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Effect of Cu Content on Some Physical Characterization of Green Sprayed Nanostructured CdO Thin Films

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Abstract.

CdO and CdO:Cu thin films with diverse content of Cu (2 and 4 wt.%) are deposited employing green spray pyrolysis technique (SPT). XRD test indicates that CdO has cubic structure with predominant orientation along (111). Crystallite size increases from 13.40 nm to 15.05 nm as Cu content increases, whilst strain decreases from 25.92 to 23.03. AFM images show Cu affects film surface topography , The grain size was in the domain of 7.292, 66.72 and 55.94 nm for the (Undoped CdO, CdO:2% Cu, CdO:4% Cu) respectively. The transparency of CdO film was decreased with Cu increasing. Refractive index and extinction values are changed with Cu content. The bandgap values were 2.63 and 2.53 eV for intended doping films respectively.

Keywords: CdO, Cu, SPT , Structural, morphology, Optical Properties, bandgap.

Introduction

The transparent conducting oxides are very important material in industrial applications, it can be used in solar cells, gas sensors, and detectors [1-5]. CdO have high transparency and high conductivity, which make it salutary for diverse applications, like photodiodes, gas sensors [6, 7,57-67]. It has n-type semiconducting properties with a rock-salt structure and a bandgap in the area of 2.2-2.7 eV [8-10]. CdO is a remarkable II–VI semiconductor [11-13]. In the current state ionic radius of Cu^{2+} is (1.35 Å), which is more than Cd^{2+} ion, (0.947 Å) [14]. Various techniques has been prepared CdO films like sputtering [15, 16], sol–gel [17,68-77], evaporation [18], PLD [19], CVD [20] and spray pyrolysis [21-29]. CdO films were grown employing SPT. It is an efficient production driving to less production time, homogeneous.

Experimental

The CdO films were grown utilizing 0.1 M of $CdCl_2$ that resolved 1:1 in redistilled water and ethanol. The 0.1 M of ($CuCl_3$) resolved in redistilled water, slight drops of HCl have joined the solution to get it fine. SPT was utilized to deposited films on glass substrates. The optimization parameters are: Substrates temperature 300 ^{O}C, area amongst spout and substrates was 29 cm, drizzling interval 9 s delayed by 45 s to evade refrigeration, drizzle rate was 4 ml/min, and N_2 is employed as a carrier gas. Film thickness was estimated utilizing weighing method to be 350 ± 25 nm. Structural properties were evaluated by XRD, while the AFM is utilized to get film topography. UV-Visible spectrophotometer is employed to record Transmittance spectra.

Results and Discussions

The XRD patterns were seen in Fig. 1. Results refereed that grown films were polycrystalline. peaks appeared at (111), (200), (220), (311), and (222) planes, which is fitted with ICDD card no. (03-065-2908). A strong peak was appeared toward (111).

The average crystallite size (D) was obtained employing the relation [30-33]:

$$D = \frac{0.9\,\lambda}{\beta cos\theta} \qquad (1)$$

Where λ is wavelength of X-rays used, β and θ are (FWHM) and diffraction angle respectively. The acquired data are given in Table 1. It is shown that D increases from 13.40 to 15.05 nm as Cu content increases.

The dislocation density (δ) is gained via the relation [34-37]:

$$\delta = \frac{1}{D^2} \qquad (2)$$

The strain (ε) is estimated by equation [38-41]:

$$\varepsilon = \frac{\beta cos\theta}{4} \qquad (3)$$

The value of ε increases with increasing Cu content, the obtained structural coefficients are displayed in Table 1. Fig. 2 symbolizes FWHM, D, δ and ε agianst Cu dopant.

Table 1. D, energy gap and structural coefficients of deposited films.

