STUDY THE UNIVERSAL BEHAVIOR OF $HgBa_2Ca_2Cu_{3-X}Te_XO_{8+\delta}$ SUPERCONDUCTING THIN FILMS

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ABSTRACT : *$HgBa_2Ca_2Cu_{3-x}$ Te_x $O_{8+\delta}$ superconducting thin films of (100nm) thickness for different x ($0 \le x \le 0.15$), were deposited on the two type of substrate glass and Si (111) by using Plus Laser Deposition (PLD) technique. The effects of tellurium addition on properties of $HgBa_2Ca_2Cu_{3-x}$ Te_x $O_{8+\delta}$ bulk and thin film samples for ($0 \le x \le 0.15$) were investigated. The structural study was approved by XRD, where all samples are polycrystalline structure and have two superconducting phases , the alteration of Te concentration appeared in the mass density, lattice parameter and the percentage (c/a). The transition temperature Tc have range (140-146)K for bulk and for thin films the range (135-141.5)K for variation of the Te content from (0-0.15)%wt. The surface morphology of the $HgBa_2Ca_2Cu_{3-x}$ Te_x $O_{8+\delta}$ films have been studied by using AFM in two and three dimensions, It was detected that the higher average roughness was (147.7nm) at (x=0.1).*

Keywords: $HgBa_2Ca_2Cu_{3-x}$ Te_x $O_{8+\delta}$/Si thin film,PLD, AFM techniques.

INTRODUCTION

Hg-based superconductors attracted considerable attention amongst other cuprates by reason of its high superconducting transition temperature, *Tc*, of 134 K and 164 K measuring by ambient and high pressure of 30 GPa, correspondingly [1,2]. Superconductivity in Hg-based family having the generic formula $HgBa_2Ca_{n-1}Cu_nO_{2n+2}$ ([Hg-12(*n*-1)*n*], Hg-Ba-Ca-Cu-O,HgBCCO) was earliest described in 1993 [3]. Hg-1212 with *Tc* = 127 K was steady phase behavior the highest Tc than gotten for 1212 phase of the other cuprates [4,5]. for the essential studies of basic intrinsic properties one requisite be in a position to synthesize these unique materials in thin film form. Additional, to achieve preferred device performance, technologically reproducible high quality single-phase films are requisite. For the combination of superconducting thin films, the variety of procedures such as chemical vapor deposition, laser ablation, molecular beam epitaxy, magnetron sputtering, physical vapor deposition, sol gel, spray pyrolysis and electrodeposition are using [6].The irreversibility streak of the undoped and the doped $HgBa_2Ca_{n-1}Cu_nO_{2n+2}$ demonstrations the maximum values of the irreversibility field at a high temperature of some known superconductor, it was strong reliant on upon dopants, which is significant from both fundamental and technological point of opinion [7]. In this research $HgBa_2Ca_2Cu_{3-x}$ Te_x $O_{8+\delta}$ superconducting thin films prepared for different x (x=0, 0.05, 0.1, 0.15), successfully deposited on glass and Si by Plus Laser Deposition (PLD) method, addition effect of Te_2O_3 on the high-superconducter material indicated that the critical temperature and the phase constructions are affect through tellurium, structural, topographical, electrical properties, characterization methods and results were investigated and reported.

EXPERIMENTAL DETAILS

$HgBa_2Ca_2Cu_{3-x}$ Te_x $O_{8+\delta}$ bulk tasters are equipp as of weighed quantity of high purity materials (99.9%) HgO, BaO, CaO, CuO and Te_2O_3 powders, the weight of each reactant are determining thru via a sensitive balance by way of sensitivity is of order (10^{-4} g) as follows in table (1) below..

Table 1.

Powder Weight	Ratio Atomic Weight
HgO	**[200.59+15.999]**
BaO	**2*[137.33 + 15.999]**
CaO	**2*[40.08 + 15.999]**
CuO	**(3-X) [63.546 +15.999]**
Te_2O_3	**x[(2* 127.60) +(3* 15.999)]**

The powder was hard-pressed interested in disk-formed pellets 15 mm in diameter and 2 mm in thickness with a manual hydraulic press sort (SPECAC), the pellets are sintering in air at 850°C for 48 h with the meaning of combined the particles of the materials composed along with the pore spaces volume amongst them were regularly reduced , follow in cooling to R.T by the same proportion of heat treatment.

