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Physical Characterization of Effect Ba Doping on Nanostructured NiO Thin Films by CSP Technique

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Abstract.

Using a chemical spray pyrolysis (CSP) technique, thin films of undoped NiO and NiO:Ba were successfully grown. All the recorded films had a polycrystalline diffraction and that the predominant peak was (111) plane. the crystallite sizes were increased from 14.46 nm to 16.74 nm as in XRD, whilst dislocation density (δ) decreased from 4.78 to 3.56, whilst strain (ε) decreased from 2.38 to 2.07, AFM images assure the existance of nanostructure. Average diameter size, surface roughness and rms values of the deposited films were (79.36, 70.25 and 68.78) nm, (8.81, 7.07 and 4.23) and (5.85, 65.12 and 2.16) nm for NiO , NiO:2% Ba and NiO:4% Ba respectively. The transmittance of undoped NiO and Bs doped films reaches 70. 0% to 77.5% in Vis- NIR regions. The E_g^{op} decreased from 3.46 to 3.36 eV as the 4% Ba doping. Results illustrate both extinction coefficient and refractive index are increasing with increasing with Ba content in NiO thin films.

Keywords: NiO, Ba doping, chemical spray pyrolysis technique, XRD, morphology, optical properties.

Introduction

Semi-transparent p-type conducting NiO films were recently enticed a lot of awareness due to their importance in a variety of scientific applications, such as (i) Materials for electrical display devices [1,2], (ii) layers to fabricate sensor [3], (iii) transparent films for electronic devices [4], and (iv) the magnetic property of nanoparticles [5–8]. A stoichiometric NiO film is a semiconductor material have a resistivity of ~10^{13} Ω_cm) [9]. NiO with an energy gap of 3.6 to 4.0 eV Recently . [10]. Metal oxide, in general, is very important because of wide range of band gap, conductive, transparent, and others [11-14].,To date, a variety of techniques for producing NiO thin films have been developed, such as dipping and electrochemical, sol–gel.[15], spin coating [16], chemical bath technique [17-19], PLD [20,51-71], ALD, sputtering [21-22], and CSP [23–32]. CSP is the most popular for wide area homogeneous NiO coatings because it eliminates the vacuum system and is simple to set up. The CSP technique is characterized by the uniform distributions and produces thin films with grain sizes that are controlled by a variety of parameters such as; the method or technique, doping material, and concentration. The effect of fabrication conditions such as the substrate temperature, has also been studied [33], and effect of thickness [34]. This study reflect the preparation of NiO thin film using CSP at 450 °C. XRD, AFM, and UV-visible Spectroscopy were employed to determine the physical characterization of the grown films.

Experimental

NiO and NiO:Ba thin films were grown by CSP technique. 0.1 M of NiO Cl_4. $5H_2O$ was dissolved in deionized water. The doping agent was Ba provided by Sigma-Aldrich – German. drops of HCl were joined the mixture to get it clear. The Conditions for preparation as: The temperature of base was 450°C. The nozzle was 30 cm from the substrate. To prevent cooling, the spraying time was extended by 80 seconds, and the spray rate was increased to 5 mL/min. As a carrier gas, nitrogen gas was used. A weighing method is used to obtain film thickness, which was 330 nm. The AFM was done to know the surface of deposited films, while the XRD is utilized to know film structure. Optical transmittance was measured employing double beam Shimadzu UV-VIS spectrophotometer.

Result and discussion

Fig. 1 shows XRD styles of Undoped NiO and doping Ba 2% and 4% thin films on glass substrate prepared via CSP technique. It can be observe that the films have peaks at 37.31°, 43.30° and 62.85° match anatase (111),(200) and (220) planes, respectively. High peak at (220) was seen that fit with ICDD card no 04-0835.

The crystallite size *D* in Table 1 estimated using Scherrer's equation [35-37]:

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

Where λ is the x-ray wavelength used, k = 0.9, and θ is Bragg's angle, and *B* is FWHM

The acquired data are offered in Table 1. It shown that *D* were increased from 14.46 nm to 16.74 nm.

the dislocation density (δ) in the films is determined by [38-40]:

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

Table 1. It shown that dislocation density (δ) decreased from 4.78 to 4.15

the strain (ε) in the films was determined by [41-43]:

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

Table 1. It shown that strain (ε) decreased from 2.38 to 2.07.

The structural parameters S_P were shown in Figure (2). Table 1 displays FWHM of preferred reflections, which provide high precision values.

