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Characterization of cupper iodine thin films fabricate by spin coating from nanoparticles produced by exploding Cu wire in Iodine solution

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Abstract : Explosive wire method is a simple and environmental friendly method that can be used in the preparation of chemical compounds. In this work cupper iodine thin films were fabricate by spin coating from nanoparticles produced by exploding copper wires with different diameters in Iodine solution, on glass substrates. The produced thin films were examined by XRD, FTIR, Uv-Visible spectroscopy, SEM and TEM to characterize their properties. The XRD proved that the thin films have nanostructure belonged to CuI poly-crystalline with cubic structure, the crystallinity and crystalline size decrease with increasing wire diameter. FTIR measurements show a peaks located at 638.92 for Cu-I stretch bond indicate on formation of copper iodide compound. It was found that the optical band gap, of CuI thin films decreases from 3.24 to 3.18 eV with increasing the Cu wire diameter from 0.18 to 0.3 mm as a result of increasing in particle size. The SEM and TEM measurements show that the thin films have nanostructures.

Keywords : exploding wire; Copper iodide; FTIR.

Introduction

Nanoparticles synthesized by different techniques like chemical[1], physical, mechanical[2] and biological methods [3]. explosion wire technique is a simplest technique to produce nanoparticles, which has recently huge interest [4]. the controlling of size of metal nanoparticle has more interest due its effect on their electrical and optical properties [5].Produced nanoparticles by exploding wires using high electric energy pass throw thin metal wire have several parameters, used to control their size and shape, such as voltage, current pulse, material type and their wire dimension[6], and the medium in which the explosion is performed, [7].

Copper iodide (CuI) is one of the promising materials for application in organic electronic devices [8]. It is an inorganic material exists in three crystalline forms: zinc blende structure below 390 °C (γ-CuI), a wurtzite structure between 390 and 440 °C (β-CuI), and a rock salt structure above 440 °C (α-CuI) [9] as shown in Fig. 1. The ions are tetrahedral coordinated when in the zinc blende or the wurtzite structure, with a Cu-I distance of 2.338 Å [10]. γ- CuI has attracted a most attention because it is wide bad gap, p- type semiconductor with unusual optical properties[11].

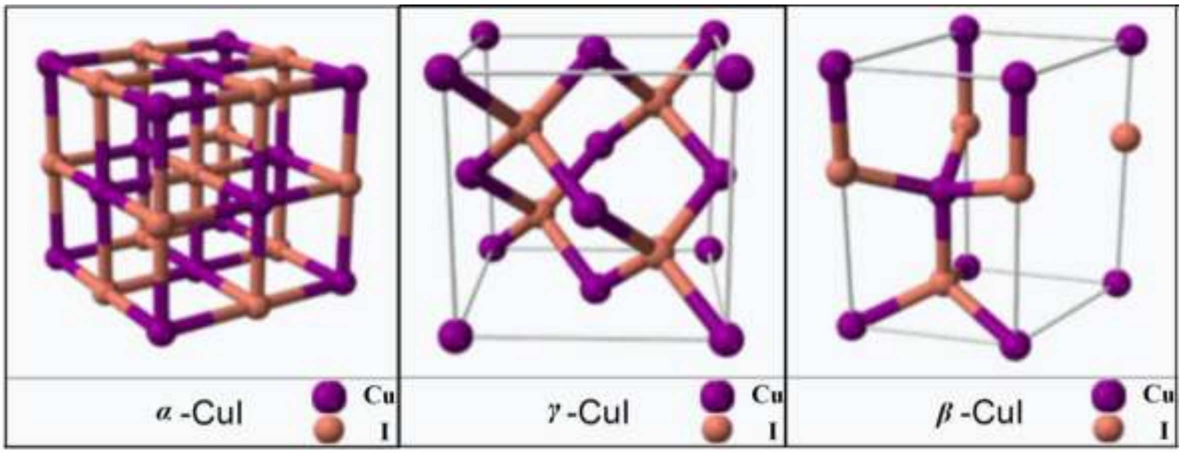

Fig. 1: Copper-iodide crystal structures [10]

Experimental part

Iodine powder (Purity: 99.99%; Alfa Asser) were used in our experiment. Iodine solution was fully dissolved in de-ionized water, Iodine weighing and dissolving as 5 mg/ml and putting it on magnetic stirrer for 35 hour parted in five days with shaking vigorously at fixed temperature (333 K) to help the material to be dissolved.