Sample	(hkl) Plane	2 □ (°)	FWHM (°)	D(nm)	Energy gap (eV)	δ (× 10^{14})(lines/m^2)	$\varepsilon \times 10^{-4}$
Undoped CdO	111	33.14	0.64	13.37	2.63	55.94	25.92
CdO: 2% Cu	111	32.85	0.60	14.17	2.58	49.80	24.27
CdO: 4% Cu	111	32.50	0.57	15.05	2.53	44.14	23.03

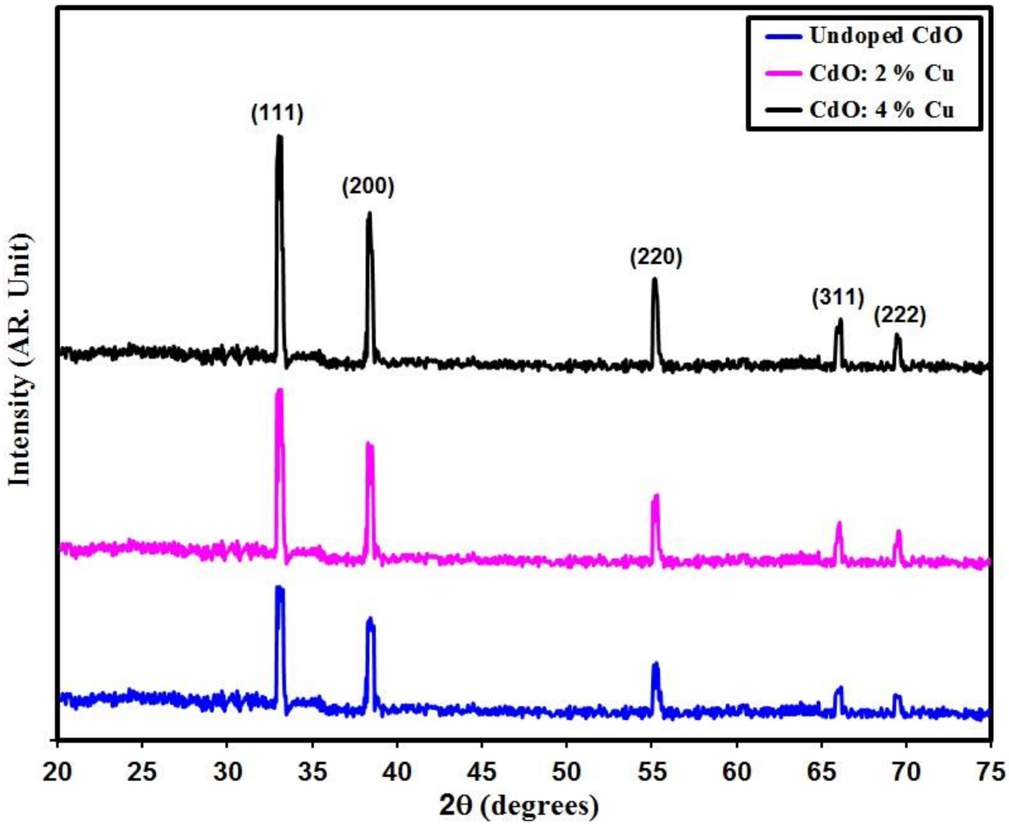

Fig.1. XRD pattern of intended films.