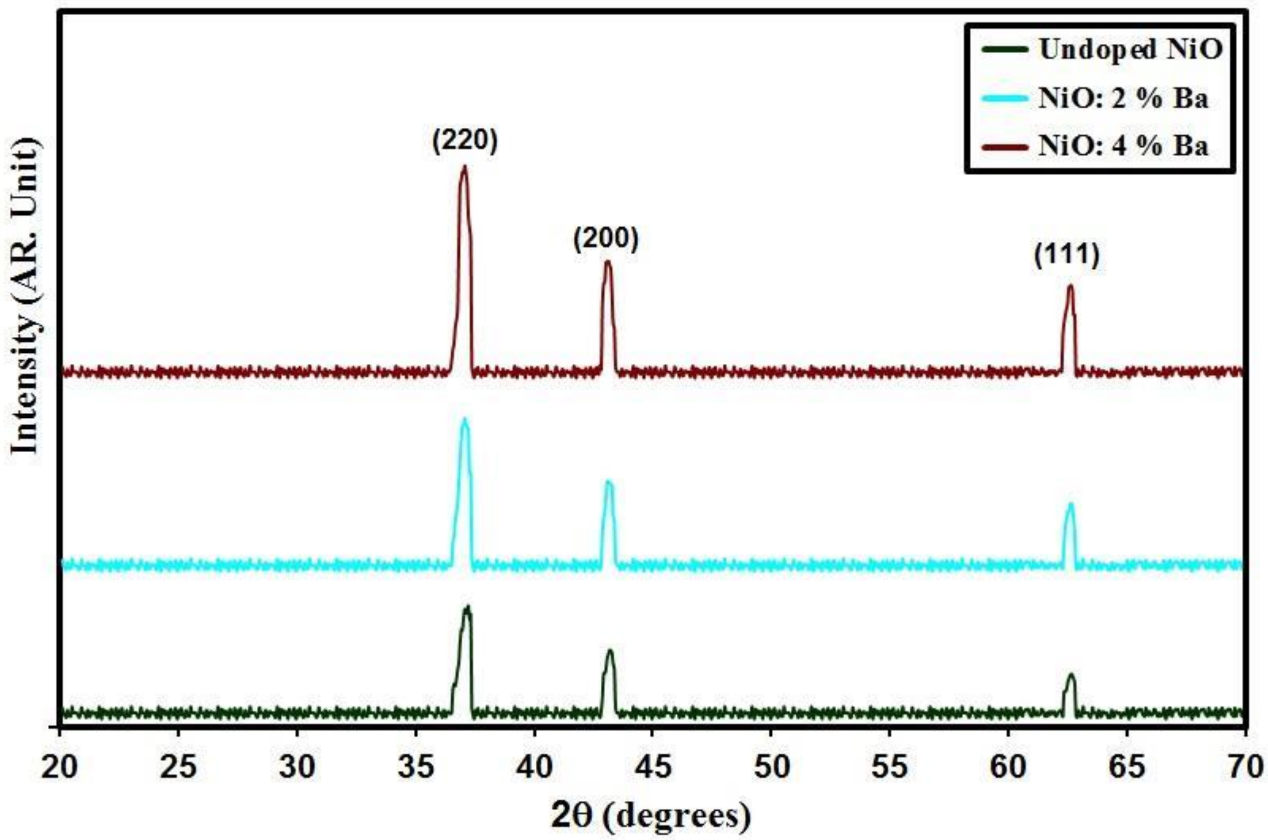

Fig.1. XRD styles of grown films.

Table 1. S_P of deposited films.

Samples	**2 θ (º)**	**(hkl) Plane**	**FWHM (º)**	***D*(nm)**	**E_g (eV)**	**δ (× 10^{15})(lines/m^2)**	**ε × 10^{-3}**
Undoped NiO	37.31	111	0.58	14.46	3.46	4.78	2.38
NiO: 2% Ba	37.00	111	0.54	15.15	3.40	4.15	2.23
NiO: 4% Ba	36.50	111	0.50	16.74	3.36	3.56	2.07

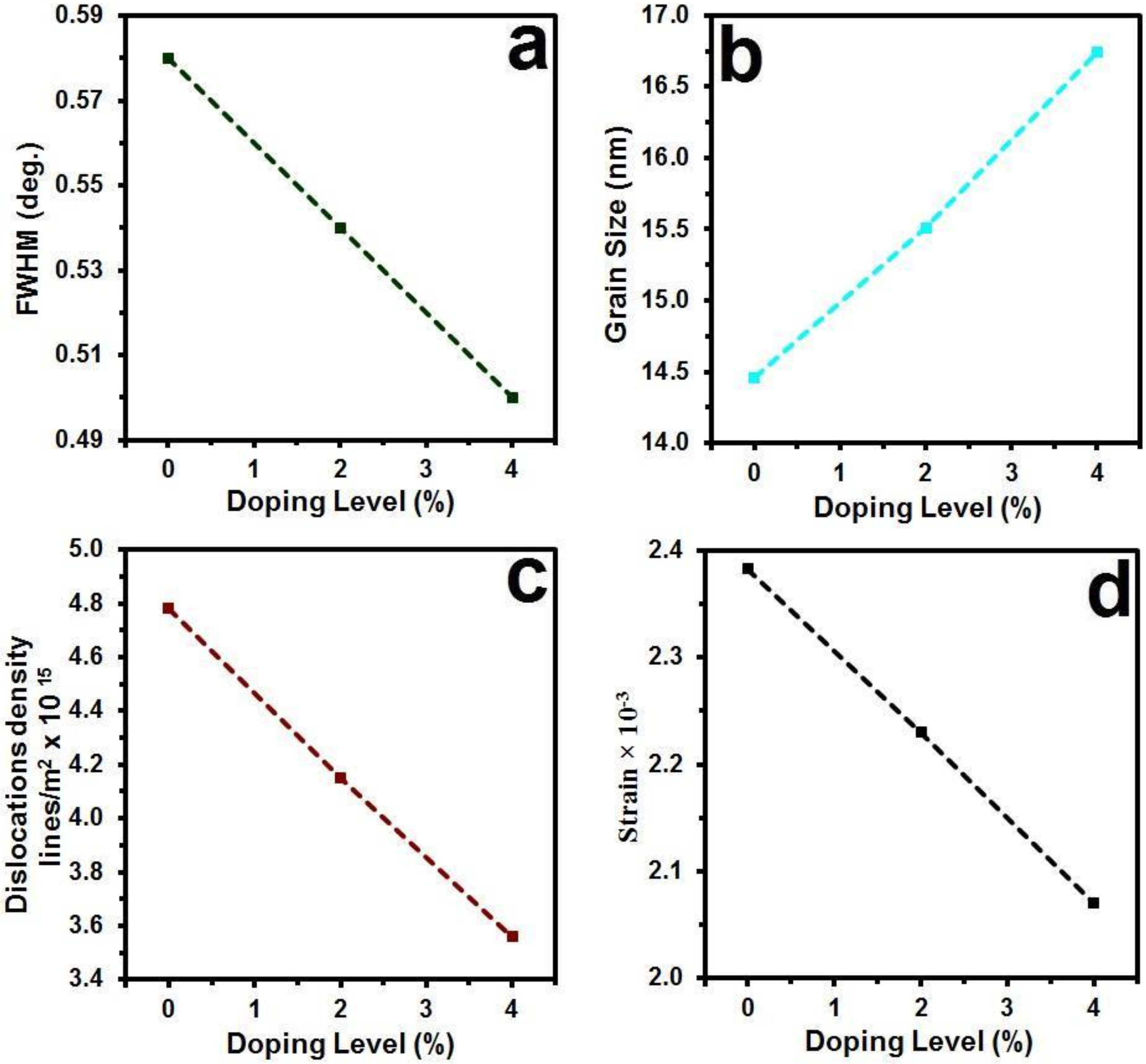

Fig.2. FWHM (a) *D* (b) δ (c) ε (d) of intended films.

Fig. 3 offers the AFM micrograph for Undoped NiO and NiO: Ba thin films. Average Particle size P_{av} and rms values of the deposited films were (79.36, 70.25 and 68.78) nm and 5.85, 5.12 and 2.16) nm for Undoped NiO , NiO: 2% Ba and NiO: 4% Ba respectively.The surface roughness increases from 8.81 nm to 7.07 nm by increment of Ba content.
The AFM parameters A_p were listed in Table (2).

