparticles (Fig. 3).

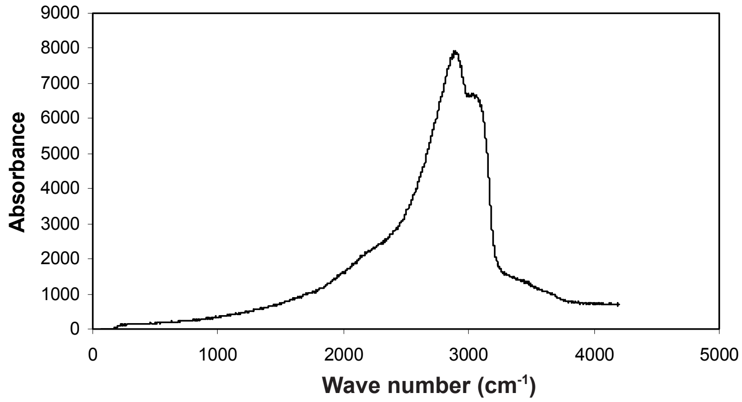

Fig. 3. Raman spectrum of Cu and Cu_2O nanoparticles

There are three clear dimensional images, obtained conveniently through SEM, give sufficient information on the desirable external surfaces of present nanostructures (Fig. 1). Hence, reporting TEM analysis appeared unnecessary for being out of the scope of this work.

Conclusion

Uniform, high-yield nanoparticles of copper and copper oxide are produced as visible explosions occur when currents of 50-200 amperes, at 220 volts, are passed through thin copper wires-with different diameters (0.001-0.01 cm) for short times (0.001-1 s) in the open air.

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