Copper wires with different diameters (0.18, 0.24 and 0.3) mm and 20 mm long were exploded using high current, with energy higher than the evaporation energy of Cu, in 100 ml Iodine solution to produce CuI nanoparticles. The basic circuit used to produce CuI nanoparticle is shown in Fig. 2.The wire was replaced after several contacts. The resulted NPs remain suspended in liquid (colloidal form). Many parameters can influence the particles produced by electro exploding wire technique. In this work, we examined the effects of wire diameter.

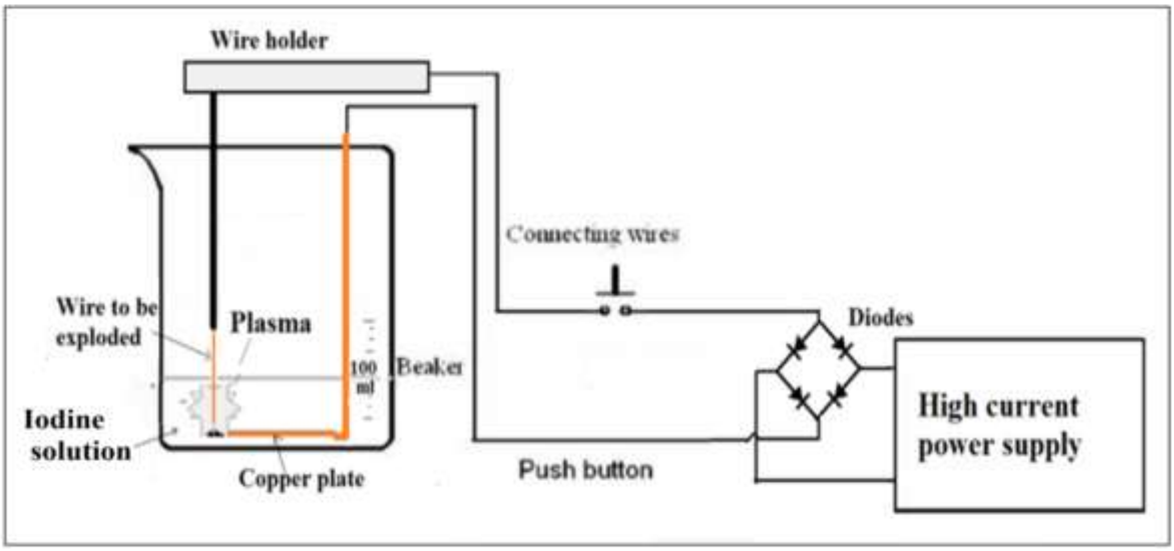

Fig. 2: Schematic diagram for exploding wire experiment.

Copper iodine thin films were fabricate by spin coating from nanoparticles produced by exploding copper wires with different diameters in Iodine solution, on glass substrates. The structure of the CuI thin films has been examined by X-ray diffraction (XRD), UV-visible absorption, Fourier Transform Infrared Spectroscopy (FTIR), Scanning electron microscope (SEM) and transmitted electron microscope (TEM).

Result and discussion

Fig. 3 shows the XRD patterns for CuI thin film, produced by exploding wire technique using 75 A current with different wire diameters, deposited on glass substrate at room temperature. This figure indicates that all films have poly-crystalline structure identical with cubic-CuI crystals (standard card No. 96-900-8845) with peaks located at 25.4958°, 29.5341°, 42.2461° and 49.9164° which corresponding to (111), (200), (220) and (311) directions respectively. The preferred orientation is along (111) direction. It can be seen that the peaks intensities increase with increasing wire diameter, which indicate on increasing the crystallinity as a result of increasing the copper amount with increasing wire diameter. Also it can noticed that the full width at half maximum (FWHM) decrease, i.e. the crystalline size increase, with increasing wire diameter.