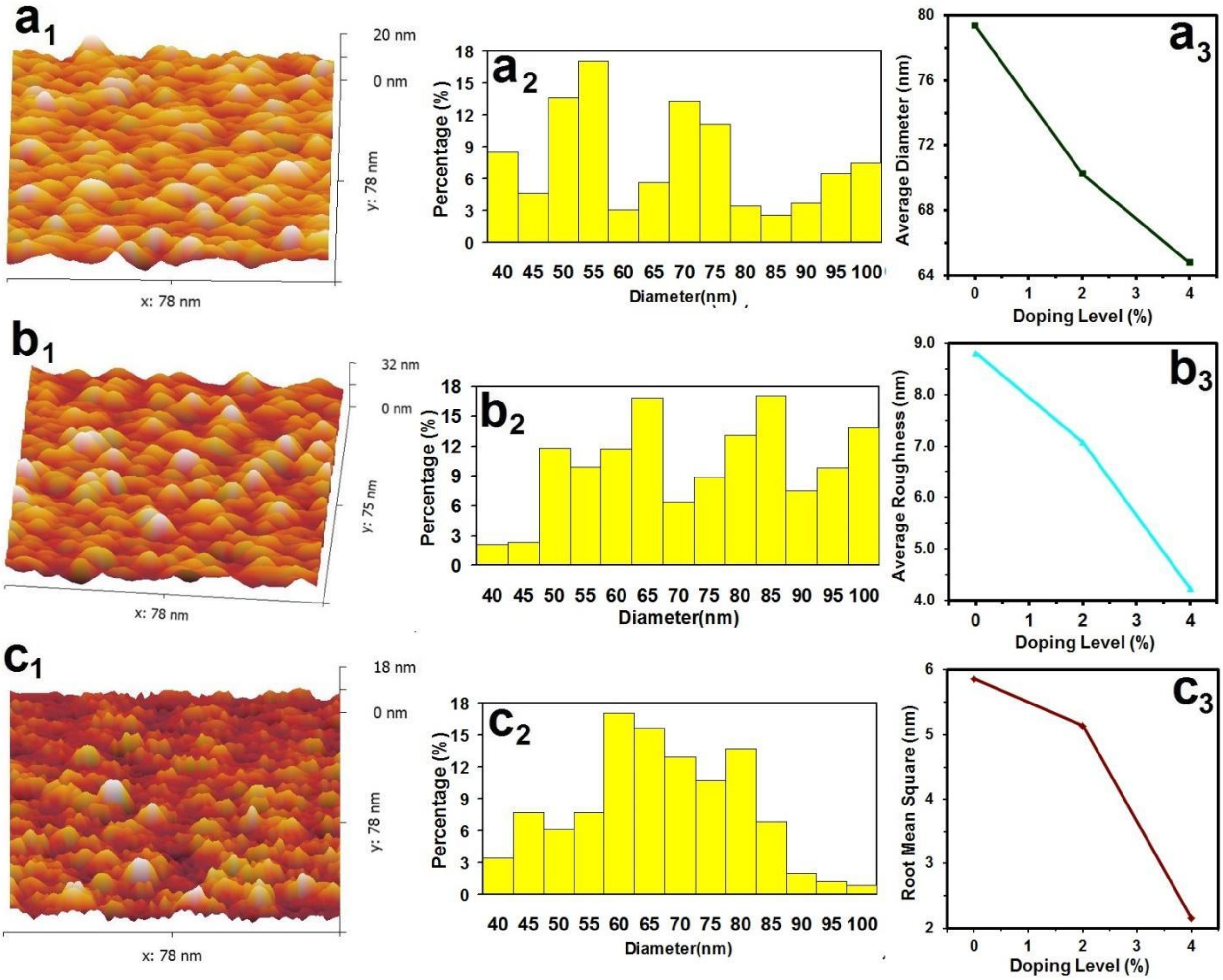

Fig.3. AFM images (a1, b1, and c1), granularly distributed (a2, b2, and c2), and A_P variance through doping (a3, b3 and c3).

Table 2. A_P of the intended films.

Samples	P_{av} nm	Ra (nm)	rms (nm)
Undoped NiO	79.36	8.81	5.85
NiO: 2% Ba	70.25	7.07	5.12
NiO: 4% Ba	68.78	4.23	2.16

The transmittance (T) spectra are shown in Fig.4 T decreases from 77.5 % to 70% as Ba doping increases from 1% to 3 %..
The absorption coefficient (α) is obtained from [44-46]:

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

Where (t) is film thickness.

α decreases with increasing Ba doping levels of 2% or 4%, as noticed in Fig.6.
The optical energy gap E_g was calculated from the Tauc relation [47,48]:

$$(\alpha h\nu) = A(h\nu - E_g)^{\frac{1}{2}} \qquad (6)$$

Where A is the constant, $(\alpha h\upsilon)^2$ against (hυ), plots are offer in Figure 4. As NiO is a direct transition semiconductor. E_g decreased from 3.46 to 3.36 eV as the 4% Ba doping.

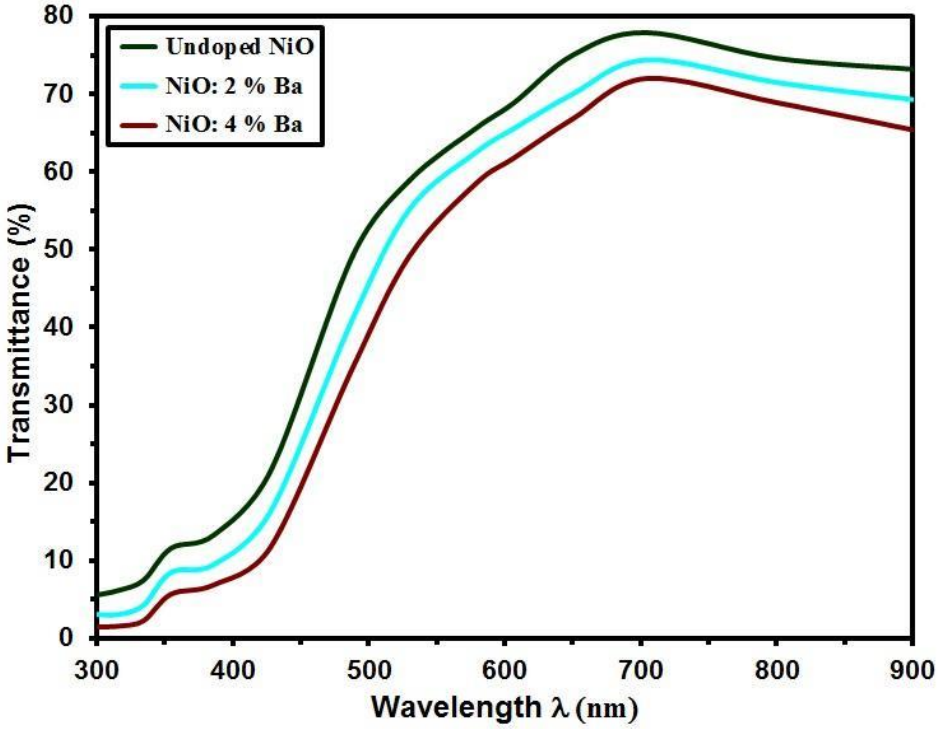

Fig. 4. T of grown films.