The all pellet are utlize as a target to armed superconducting thin film models of (100nm) thickness grown glass and n-type silicon wafers (Si) substrate (111) at R.T through used Pulsed Laser Deposition method. In PLD of thin films of $HgBa_2Ca_2Cu_{3-x}$ Te_x $O_{8+\delta}$ target was mounted in vacuum chamber 10^{-4} mbar, and ablated by a double frequency with Q- switched Nd:YaG pulsed laser. The laser had a wavelength of (532 nm) and the beam energy was focused onto the target to get an flounce 0.6-0.7J/cm2, the ablated frequency at (6 Hz) by second harmonic with Q-switched Nd :YaG pulse laser. The construction of the equipped samples was gotten via used X-ray diffraction (XRD) deflect meter (SHIMADZU Japan XRD 600), foundation Cu K_α radiation of wavelength 1.5405 A°. The four point probe process is using to quantity the resistivity besides regulate the critical temperature (Tc) for the bulk and films, the morphologies of the $HgBa_2Ca_2Cu_{3-x}$ Te_x $O_{8+\delta}$ films were analyzed by atomic force microscopy (AFM) type origin USA model AA300-CSPM .

RESULTS AND DISCUSSION

The XRD designs for $HgBa_2Ca_2Cu_{3-x}$ Te_x $O_{8+\delta}$ bulk samples for different values of x where (x=0.05, 0.1, 0.15) was signify in Fig. ($1_{a,b,c,d}$) respectively. It is clear from designs the polycrystalline nature and wholly peaks associated to the tetragonal phase, the dominant high Tc phase (H phase) together with the amount of little Tc phase (L phase) and a slight amount of indefinite phases, the effects of x content make the peak position are shifting with increasing it.