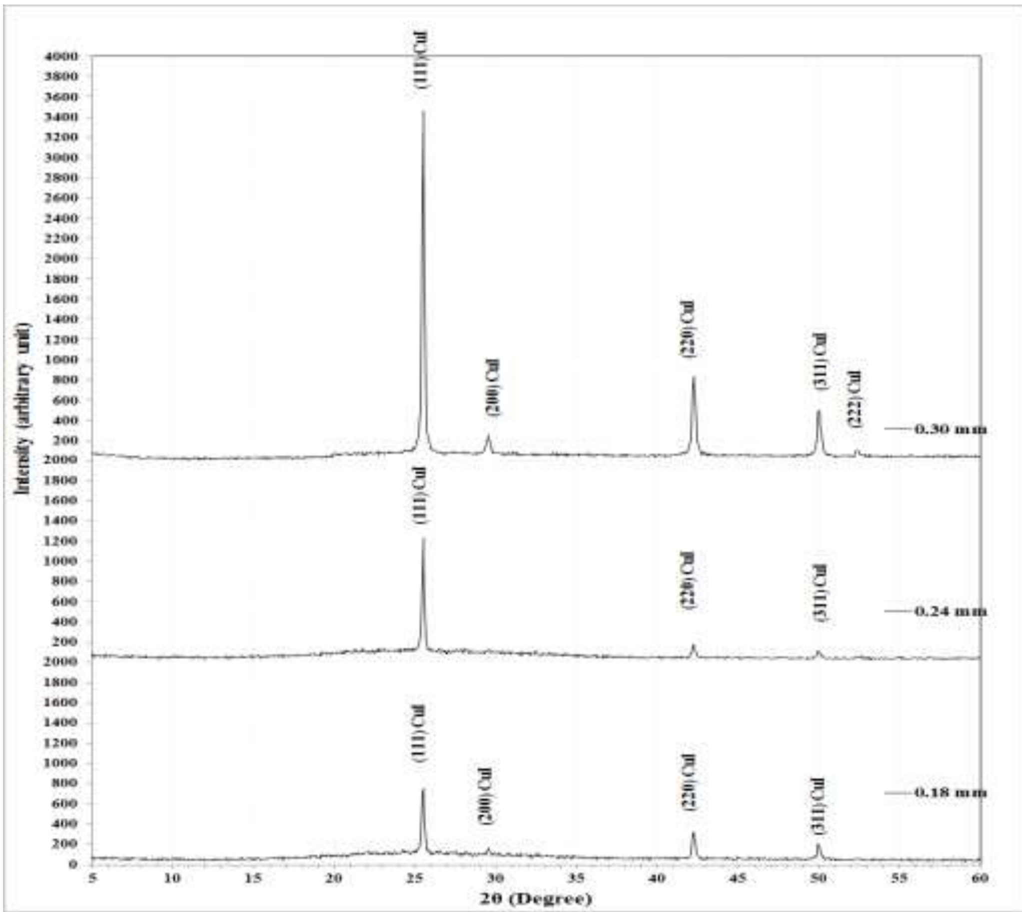

Fig. 3: X-ray diffraction patterns for CuI thin films using 75 A current with different wire diameters.

Table (1) shows Bragg angle (2θ), miller indices (hkl), experimental and standard inter molecular planer distance (d_{hkl}), FWHM and crystalline size (C.S) for all peaks observed in XRD patterns, for the CuI thin films using 75 A current and three different wire diameters.

Table 1: XRD parameters for produced CuI thin films using 75 A current with different wire diameters.

D (mm)	2θ (Deg.)	FWHM (Deg.)	d_{hkl} Exp.(Å)	C.S (nm)	d_{hkl} Std.(Å)	hkl
0.18	25.4958	0.2151	3.4909	37.9	3.4888	(111)
	29.5341	0.2389	3.0221	34.4	3.0213	(200)
	42.2461	0.2390	2.1375	35.6	2.1364	(220)
	49.9164	0.2389	1.8255	36.7	1.8219	(311)
0.24	25.5095	0.1721	3.4890	47.3	3.4888	(111)
	42.2442	0.1676	2.1376	50.8	2.1364	(220)
	49.9604	0.1662	1.8240	52.7	1.8219	(311)
0.3	25.5038	0.1621	3.4898	50.2	3.4888	(111)
	29.5025	0.1621	3.0253	50.7	3.0213	(200)
	42.2499	0.1520	2.1373	56.0	2.1364	(220)
	49.9948	0.1567	1.8229	55.9	1.8219	(311)
	52.3584	0.1663	1.7460	53.2	1.7444	(222)

Fig. 4 shows the variation of crystalline size along the preferred orientation (111) for CuI produced with different wire diameters. This figure shows that the crystalline size increase with increasing wire diameters, while decrease with increasing current. These results agree with previous researches [4].