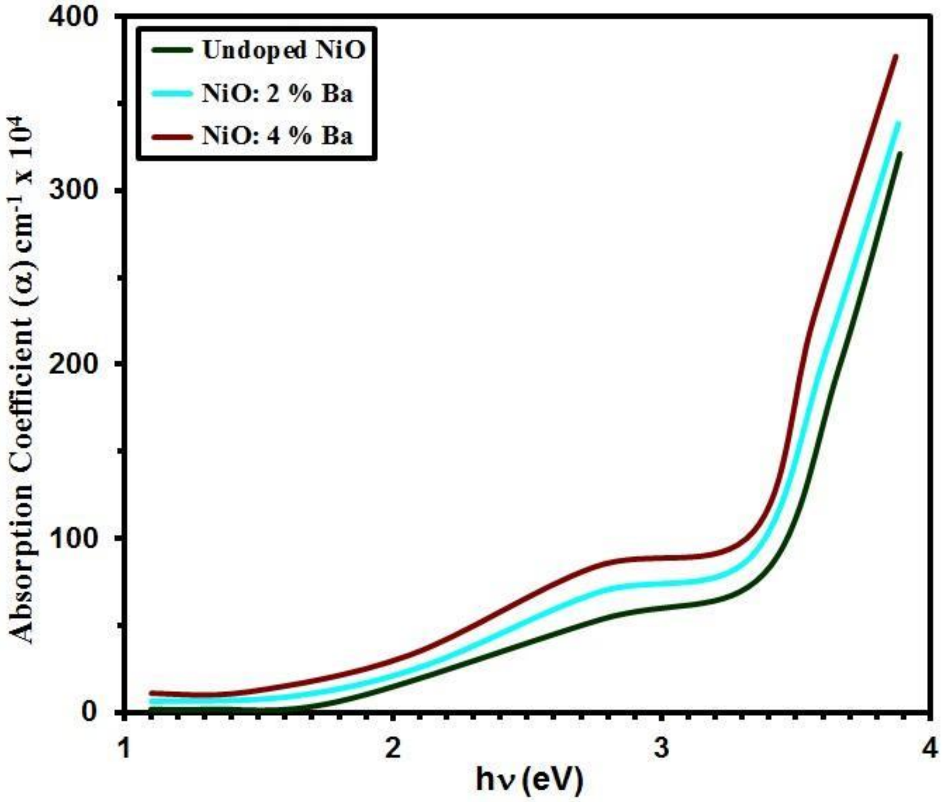

Fig. 5. α Vs hν for intended films.

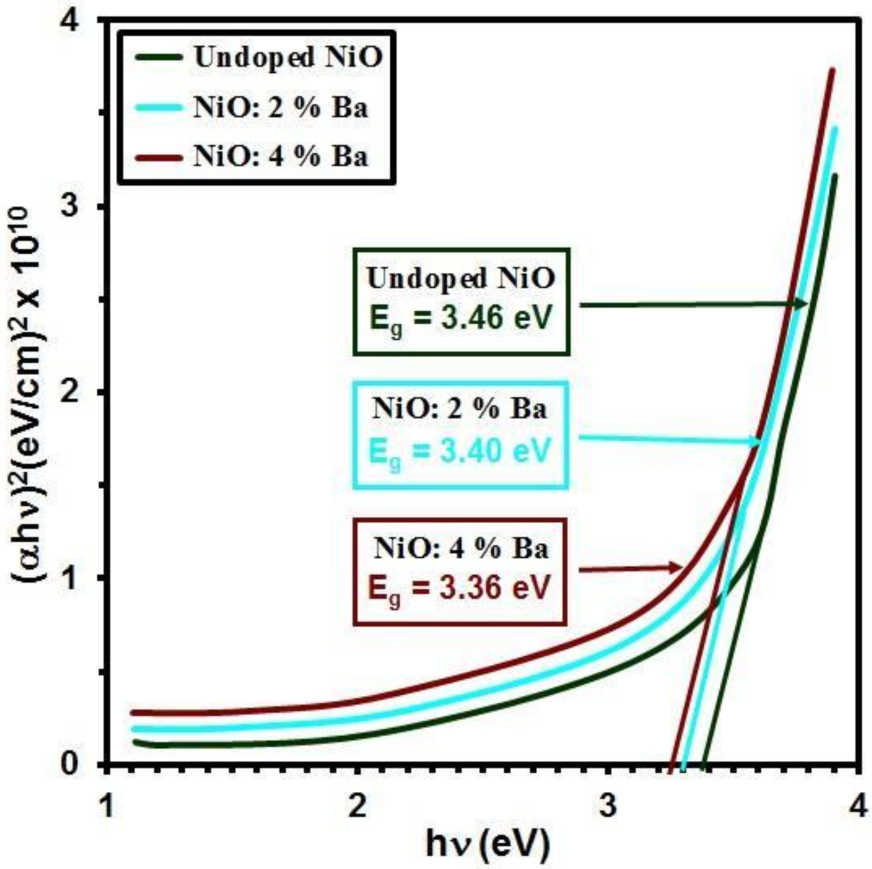

Fig. 6. $(\alpha h\nu)^2$ Vs hν of deposit films.

To find the extinction coefficient (k) following relation was employed [49]:

$$k = \frac{\alpha\lambda}{4\pi} \quad \text{----- (7)}$$

Where λ is the wavelength. Figure 7 offer the variance of *k* of NiO and Ba: NiO films versus the wavelength. Figure 7 offers that *k* increases with increasing the content of Ba. To calculate the refractive index (*n*) of NiO and NiO: Ba thin films. We can use the following relationship [50]:

$$n = \left(\frac{1+R}{1-R}\right) + \sqrt{\frac{4R}{(1-R)^2} - k^2} \quad \text{----- (8)}$$

Where R is the reflectivity.

Figure (8) represents *n* plot vs. wavelength. Refractive index diagram, divided into two regions: abnormal dispersion and normal dispersion. *n* increases with increasing the Ba content, as shown in Fig (8).