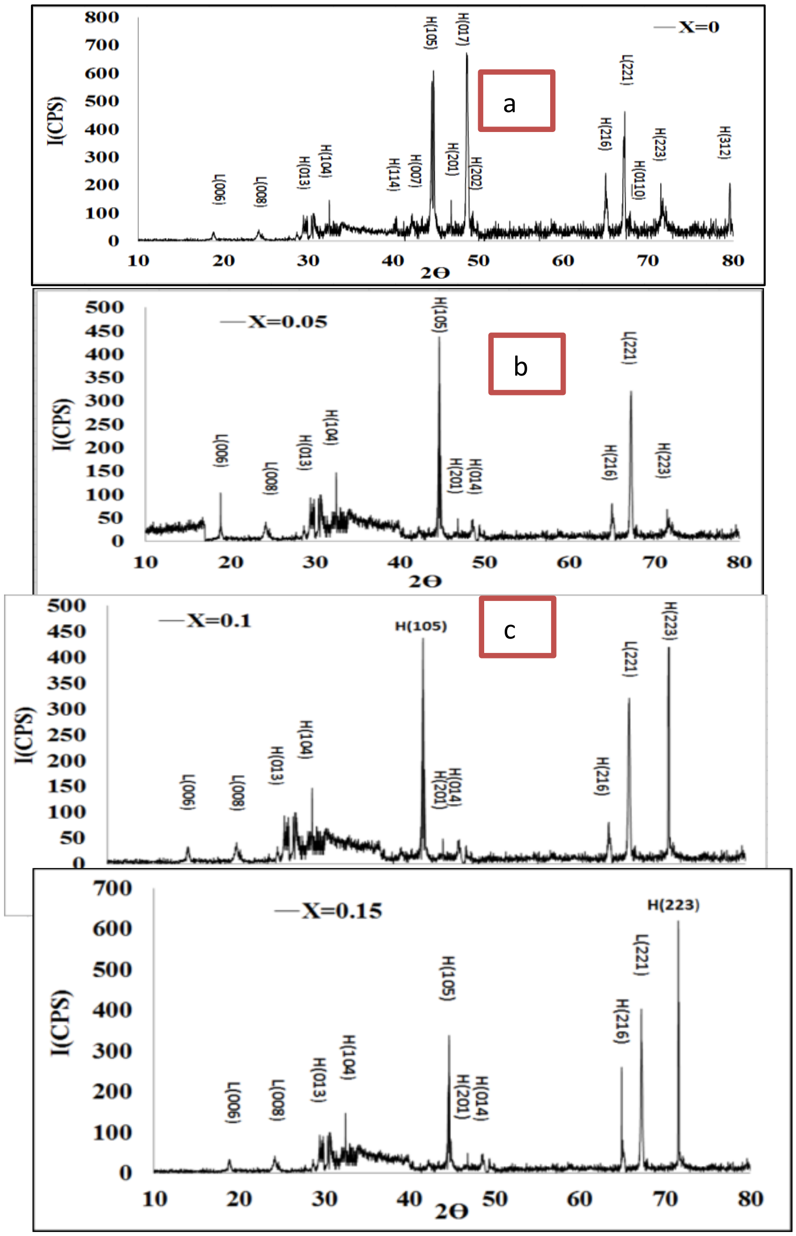

Fig. 1: X-ray curving form $HgBa_2Ca_2Cu_{3-x}$ Te_x $O_{8+\delta}$ for diverse values of x.

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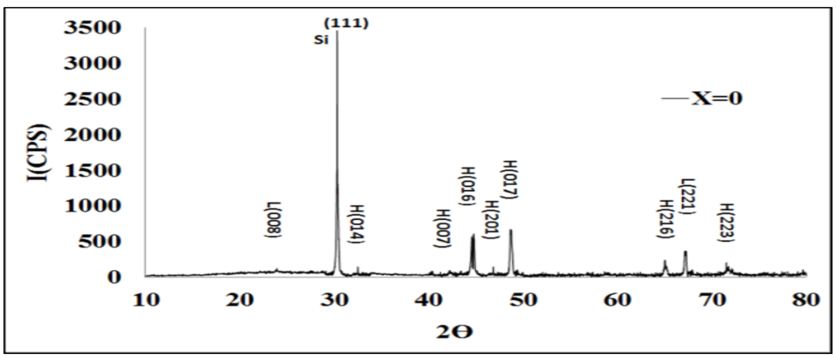
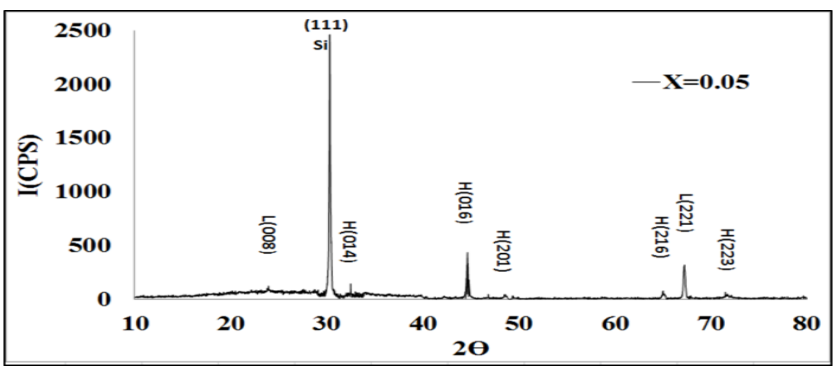
Table 1: Lattice parameters (a, c) and ratio c/a of bulk $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ samples

Samples	a(Å)	c (Å)	c/a	V(Å)^3	ρ_m (g/cm^3)	Vph(2223) %	Vph(2212) %
$HgBa_2Ca_2Cu_3O_{8+\delta}$	3.701	15.103	4.080789	206.8718	4.225012	83.78125	16.21875
$HgBa_2Ca_2Cu_{2.95}Te_{0.05}O_{8+\delta}$	3.614	15.303	4.234366	199.8724	4.448818	66.25723	33.74277
$HgBa_2Ca_2Cu_{2.9}Te_{0.1}O_{8+\delta}$	3.602	15.48	4.297612	200.8438	4.502783	76.98846	23.01154
$HgBa_2Ca_2Cu_{2.85}Te_{0.15}O_{8+\delta}$	3.08	15.841	5.143182	150.2741	6.118927	77.01552	22.98448

The lattice constants (a), (c) in addition (c/a) proportion are show in table (1), it can note that c/a ratio and volume fraction are increases with Te content .This is because the difference in ionic radii of Te and Cu which leads to decrease the volume of unit cell of the latticeThe distortion in the lattice constant by means of addition or deficiency of some atoms, alters the amount of charge transfer from Cu layer to Te layer, this will be a driving force to the combination generation of superconductor. This behavior is well agreed with the report of other worker [8].