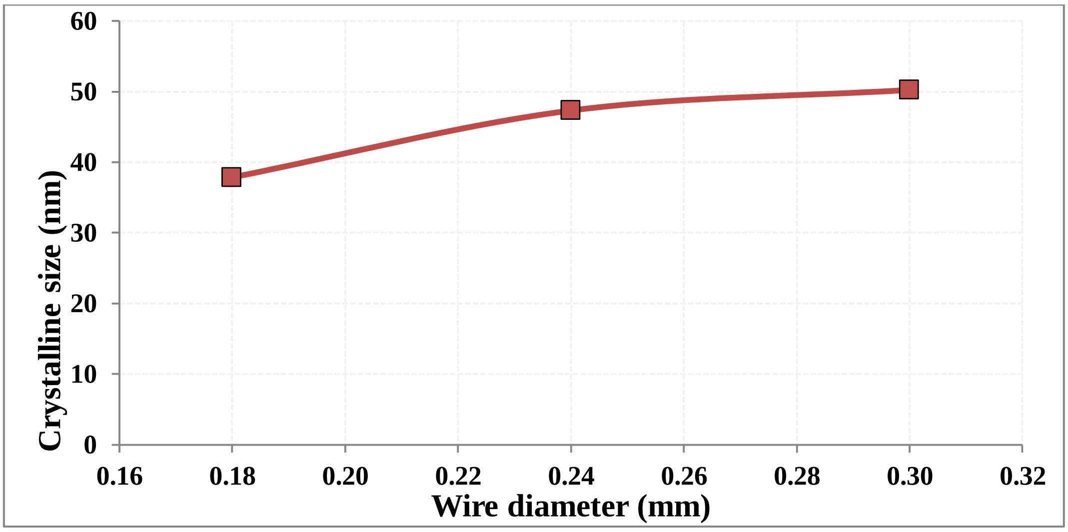

Fig. 4: Variation of crystalline size with wire diameter.

Fig. (5) Shows the variation of absorbance as a function of wavelength, within the range (300 – 1100) nm for CuI thin films, deposited on glass substrates, produced at different wire diameters and used current.It can be noticed that the absorbance increase slightly with increasing wire diameter as could be expected. The absorbance patterns experience a red shift with increasing wire diameter, indicate on decreasing band gap where the crystal size decrease with decreasing wire diameter.

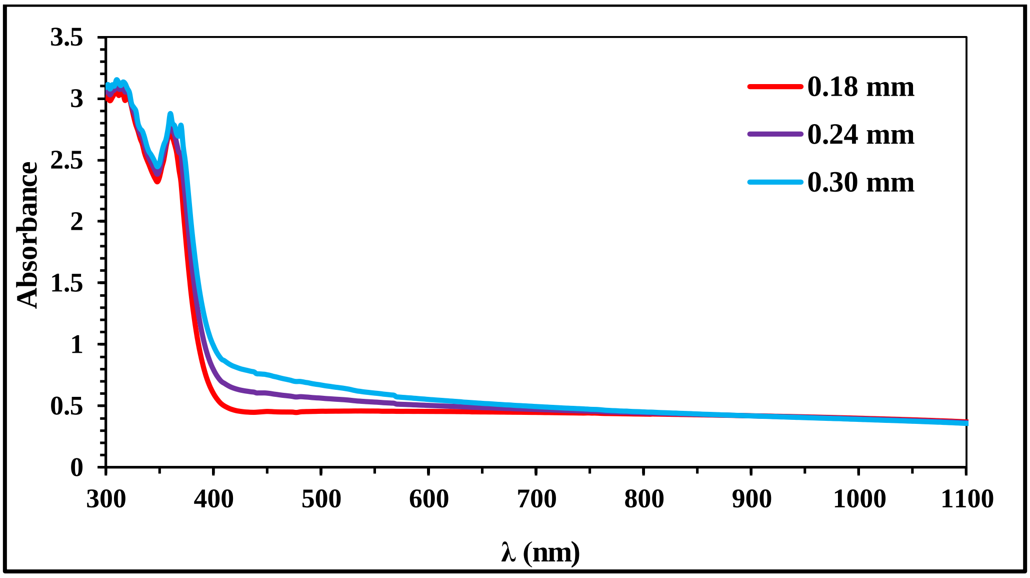

Fig. 5: UV-visible absorbance for CuI nanostructure films deposited on glass substrate using different wire diameters.