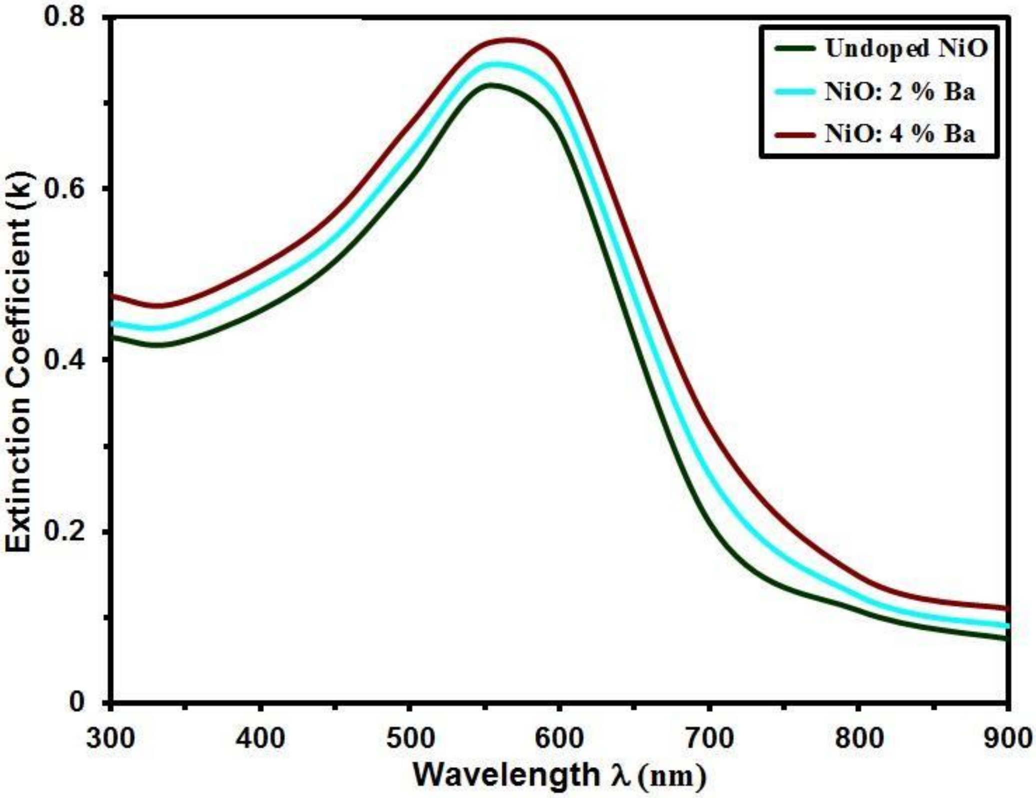

Fig. 7: k of intended films.

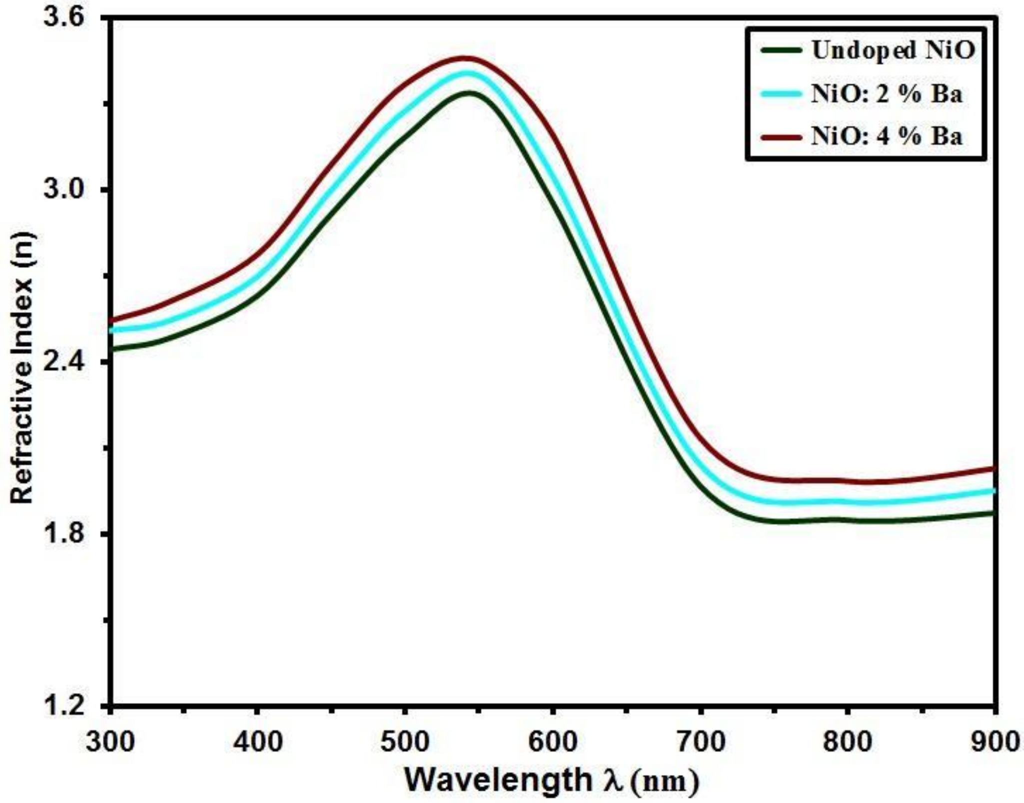

Fig. 8. n of deposit films

Conclusion

Chemical spray pyrolysis has been shown to be a useful technique for preparing high percentages of NiO and NiO: Ba deposition of 2% and 4%. The XRD show s predominant peak (220) for NiO films, the crystallite sizes were increased from 14.46 nm to 16.74 nm, whilst dislocation density (δ) decreased from 4.78 to 3.56, whilst strain (ε) decreased from 2.38 to 2.07. AFM image showed that , Average Particle size increases from (79.36 to 68.78) nm ,The surface roughness increases from 8.81 nm to 4.23 nm by increasing transmittance of Undoped NiO and NiO: Mn films decreases from 77.5 % to 70% as Ba content increases from 1% to 3 %. E_g decreased from 3.46 eV for pure to 3.36 eV for 4wt.% Ba doped NiO film. α, n and k are increasing with Ba content in NiO thin films.