Fig. ($2_{a,b,c,d}$) show the XRD designs for $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ thin films in (x=0.05, 0.1, 0.15), it is interesting to note increase the degree of crystallinity for thin films and variation in intensity than position of the peaks which demonstrating the change of the lattice parameters of the thin samples. All peaks associated to the polycrystalline tetragonal phase construction beside two main phases were detected where the dominant high Tc phase (H phase), the special effects of x make high crystal quality. Also, we show peak with (111) as of the substrate and the structure at the base of the Si(111) reflection is by reason of the absorption edge of Si. The lattice constant of thin films samples were premeditated for the strong peaks in the XRD, table (2) designates that a alteration in the structural parameters with chance variation in both (a), (c) lattice constants and the (c/a) ratio with increasing Te content.





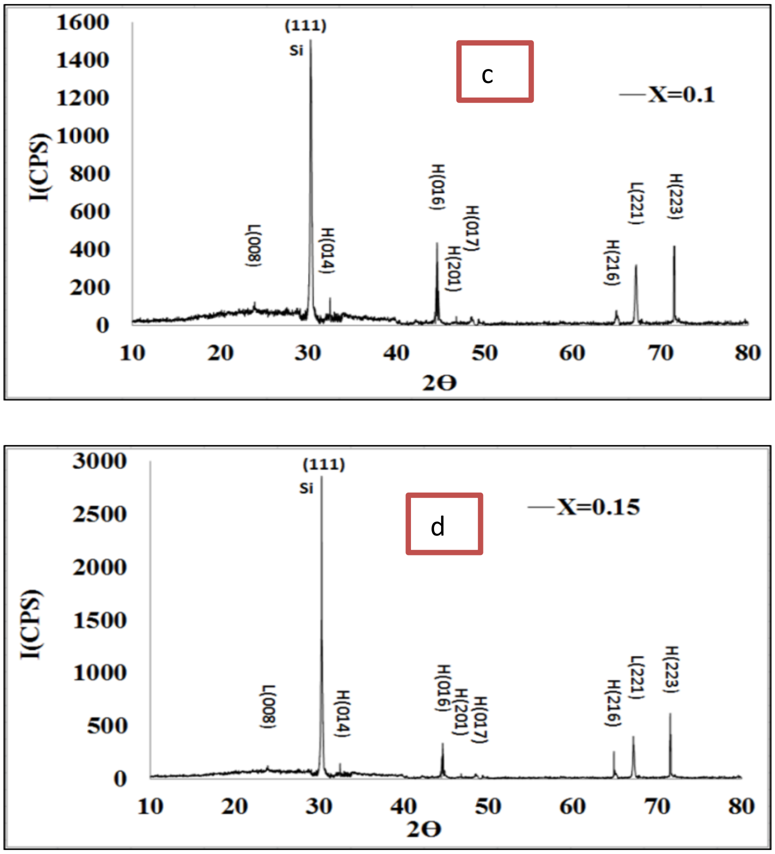


Fig. ($2_{a,b,c,d}$) show the XRD designs for $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ thin films in (x=0.05, 0.1, 0.15),

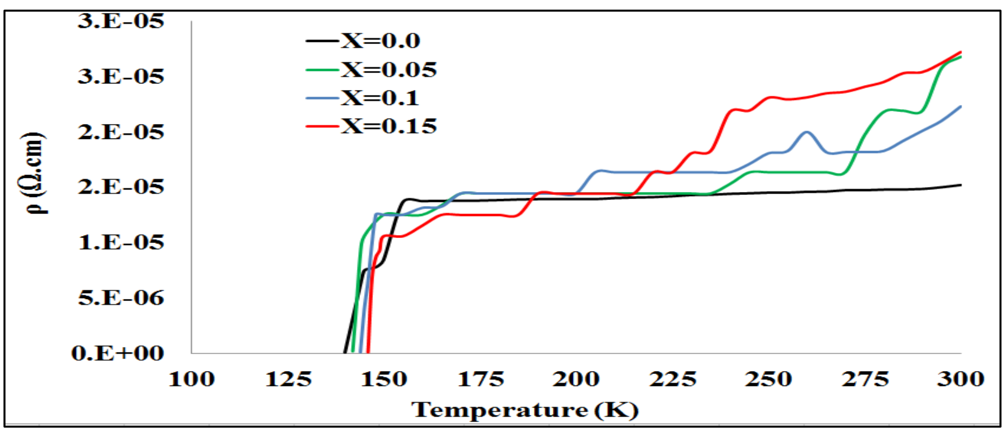


Fig (3). Temperature versus resistivity for $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ bulk samples for different x.