The optical energy band gap (E_g^{opt}) for CuI thin films produced with different wire diameter using 75 A current have been determined by Tauc equation. It was found that CuI nanostructure films have allowed direct transition. The optical energy band gap (E_g^{opt}) determined by extrapolation he portion at $(\alpha h\upsilon)^2$ =0 as shown in Fig. 6.It can see that the E_g^{opt} decreases from 3.24 to 3.18 eV with increasing the wire diameter from 0.18 to 0.3 mm as a result of increasing crystal size.

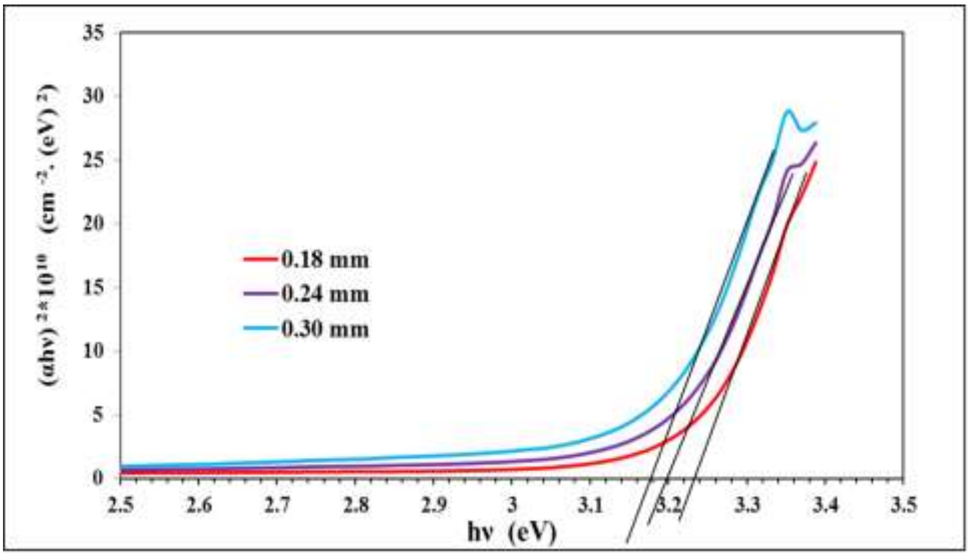

Fig. 6: Tauc relation for CuI nanostructure films deposited on glass substrate using 75 A current and different wire diameters

Fig. 7 shows the FTIR transmission patterns for CuI nanostructure films, deposited by spin coting and the deposited nanoparticles produced by exploding wire technique using 75 A current with different wire diameters and table 2 show the FTIR bonds for CuI nanostructure films where the nanoparticles produced by exploding wire technique using 75 A current with different wire diameters 0.18, 0.24and 0.30 mm. the FTIR transmission patterns shows one peaks located at 638.92 for Cu-I stretch bond which indicate on formation of copper iodide compound, and additional bonds located at 1080.31 for C-O bond, 1400.22 C-H bend vibration, 1618.90 for C=O, 343.76, 2368.05 for C=N and 3368.28 O-H stretch cm^{-1} may be corresponding to adsorbed atmospheric gasses [12]. The peaks seem as decreasing in their intensities as a result of increasing of their surface area, and its chemical efficiency decreases with the decrease of surface area.