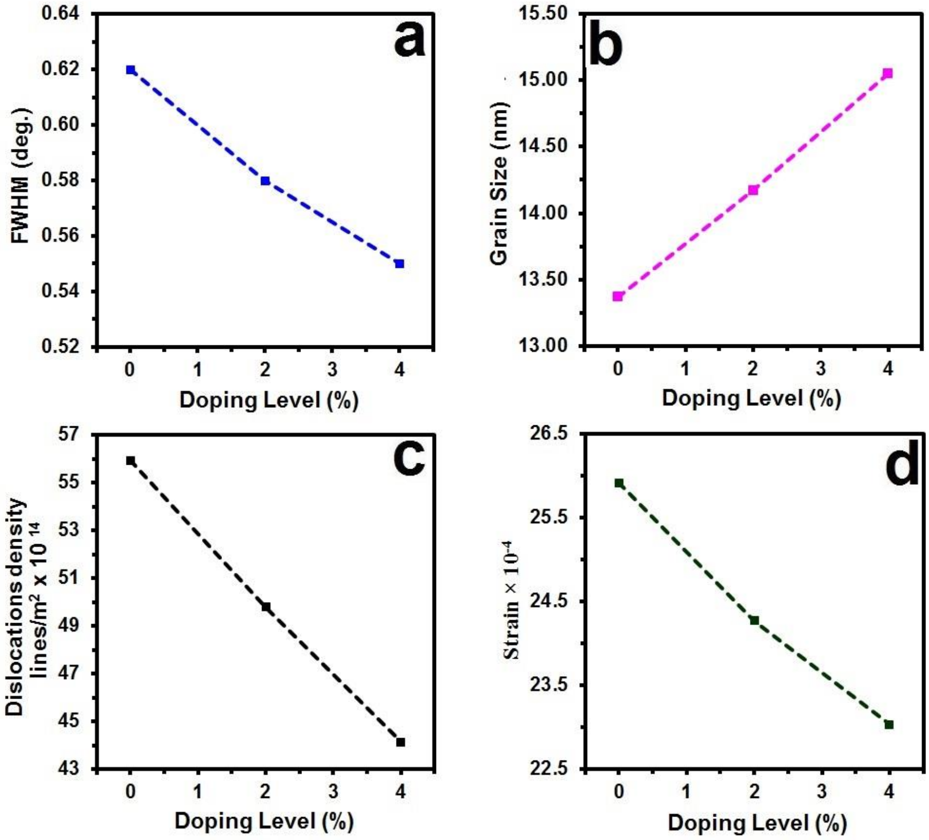

Fig.2. FWHM (a) *D* (b) δ (c) ε (d) of intended films.

Fig. 3 offers AFM images of intended films. films display pyramidal shape. The particle size T_p of the deposited films was in the domain of 7.292, 66.72 and 55.94 nm for the (Undoped CdO, CdO:2% Cu, CdO:4% Cu) respectively. RMS values show increment from 7.84 to 4.23 nm with doping and surface roughness R_a values were increase from 1.63-4.23 nm.

AFM parameters against Cu dopant are shown in Fig. 3 (a_3, b_3,and c_3). Table 2 list values of AFM parameters P_{AFM}.

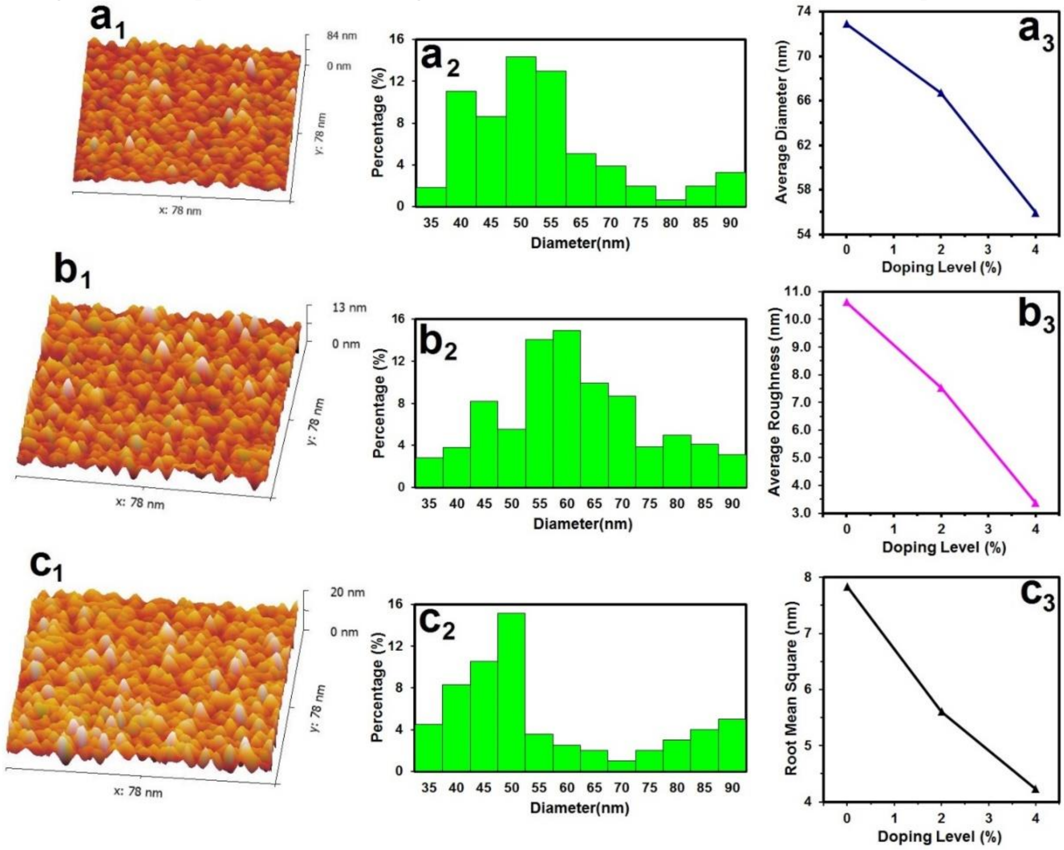

Fig.3. AFM information

Table 2. P_{AFM} of intended films.