The resultant crystal unit cell increase depending on the (Ionic Radius) for Cu which moderately be substituted by Te ions, also increment of oxygen in $HgBa_2Ca_2Cu_{3-x}O_{8+\delta}$ system, this results are a good agreement with other studies [9,10]. Fig (3) shows variation electrical resistance in bulk for $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ sampls in different Te addition, values of the critical temperature are listed in Table (3). We can see from figure that the critical transition temperature be contingent with the concentration of Te, where Tc rises with the increasing of Te ratio, this increase may be attributed to level produced from Te existence make non-equilibrium of the charge density and that causes a destruction of the excitons.

Fig. 2: X-ray pattern for $HgBa_2Ca_2Cu_{3-x}\ Te_x\ O_{8+\delta}$ thin films.

Table 2: Lattice parameters (a, c) and ratio c/a for the $HgBa_2Ca_2Cu_{3-x}\ Te_x\ O_{8+\delta}$ thin film samples

Sample	a (Å)	c (Å)	C/a	V(Å)^3	ρ_m (g/cm^3)	Vph(2223) %	Vph(2212) %
$HgBa_2Ca_2Cu_3O_{8+\delta}$	3.94	15.11	3.835025	234.5616	3.726254	83.25	16.75
$HgBa_2Ca_2Cu_{2.95}\ Te_{0.05}\ O_{8+\delta}$	3.57	15.15	4.243697	193.0852	4.605199	62.74	37.26
$HgBa_2Ca_2Cu_{2.9}\ Te_{0.1}\ O_{8+\delta}$	3.52	15.24	4.329545	188.8297	4.789268	73.64	26.36
$HgBa_2\ Ca_2Cu_{2.85}\ Te_{0.15}\ O_{8+\delta}$	3.11	15.89	5.109325	153.6897	5.98294	74.19	25.812

Table(3): Values of $T_{c(off)}$, $T_{c(on)}$, ΔT and oxygen δ content a of bulk $HgBa_2Ca_2Cu_{3-x}\ Te_x\ O_{8+\delta}$ samples

Samples	$T_{c(off)}$ (k)	$T_{c(on)}$ (k)	ΔT(k)	$E_g(2\Delta)$ eV	δ
$HgBa_2Ca_2Cu_3O_{8+\delta}$	140	143	3	0.042263	0.05205
$HgBa_2Ca_2Cu_{2.95}\ Te_{0.05}\ O_{8+\delta}$	142	145	3	0.042866	0.0541
$HgBa_2Ca_2Cu_{2.9}\ Te_{0.1}\ O_{8+\delta}$	144	148	4	0.04347	0.0642
$HgBa_2\ Ca_2Cu_{2.85}\ Te_{0.15}\ O_{8+\delta}$	146	149	3	0.044074	0.0707

Fig.(4) shows change electrical resistance with temperature for different Te ratio. The critical temperaturefor thin films samples rang T_C ~ (135-141.5)K see table (4), the samples have lower transition temperature than those of the bulk samples, from XRD revisions and electrical resistance measurements we establish that the covering of the substrate by H phase film is much better, and Te production the weak connection between grains and later decreases the barrier between theses boundaries [11]. Furthermore, the transition temperature increases with increase Te ratio due to the growing of the films thru improved intergranular then intergranular properties