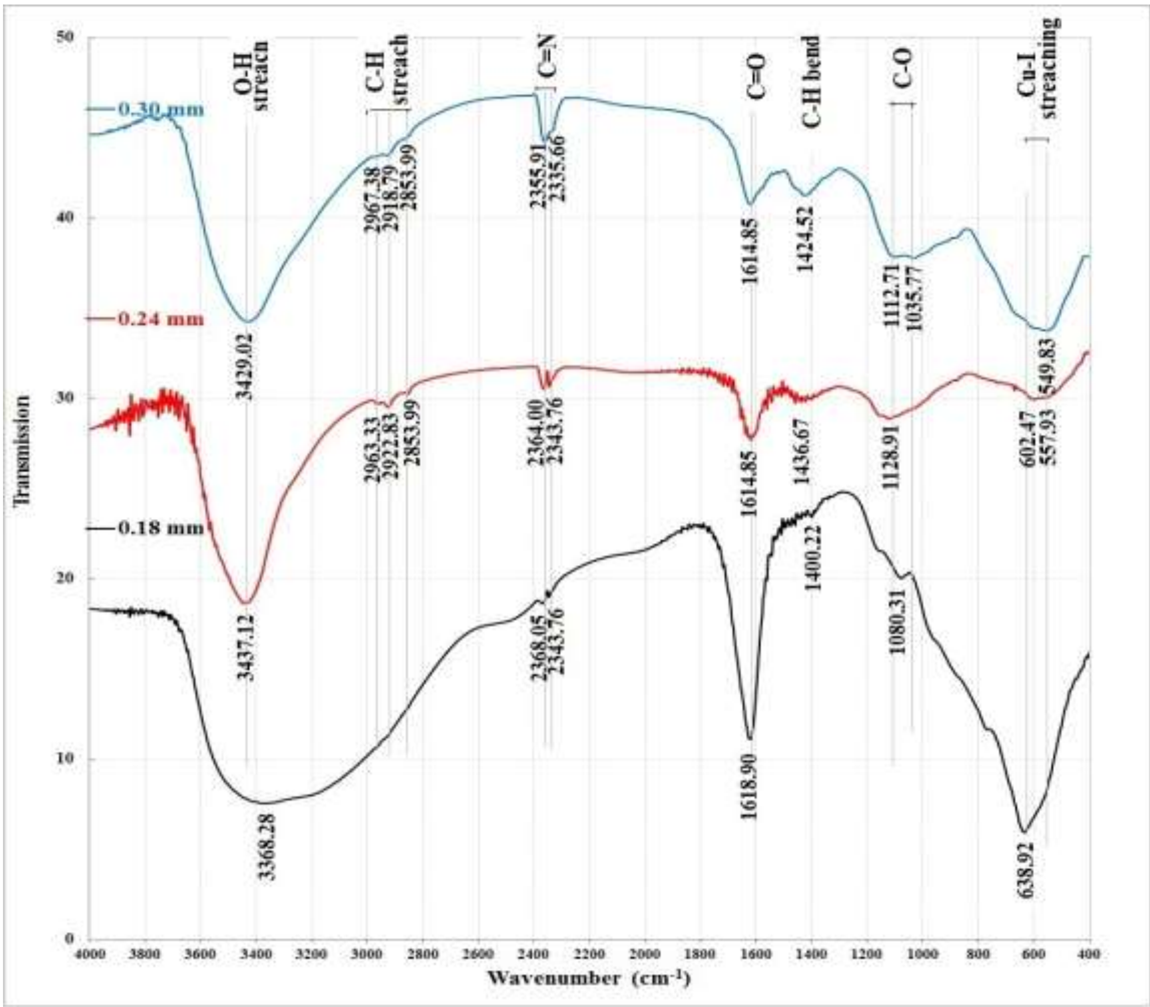

Fig. 6: FTIR for CuI nanostructure films where the nanoparticles produced by exploding wire technique using 75 A current with different wire diameters

Table 2: FTIR bonds for CuI nanostructure films where the nanoparticles produced by exploding wire technique using 75 A current with different wire diameters 0.18, 0.24and 0.30 mm

	0.18 mm	**0.24 mm**	**0.30 mm**
Cu-I stretch	638.92	557.93, 602.47	549.83
C-O	1080.31	1128.91	1035.77, 1112.71
C-H bend	1400.22	1436.67	1424.52
C=O	1618.90	1614.85	1614.85
C=N	2343.76, 2368.05	2343.76, 2364.00	2335.66, 2355.91
C-H stretch	-	2853.99, 2922.83, 2963.33	2853.99, 2918.79, 2967.38
O-H stretch	3368.28	3437.12	3429.02

Fig. 8 show SEM images for CuI nanostructure films, deposited by spin coting and the deposited nanoparticles produced by exploding wire technique using 75 A current with different wire diameters 0.18, 0.24and 0.30. This figure illustrates CuI nanoparticles as crystals with different diameters mixed with foam like shape. Also this figure demonstrates that the average grain size increase with increasing wire diameters.