Samples	T_p nm	R_a (nm)	R. M. S. (nm)
Undoped CdO	72.92	1.63	7.84
CdO: 2% Cu	66.72	7.53	5.61
CdO: 4% Cu	55.94	3.37	4.23

Fig. 4 displays the transmittance (T) spectra of deposit films. T in the UV–Vis area decreased with increasing Cu content and was over 90% transmittance at pure CdO films. T edge moves across longer wavelength by Cu content increases, which mentions a decrement in bandgap of grown films. The decrease in T films doped with 2 and 4 at.% content may be due to the integration of extra Cu in the CdO lattice [42].

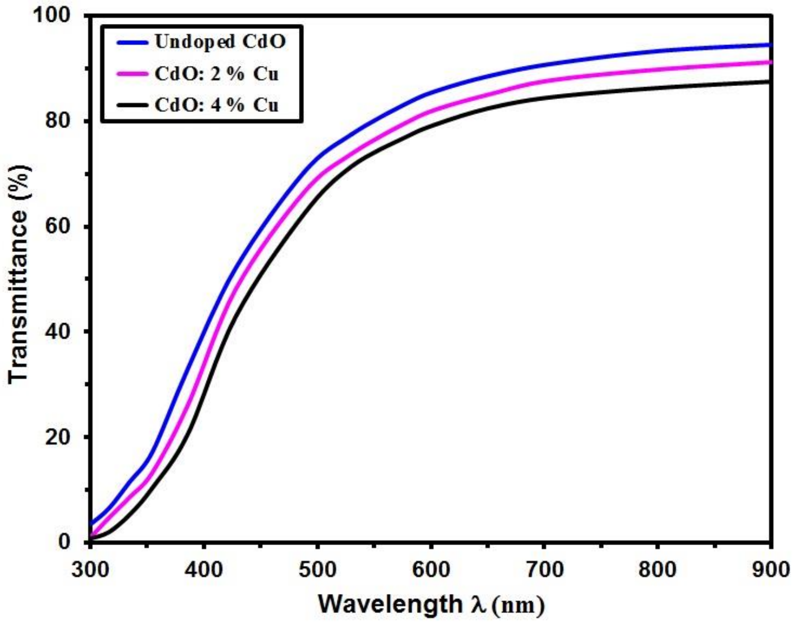

Fig. 4: Transmittance against wavelength of the intended films.

Fig. 5 offers a graph of absorption coefficient (α) versus wavelength, which was evaluated from equation (1) [43-46]:

$$\alpha = (2.303\times A)/d \quad (4)$$

Where A is absorbance and d is film thickness. Fig. 4 offers values of α that increased with the increment of Cu content. CdO produced lowest α of 5.5×10^4 cm^{-1}, those deposited at 2wt% produced 7.5×10^4 cm^{-1}, while at 4wt% highest of α at 8.2×10^4 cm^{-1}. The increment of α with an increment of Cu doping can be assigned to the carrier absorption [47].

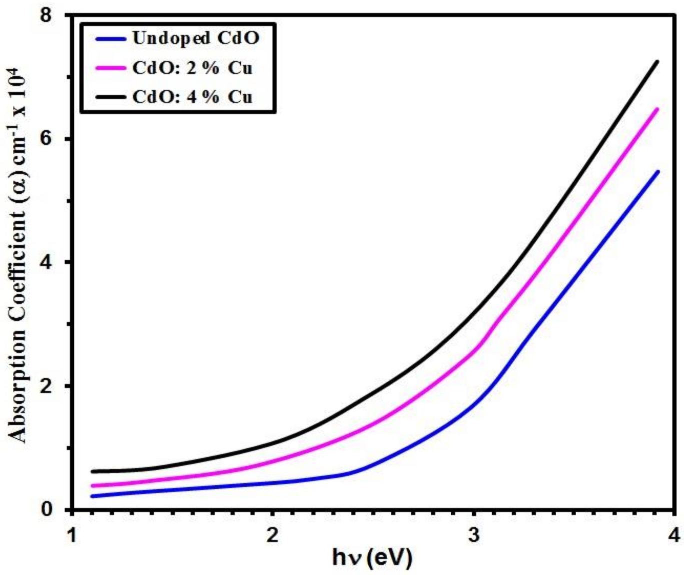

Fig. 5: α against wavelength for the intended films.