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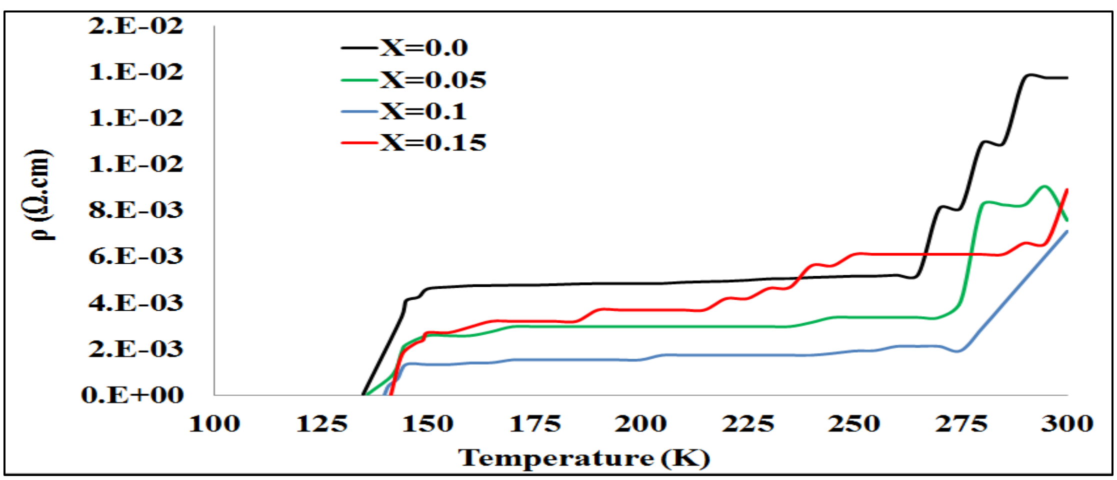

Fig (4). Temperature versus resistivity for $HgBa_2Ca_2Cu_{3-x}\ Te_x\ O_{8+\delta}$ thin films samples for different x.

Table(4): Values of $T_{c(off)}$, $T_{c(on)}$, ΔT for the $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ thin film samples

Samples	$T_{c(off)}$ (k)	$T_{c(on)}$ (k)	ΔT(k)	$E_g(2\Delta)$ eV	Vph(2223) high	Vph(2223)low
$HgBa_2Ca_2Cu_3O_{8+\delta}$	135	145	10	0.040753	83.25	16.75
$HgBa_2Ca_2Cu_{2.95}Te_{0.05}O_{8+\delta}$	136	145	11	0.041055	62.74	37.26
$HgBa_2Ca_2Cu_{2.9}Te_{0.1}O_{8+\delta}$	140	142	2	0.042263	73.64	26.36
$HgBa_2Ca_2Cu_{2.85}Te_{0.15}O_{8+\delta}$	141.5	144	3.5	0.042715	74.19	25.812