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References

1. [1] Sun, H.; Chen, S.C.; Peng,W.C.; Wen, C.K.;Wang, X.; Chuang, T.H. The Influence of Oxygen Flow Ratio on the Optoelectronic Properties of p-Type Ni1-xO Films Deposited by Ion Beam Assisted Sputter. Coatings, 8 (2018) 168.
2. [2] Kitao, M.; Izawa, K.; Urabe, K.; Komatsu, T.; Kuwano, S.; Yamada, S. Preparation and electrochromic properties of rf-sputtered NiOx films prepared in Ar/O2/H2 atmosphere. Jpn. J. Appl. Phys., 33 (1994) 6656–6662.
3. [3] Kumagai, H.; Matsumoto, M.; Toyoda, K.; Obara, M. Preparation and characteristics of nickel oxide thin film by controlled growth with sequential surface chemical reactions. J. Mater. Sci. Lett. 15 (1996) 1081–1083.
4. [4] Zhang, J.Y.; Li, W.W.; Hoye, R.L.Z.; MacManus-Driscoll, J.L.; Budde, M.; Bierwagen, O.; Wang, L.; Du, Y.; Wahila, M.J.; Piper, L.F.J.; et al. Electronic and transport properties of Li-doped NiO epitaxial thin films. J. Mater. Chem. , C 6 (2018) 2275–2882.
5. [5] Tiwari, S.D.; Rajeev, K.P. Magnetic properties of NiO nanoparticles. Thin Solid Film, 505 (2006) 113–117.
6. [6] Tadic, M.; Nikolic, D.; Panjan, M.; Blake, G.R. Magnetic properties of NiO (nickel oxide) nanoparticles: Blocking temperature and Neel temperature. J. Alloys Compd, 647 (2015) 1061–1068.
7. [7] Cristina, G.; Francis, L.D.; Maurizio, M.M.; Stefano, C.; Francesco, M.M.; Alfonso, P.; Claudia, I.; Claudio, S. Magneto-Plasmonic Colloidal Nanoparticles Obtained by Laser Ablation of Nickel and Silver Targets in Wate. J. Phys. Chem., C 121(2017) 3597–3606.
8. [8] Arif, M.; Sanger, A.; Shkir, M.; Singh, A.; Katiyar, R.S. Influence of interparticle interaction on the structural, optical and magnetic properties of NiO nanoparticles. Phys. B 2019, 552, 88–95.
9. [9] Adler, D.; Feinleib, J. Electrical and optical properties of narrow-band materials. Phys. Rev., B2 (1970) 3112.
10. [10] Chanae Parka , Juhwan Kima , Kangil Leea , Suhk Kun Oha , Hee Jae Kanga, and Nam Seok Park, Electronic, Optical and Electrical Properties of Nickel Oxide Thin Films Grown by RF Magnetron Sputtering, Appl Sci Converg Technol., 24 (2015) 72-76.
11. [11] Hassan, E.S., Elttayef, A.K., Mostafa, S.H., Salim, M.H., Chiad, S.S., Silver oxides nanoparticle in gas sensors applications, Journal of Materials Science: Materials in Electronics 30(17) (2019) 15943-15951.
12. [12] Hadi, E.H., Abbsa, M.A., Khadayeir, A.A., Abood, Z.M., Habubi, N.F., Chiad, S.S., Effects of Mn doping on the characterization of nanostructured TiO2 thin films deposited via chemical spray pyrolysis method, Journal of Physics: Conference Series, (2020) 1664(1) 012069..
13. [13] Ahmed, F.S., Ahmed, N.Y., Ali, R.S., Habubi, N.F., Abass, K.H., Chiad, S.S., "Effects of substrate type on some optical and dispersion properties of sprayed CdO thin films", NeuroQuantology, 18(3) (2020) 56-65.
14. [14] Abdulmunem, O.M., Jabbar, A.M., Muhammad, S.K., Dawood, M.O., Chiad, S.S., Habubi, N.F., Investigation of Co-doped Cu2O thin films on the structural, optical and morphology by SPT, Journal of Physics: Conference Series, 1660(1), (2020) 012055. .
15. [15] S.R. Nalage, M.A. Chougule, Shashwati Sen, P.B. Joshi, V.B. Patil, Sol-gel synthesis of nickel oxide thin films and their characterization.Thin Solid Films, 520 (2012) 4835-4840.
16. [16] F. Vera, R. Schrebler, E. Munoz, C. Suarez, P. Cury, A. Gomez, R.Cordova, R.E. Marotti, E.A. Dalchiele, Preparation and characterization of Eosin B- and Erythrosin J-sensitized nanostructured NiO thin film photocathodes.Thin Solid Films, 490 (2005)182-188.
17. [17] L. Barkat, L. Cattin, A. Reguig, M. Regragui, J.C. Bernede Comparison of the physico-chemical properties of NiO thin films deposited by chemical bath deposition and by spray pyrolysis. Mater Chem Phys, 89 (2005)11-20.
18. [18] I. Fasaki, A. Koutoulaki, M. Kompitsas, C. Charitidis1. Fasaki I, Koutoulaki A, Kompitsas M, Charitidis C, Structural, electrical and mechanical properties of NiO thin films grown by pulsed laser deposition. Appl Surf Sci, 257 (2010)429-433.
19. [19] B. Pejova, T. Kocareva, M. Najdoski, I. Grosdanov, A solution growth route to nanocrystalline nickel oxide thin films. Appl Surf Sci, 271 (2000) 271-278
20. [20] M. Ristova, J. Velveska, M. Ristov, Chemical bath deposition and electrochromic properties of NiO x films Solar Energy Mater. Solar Cells, 71 (2002)219-230.
21. [21] Y.M. Lu, W.S. Hwang, J.S. Yang, Effects of substrate temperature on the resistivity of non-stoichiometric sputtered NiO x films. Surf Coat Technol, 155(2002) 231-235.