Energy gap (E_g) values were obtained by the formula [48-51]:

$$(\alpha h\nu) = A\left(h\nu - E_g\right)^{\frac{1}{2}} \qquad (5)$$

Where A is constant, $h\nu$ is the photon energy. It was observed that the relation shows linear dependence for n=1/2 which conforms that deposited CdO material is direct band gap semiconductor. E_g was specified by extrapolating the linear part at $\alpha = 0$ on the photon energy axis.

The undoped CdO thin film recorded larger than E_g value when compared with cu content (2 and 4 wt%) as shown in Fig. 6. Showing a decrease in its value with the increment of Cu. This decrease enhances visible light capturing in solar cell [52].

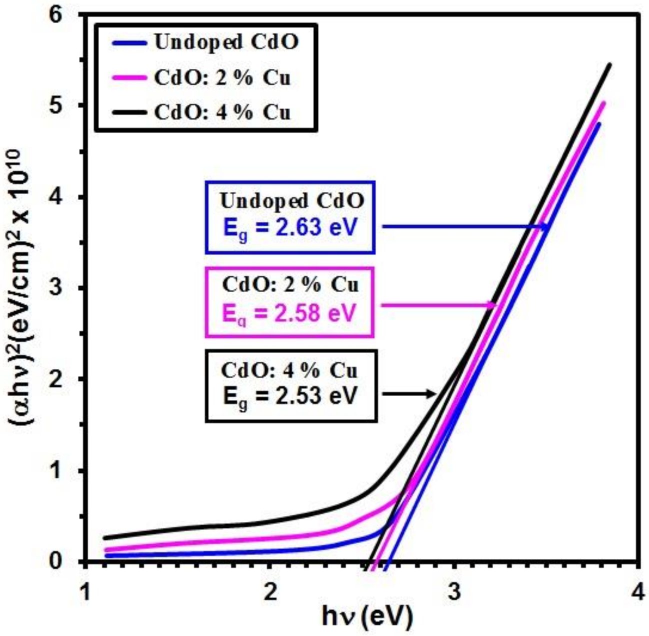

Fig.6: E_g of the intended films.

The extinction coefficient (k) calculation via the equation [53]:

$$k = \frac{\alpha\lambda}{4\pi} \qquad \text{-----6}$$

Fig. 7 displays that k increased with an increase in dopant content. The deposited films suffer an increment in k with increment of Cu dopant, which is a result of increasing α[54-55].