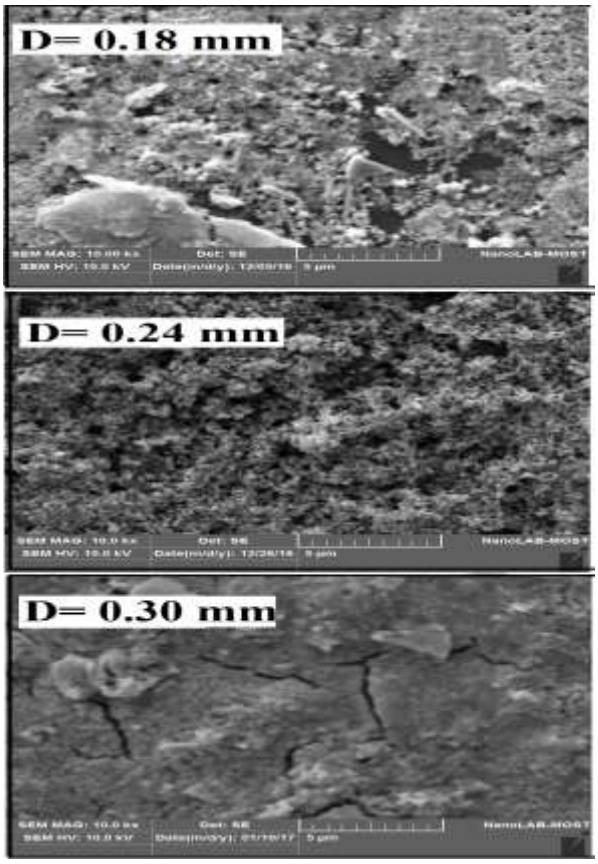

Fig. 8: SEM images for CuI nanostructure films, deposited by spin coting on glass substrates and the deposited nanoparticles produced by exploding wire technique using 75 A current with different wire diameters 0.18, 0.24and 0.30 mm.

Fig. 9 shows the TEM image with ×92000 magnification power and the granulate accumulation distribution chart for CuI nanostructure films, deposited by spin coting on glass substrates and the deposited nanoparticles produced by exploding wire technique using 75 A current and 0.24 mm weir diameter. The grain diameter was calculated for more than 100 particles and distributed in the form of equal intervals and finding the percentage of grains presence in each period. The average of grains size was 16.46 nm.

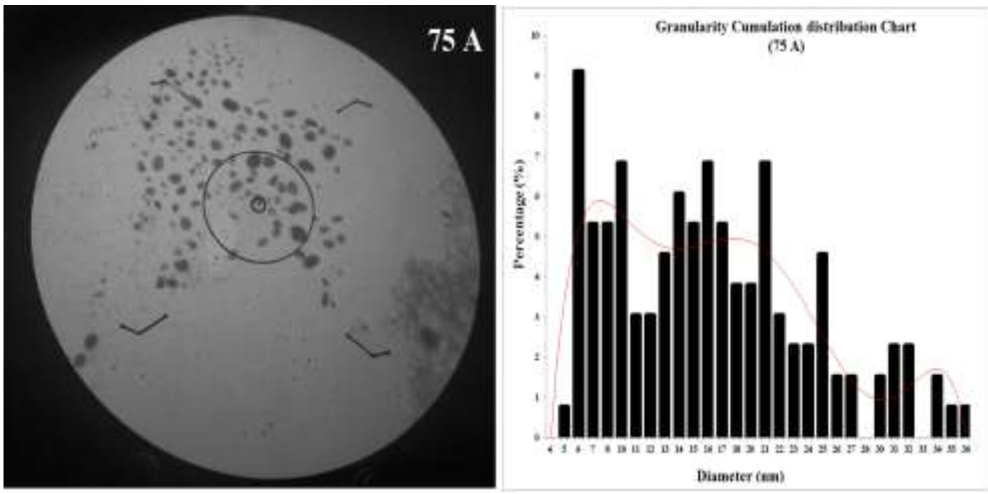

Fig. 9: TEM image with ×92000 magnification power and the granulate accumulation distribution chart for CuI nanostructure films, deposited by spin coting on glass substrates and the deposited nanoparticles produced by exploding wire technique using 75 A current and 0.24 mm weir diameter

Conclusions

Explosive wire method is a simple and environmental friendly method that can be used in the preparation of chemical compounds. and the thin films crystalline size depend on wire diameters which used as arrow material for production the nanoparticles which used later for thin films deposition.

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