22.[22] J.L. Yang, Y.S. Lai, J.S. Chen, Effect of heat treatment on the properties of non-stoichiometric p-type nickel oxide films deposited by reactive sputtering Thin Solid Films, 488 (2005) 242-246.
23.[23] V. Gowthami, M.Meenakshi a, P.Perumal a, R.Sivakuma b, C.Sanjeeviraja, Preparation of rod shaped nickel oxide thin films by a novel and cost effective nebulizer technique. Mater Sci Semicond Process, 27 (2014)1042–1049.
24.[24] M. M. Gomaa, M. Boshta, B. S. Farag, M. B. S. Osman, Structural and optical properties of nickel oxide thin films prepared by chemical bath deposition and by spray pyrolysis techniques. J Mater Sci Mater Electron, 27 (2016) 711-717.
25.[25] M. Jlassi, I. Sta, M. Hajji, H. Ezzaouia, Synthesis and characterization of nickel oxide thin films deposited on glass substrates using spray pyrolysis. Appl Surf Sci., 308 (2014)199-205.
26.[26] L. Cattin, B.A. Reguig, A. Khelil, M. Morsli, K. Benchouk, J.C. Berne`de, Properties of NiO thin films deposited by chemical spray pyrolysis using different precursor solutions, Applied Surface Science, 254(18) (2018) 5814-5821.
27.[27] Salloom, H.T., Hadi, E.H., Habubi, N.F., Chiad, S.S., Jadan, M., Addasi, J.S., Characterization of silver content upon properties of nanostructured nickel oxide thin films, Digest Journal of Nanomaterials and Biostructures, 15(4), (2020) 1189-1195,.
28.[28] Hassan, E.S., Khudhair, D.M., Muhammad, S.K., Jabbar, A.M., Dawood, M.O., Habubi, N.F., Chiad, S.S., Structural and Optical Properties of Sprayed Ba Doped CdS Nanostructure Thin Films, Journal of Physics: Conference Series ,1660(1) (2020) 012066..
29.[29] Al Rawas, A.S., Slewa, M.Y., Bader, B.A., Habubi, N.F., Chiad, S.S., Physical characterization of nickel doped nanostructured TiO_2 thin films, Journal of Green Engineering10 (9) (2020) 7141-7153.
30.[30] Qader, K.Y., Hadi, E.H., Habubi, N.F., Chiad, S.S., Jadan, M., Addasi, J.S., Effects of ni-doping on the characterization of nanostructured cds thin films, International Journal of Thin Films Science and Technology, 10 (1) (2021) 41-44, 2021.
31.[31] N. N. Jandow, N. F. Habubi, S. S. chiad, I. A. Al-Baidhany and M. A. Qaeed, Annealing Effects on Band Tail Width, Urbach Energy and Optical Parameters of Fe_2O_3:Ni Thin Films Prepared by Chemical Spray Pyrolysis Technique, International Journal of Nanoelectronics and Materials, Malaysia, 12 (1) (2019)1-10.
32.[32] M. O. Dawood, S.S. Chiad, A. J. Ghazai, N. F. Habubi and O. M. Abdulmunem, Effect of Li doping on structure and optical properties of NiO nano thin-films by SPT, AIP Conference Proceedings , 2213 (1) (2020) 020102.
33.[33] A. Boukhachem, R. Boughalmi, M. Karyaoui, A. Mhamdi, R. Chtourou,K. Boubaker and M. Amlouk, Study of substrate temperature effects on structural, optical, mechanical and opto-thermal properties of NiO sprayed semiconductor thin films. Mater Sci Eng B Solid-State Mater Adv Technol, 188 (2014) 72-77.
34.[34] Safwat A. Mahmoud, Shereen Alshomer, Mou'ad A. Tarawnh, Structural and Optical Dispersion Characterisation of Sprayed Nickel Oxide Thin Films. J Mod Phys., 2 (2011) 1178-1186.
35.[35] X. . Xia, J. P. Tu, J. Zhang, X. L. Wang, W. K. Zhang, and H. Huang, "Electro chromic properties of porous NiO thin films prepared by a chemical bath deposition", Sol. Energy Mater. Sol. Cells, 92 (2008) 628-633.
36.[36] Hassan, E.S., Mubarak, T.H., Chiad, S.S., Habubi, N.F., Khadayeir, A.A., Dawood, M.O., Al-Baidhany, I.A., Physical Properties of indium doped Cadmium sulfide thin films prepared by (SPT), Journal of Physics: Conference Series 1294(2) ,2019, 022008.
37.[37] Khadayeir, A. A., Hassan, E. S., Mubarak, T. H., Chiad, S.S., Habubi, N. F., Dawood, M.O., Al-Baidhany, I. A., The effect of substrate temperature on the physical properties of copper oxide films, Journal of Physics: Conference Series, 1294 (2) (2019) 022009.
38.[38] H. A. Juybari, M.-M. Bagheri-Mohagheghi, and M. Shokooh- Saremi, "Nickel-lithium oxide alloy transparent conducting films deposited by spray pyrolysis technique," Journal of Alloys and Compounds, 509 (6) (2011) 2770–2775.
39.[39] Chiad, S.S., Habubi, N.F., Abass, W.H., Abdul-Allah, M.H., Effect of thickness on the optical and dispersion parameters of Cd0.4Se0.6 thin films, Journal of Optoelectronics and Advanced Materials, 18(9-10) (2016) 822-826.
40.[40] Ahmed, F.S., Ahmed, N.Y., Ali, R.S., Habubi, N.F., Abass, K.H. and Chiad, S.S. Effects of Substrate Type on Some Optical and Dispersion Properties of Sprayed CdO Thin Films, NeuroQuantology, 18 (3) (2020) 56-65.
41.[41] A. S. Riad, S. A. Mahmoud, and A. A. Ibrahim, Structural and DC electrical investigations of ZnOthin films prepared by spray pyrolysis technique, Physica B: CondensedMatter, 296 (4) (2001) 319–325, 2001.
42.[42] Sharba, K.S., Alkelaby, A.S., Sakhil, M.D., Abass, K.H., Habubi, N.F., Chiad, S.S., Enhancement of urbach energy and dispersion parameters of polyvinyl alcohol with Kaolin additive, NeuroQuantology, 18(3) (2020) 66-73.
43.[43] Muhammad, S. K., Hassan, E.S., Qader, K.Y., Abass, K.H., Chiad, S. S., Habubi, N. F., Effect of vanadium on structure and morphology of SnO_2 thin films, Nano Biomedicine and Engineering, 12(1) (2020) 67-74, 2020.
44.[44] Chiad, S. S. and Mubarak, T. H.,The Effect of Ti on Physical Properties of Fe_2O_3 Thin Films for Gas Sensor Applications, International Journal of Nanoelectronics and Materials, 13(2) (2020) 221-232.
45.[45] Ali, R.S., Sharba, K.S., Jabbar, A.M., Chiad, S.S., Abass, K.H., Habubi, N.F., Characterization of ZnO thin film/p-Si fabricated by vacuum evaporation method for solar cell applications, NeuroQuantology, 18(1) (2020) 26-31.
46.[46] Chiad, S.S., Noor, H.A., Abdulmunem, O.M., Habubi, N.F., Jadan, M., Addasi, J.S., Optical and structural performance of nanostructured Te thin films by (CSP) with various thicknesses, Journal of Ovonic Research, 16 (1) (2020) 35-40.
47.[47] Latif, D.M.A., Chiad, S.S., Erhayief, M.S., Abass, K.H., Habubi, N.F., Hussin, H.A., Effects of FeCl3 additives on optical parameters of PVA, 2018, Journal of Physics: Conference Series, 1003(1) (2018).
48.[48] Habubi, N.F., Oboudi, S.F., Chiad, S.S., Study of some optical properties of mixed SnO2-CuO Thin Films, Journal of Nano- and Electronic Physics, 4(4) (2012) 04008 (4).