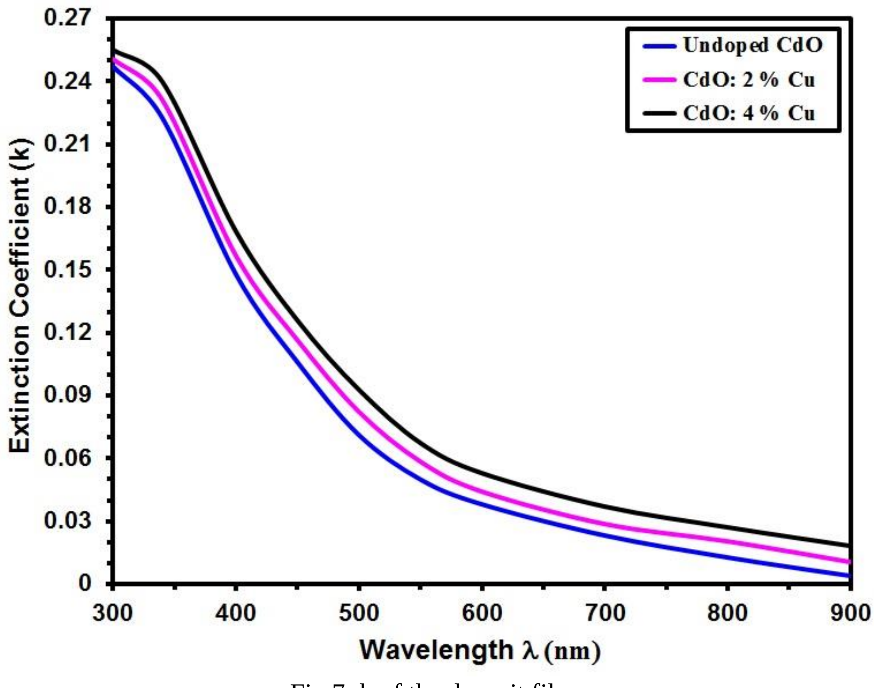

Fig.7: k of the deposit films

Refractive index n was obtained from the formula [56]:

$$n = \left(\frac{1+R}{1-R}\right) + \sqrt{\frac{4R}{(1-R)^2} - k^2} \text{-----}4$$

Where R is the reflectance.

From Figure 8 we can observe that the pure CdO films had the lowest values of n is (2.4) at wavelength 500nm, while those deposited at 3wt% has (2.65). n decreased exponentially with an increase in wavelength at range (600-900)nm. It has been notified that doping CdO with Cu using SPT produced n prolongation from 1.60 to 2.20 at 500 nm [52].

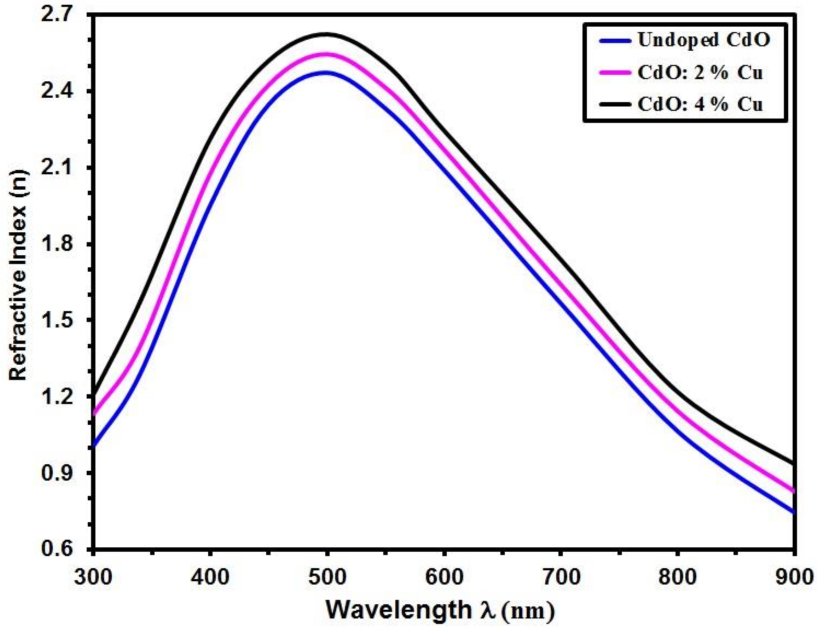

Fig. 8. n against wavelength for the intended films.

Conclusion

The Cu-doped CdO films were grown by (SPT) by varying doping. XRD styles displayed that films have (111) dominant peak. The Grain size for pure CdO is about (13.37- 15.05) nm with CdO:4% Cu, whereas the strain(%) parameter increased from (25.92-23.03) × 10^{-4}. AFM shows that grain size was monitored in the domain of 7.292, 66.72 and 55.94 nm for the (Undoped CdO, CdO:2% Cu, CdO:4% Cu) respectively. The transmittance in UV–VIS area decreased with increasing of Cu content and was over 90% transmittance at pure CdO films. α increases with increasing dopant concentration in the visible region. Pure CdO thin film recorded 2.63 eV band gap value and the doped Cu with (2 and 4 wt%) recorded 2.53eV. The extinction coefficient and refractive index are similar behavior corresponding absorption coefficient increase with increasing doping concentration. These results proposed that the deposited films can be employed for photovoltaic devices.

Acknowledgments

This paper is backup via Mustansiriyah University (www. uomustansiriyah.edu.iq) .

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