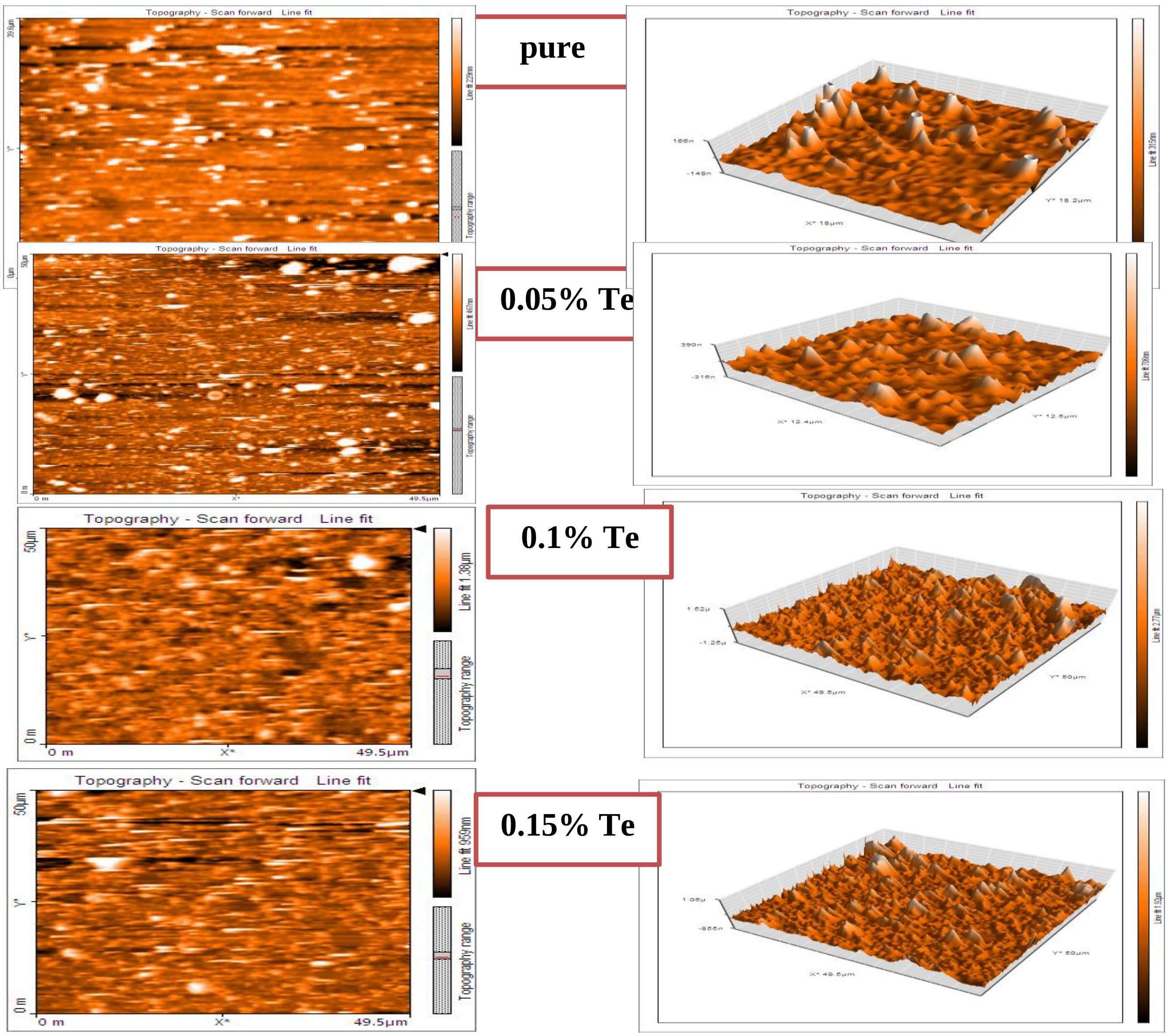

Fig (5): 2D &3D AFM descriptions for $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ sample.

The relationship between the value of the energy gap at zero temperature and the value of 2Δ in the superconducting transition temperature (expressed in energy units) takings the general value of 3.5, independent of material [12,13].

$$2\Delta = 3.5K_B T_c \quad \text{For } T_c = 0\text{ K}$$

where K_B is the Boltzman constant.

It is observed from table (3)and (4)that the energy gap values increase when the Te content increased in bulk and thin films of $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ samples by reason of the increased Te ratio produced variation construction of these samples resultant modification

in an energy gap value. The surface morphology of $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ thin films for different values of x (0 to 0.15) are shown in Fig. (5).

It is understood that the films were uniform , dense and finer grained structure. The surface morphology alteration with Te ratio as a result of the realization of different surface energies which is leading to crystallites of changing crystalline nature and size[8]. Table (5) signify the average diameter, average roughness and Root Mean Square for all sample films. It is clear from table that the average roughness increases with the increasing of Te percentage due to good degree of crystallinity through increasing the average size of a particle and this enhancement of the roughness accompanied by increase average diameter, and Root Mean Square.

Table (5). Average diameter, average roughness and RMS for $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ films

Samples	diameter (nm)	roughness (nm)	RMS (nm)
$HgBa_2Ca_2Cu_3O_{8+\delta}$	85.23	39.35	88.86
$HgBa_2Ca_2Cu_{2.95}Te_{0.05}O_{8+\delta}$	92.46	70.36	115.92
$HgBa_2Ca_2Cu_{2.9}Te_{0.1}O_{8+\delta}$	101.57	147.7	205.14
$HgBa_2Ca_2Cu_{2.85}Te_{0.15}O_{8+\delta}$	117.9	102.15	148.13

. CONCLUSION

Successful deposite for $HgBa_2Ca_2Cu_{3-x}Te_xO_{8+\delta}$ superconducting thin films by useful technique plus laser deposition, XRD examines for bulk and thin films displayed a polycrystalline tetragonal phase with the dominant high Tc phase (H phase), and the Tc for the all thin films is less than that of the bulk samples, in addition the transition temperature increases with increase Te. The AFM image show the average roughness increases with the increasing of Te content and the finest preparation condition presented an average diameter nearby (~ 99nm).

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