49.[49] Sharma, R., Acharya, A.D., Shrivastava, S.B., Patidar, M., Gangrade, M., Shripathi, T., Ganesan, V.: Studies on the structure optical and electrical properties of Zn-doped NiO thin films grown by spray pyrolysis. Optik Int. J. Light Electron Opt., 127 (2016) 4661–4668.
50.[50] J.D.Desai, S.-K.Min, K.-D. Jung, andO.-S. Joo, “Spray pyrolytic synthesis of large area NiOx thin films from aqueous nickel acetate solutions,” Applied Surface Science, 253 (4) (2006) 1781–1786, 2006.
51.JALIL, A. T., DILFY, S. H., KAREVSKIY, A., & NAJAH, N. (2020). Viral Hepatitis in Dhi-Qar Province: Demographics and Hematological Characteristics of Patients. International Journal of Pharmaceutical Research, 12(1). https://doi.org/10.31838/ijpr/2020.12.01.326
52.Dilfy, S. H., Hanawi, M. J., Al-bideri, A. W., & Jalil, A. T. (2020). Determination of Chemical Composition of Cultivated Mushrooms in Iraq with Spectrophotometrically and High Performance Liquid Chromatographic. Journal of Green Engineering, 10, 6200-6216.
53.Jalil, A. T., Al-Khafaji, A. H. D., Karevskiy, A., Dilfy, S. H., & Hanan, Z. K. (2021). Polymerase chain reaction technique for molecular detection of HPV16 infections among women with cervical cancer in Dhi-Qar Province. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2021.05.211
54.Jalil, A. T., Kadhum, W. R., Khan, M. U. F., Karevskiy, A., Hanan, Z. K., Suksatan, W., ... & Abdullah, M. M. (2021). Cancer stages and demographical study of HPV16 in gene L2 isolated from cervical cancer in Dhi-Qar province, Iraq. Applied Nanoscience, 1-7. https://doi.org/10.1007/s13204-021-01947-9
55.Widjaja, G., Jalil, A. T., Rahman, H. S., Abdelbasset, W. K., Bokov, D. O., Suksatan, W., ... & Ahmadi, M. (2021). Humoral Immune mechanisms involved in protective and pathological immunity during COVID-19. Human Immunology. https://doi.org/10.1016/j.humimm.2021.06.011
56.Moghadasi, S., Elveny, M., Rahman, H. S., Suksatan, W., Jalil, A. T., Abdelbasset, W. K., ... & Jarahian, M. (2021). A paradigm shift in cell-free approach: the emerging role of MSCs-derived exosomes in regenerative medicine. Journal of Translational Medicine, 19(1), 1-21. https://doi.org/10.1186/s12967-021-02980-6
57.Hanan, Z. K., Saleh, M. B., Mezal, E. H., & Jalil, A. T. (2021). Detection of human genetic variation in VAC14 gene by ARMA-PCR technique and relation with typhoid fever infection in patients with gallbladder diseases in Thi-Qar province/Iraq. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2021.05.236
58.Saleh, M. M., Jalil, A. T., Abdulkereem, R. A., & Suleiman, A. A. Evaluation of Immunoglobulins, CD4/CD8 T Lymphocyte Ratio and Interleukin-6 in COVID-19 Patients. TURKISH JOURNAL of IMMUNOLOGY, 8(3), 129-134. https://doi.org/10.25002/tji.2020.1347
59.Turki Jalil, A., Hussain Dilfy, S., Oudah Meza, S., Aravindhan, S., M Kadhim, M., & M Aljeboree, A. (2021). CuO/ZrO2 nanocomposites: facile synthesis, characterization and photocatalytic degradation of tetracycline antibiotic. Journal of Nanostructures.
60.Sarjito, Elveny, M., Jalil, A., Davarpanah, A., Alfakeer, M., Awadh Bahajjaj, A. & Ouladsmane, M. (2021). CFD-based simulation to reduce greenhouse gas emissions from industrial plants. International Journal of Chemical Reactor Engineering, (), 20210063. https://doi.org/10.1515/ijcre-2021-0063
61.Marofi, F., Rahman, H. S., Al-Obaidi, Z. M. J., Jalil, A. T., Abdelbasset, W. K., Suksatan, W., ... & Jarahian, M. (2021). Novel CAR T therapy is a ray of hope in the treatment of seriously ill AML patients. Stem Cell Research & Therapy, 12(1), 1-23. https://doi.org/10.1186/s13287-021-02420-8
62.Jalil, A. T., Shanshool , M. T. ., Dilfy, S. H. ., Saleh, M. M., & Suleiman, A. A. . (2021). HEMATOLOGICAL AND SEROLOGICAL PARAMETERS FOR DETECTION OF COVID-19. Journal of Microbiology, Biotechnology and Food Sciences, e4229. https://doi.org/10.15414/jmbfs.4229
63.Vakili-Samiani, S., Jalil, A. T., Abdelbasset, W. K., Yumashev, A. V., Karpisheh, V., Jalali, P., ... & Jadidi-Niaragh, F. (2021). Targeting Wee1 kinase as a therapeutic approach in Hematological Malignancies. DNA repair, 103203. https://doi.org/10.1016/j.dnarep.2021.103203
64.NGAFWAN, N., RASYID, H., ABOOD, E. S., ABDELBASSET, W. K., Al-SHAWI, S. G., BOKOV, D., & JALIL, A. T. (2021). Study on novel fluorescent carbon nanomaterials in food analysis. Food Science and Technology. https://doi.org/10.1590/fst.37821
65.Marofi, F., Abdul-Rasheed, O. F., Rahman, H. S., Budi, H. S., Jalil, A. T., Yumashev, A. V., ... & Jarahian, M. (2021). CAR-NK cell in cancer immunotherapy; A promising frontier. Cancer Science, 112(9), 3427. https://doi.org/10.1111/cas.14993
66.Abosaooda, M., Wajdy, J. M., Hussein, E. A., Jalil, A. T., Kadhim, M. M., Abdullah, M. M., ... & Almashhadani, H. A. (2021). Role of vitamin C in the protection of the gum and implants in the human body: theoretical and experimental studies. International Journal of Corrosion and Scale Inhibition, 10(3), 1213-1229. https://dx.doi.org/10.17675/2305-6894-2021-10-3-22
67.Jumintono, J., Alkubaisy, S., Yánez Silva, D., Singh, K., Turki Jalil, A., Mutia Syarifah, S., ... & Derkho, M. (2021). Effect of Cystamine on Sperm and Antioxidant Parameters of Ram Semen Stored at 4° C for 50 Hours. Archives of Razi Institute, 76(4), 923-931. https://dx.doi.org/10.22092/ari.2021.355901.1735
68.Roomi, A. B., Widjaja, G., Savitri, D., Turki Jalil, A., Fakri Mustafa, Y., Thangavelu, L., ... & Aravindhan, S. (2021). SnO2: Au/Carbon Quantum Dots Nanocomposites: Synthesis, Characterization, and Antibacterial Activity. Journal of Nanostructures.
69.Raya, I., Chupradit, S., Kadhim, M. M., Mahmoud, M. Z., Jalil, A. T., Surendar, A., ... & Bochvar, A. N. (2021). Role of Compositional Changes on Thermal, Magnetic and Mechanical Properties of Fe-PC-Based Amorphous Alloys. Chinese Physics B. https://doi.org/10.1088/1674-1056/ac3655

70. Chupradit, S., Jalil, A. T., Enina, Y., Neganov, D. A., Alhassan, M. S., Aravindhan, S., & Davarpanah, A. (2021). Use of Organic and Copper-Based Nanoparticles on the Turbulator Installment in a Shell Tube Heat Exchanger: A CFD-Based Simulation Approach by Using Nanofluids. Journal of Nanomaterials. https://doi.org/10.1155/2021/3250058
71. Raya, I., Chupradit, S., Mustafa, Y., H. Oudaha, K., M. Kadhim, M., Turki Jalil, A., J. Kadhim, A., Mahmudiono, T., Thangavelu, L. (2021). Carboxymethyl Chitosan Nano-Fibers for Controlled Releasing 5-Fluorouracil Anticancer Drug. Journal of Nanostructures,