Наносистеми, наноматеріали, нанотехнології
Nanosistemi, Nanomateriali, Nanotehnologii
2024, т. 22, № 3, сс. 665–673
https://doi.org/10.15407/nnn.22.03.665

PACS numbers: 78.20.Ci, 78.67.Sc, 81.07.Pr, 81.40.Tv, 82.35.Np, 85.35.-p

Exploring the Optical Properties of PVA–ZrO_2–Sb_2O_3 Nanostructures for Low-Cost Nanoelectronics Fields

Ahmed Hashim[1] and Aseel Hadi[2]

[1]*College of Education for Pure Sciences,*
Department of Physics,
University of Babylon,
Hillah, Iraq
[2]*College of Materials Engineering,*
Department of Ceramic and Building Materials,
University of Babylon,
Hillah, Iraq

The present work goals are to fabricate the PVA–ZrO_2–Sb_2O_3 nanostructures to use in low-cost nanoelectronics applications. The optical properties of PVA–ZrO_2–Sb_2O_3 nanostructures are examined at wavelength ranged from 200 nm to 800 nm. The results confirm that the absorbance and absorption coefficient of PVA are increased with rising in the ZrO_2–Sb_2O_3-nanoparticles' content. The transmittance and energy gap are decreased with increasing in the ZrO_2–Sb_2O_3-nanoparticles' content. The results indicate that the PVA–ZrO_2–Sb_2O_3 nanostructures can be considered as a key for various nanoelectronics fields.

Метою даної роботи є виготовлення наноструктур полівініловий спирт (ПВС)–ZrO_2–Sb_2O_3 для використання в недорогих застосуваннях наноелектроніки. Досліджено оптичні властивості наноструктур ПВС–ZrO_2–Sb_2O_3 в діяпазоні довжин хвиль від 200 нм до 800 нм. Результати підтверджують, що абсорбція та коефіцієнт поглинання ПВС зростають зі збільшенням вмісту наночастинок (НЧ) ZrO_2–Sb_2O_3. Зі збільшенням вмісту НЧ ZrO_2–Sb_2O_3 коефіцієнт пропускання й енергетична щілина зменшуються. Результати вказують на те, що наноструктури ПВС–ZrO_2–Sb_2O_3 можна вважати ключовими для різних галузей наноелектроніки.

Key words: PVA, ZrO_2–Sb_2O_3, nanocomposites, energy gap, optical properties.

Ключові слова: полівініловий спирт, ZrO_2–Sb_2O_3, нанокомпозити, енергетична щілина, оптичні властивості.

(Received 18 August, 2023)

1. INTRODUCTION

Electronics has been undergoing a disruptive evolution, investing in lightweight, soft and flexible devices instead of heavy, bulky, and rigid devices. Thus, flexible electronics is a fast-growing field that promises to develop new commercial products such as displays, solar cells, and biomedical sensors. These devices can be incorporated into clothing and other everyday items that ensure they revolutionize our daily lives. In this way, the electronic industry opens up new opportunities, and endless manufacturing advances in thin-film materials and devices will make flexible electronics ubiquitous [1]. Semiconductor materials have yielded valuable information beyond the most advanced knowledge in the technological field in recent years. These materials have essential widespread applications, including–VI semiconductor materials, such as solar cells, light emitting devices [2].

The surface of metal oxides is a key factor for effective interaction with target molecules, however, reducing the size of metal oxide particles to the nanoscale, increases the active surface area and induces a new effect due to quantum confinement such as band gap widening, UV-absorption, room temperature, and photoluminescence [3].

Polyvinyl alcohol (PVA) is a semicrystalline polymer having a high dielectric strength, good thermostability, high mechanical strength, chemical resistance, excellent film forming properties and optical transparency. The existence of the hydroxyl group, (–OH), gives PVA special properties due to the strong –OH interaction between intra and intermolecular polymer chains [4].

Antimony trioxide nanoparticles (NPs; nano-Sb_2O_3) have been widely concerned because of good synergistic fire-retardant effect between nano-Sb_2O_3 and halogen flame-retardants [5].

Nanosize zirconia has attracted much attention due to its specific optical and electrical properties as well as other potential applications in transparent optical devices, electrochemical capacitor electrodes, oxygen sensors, fuel cells, catalysts and advanced ceramics [6].

The nanocomposites compose of two or more materials have huge applications in various fields like electronics and optoelectronics [7–21], optical fields [22–31], radiation shielding and bioenvironmental [32–37], sensors [38–40], energy storage [41–43] and antibacterial [44–50]. This work deals with fabrication and optical properties of PVA–ZrO_2–Sb_2O_3 nanostructures to use in nanoelectronics fields.

2. MATERIALS AND METHODS

Films of PVA–ZrO_2–Sb_2O_3 nanostructures were fabricated by using casting technique. The 0.5 gm of PVA was dissolved in 30 ml of distilled water by using magnetic stirrer to mix the polymer for 1 hour to obtain more homogeneous solution. Then, ZrO_2 and Sb_2O_3 nanoparticles were added to PVA solution with constant ratio 1:1 and contents of 2.2%, 4.4% and 6.6%. The optical properties of PVA–ZrO_2–Sb_2O_3-nanostructures' films were examined using the double beam spectrophotometer (Shimadzu, UV-1800Å) at wavelength ranged from 200 nm to 800 nm.

The absorption coefficient (α) is given by [51] as follows:

$$\alpha = 2.303(A/t), \quad (1)$$

where A is the absorbance and t is the thickness of films.

The energy gap is determined by means of equation [52]

$$\alpha h\nu = C(h\nu - E_g)^r, \quad (2)$$

where C is the constant; $h\nu$ is the energy of photon; E_g is the energy gap, and $r = 2$ and 3 for allowed and forbidden indirect transitions.

3. RESULTS AND DISCUSSION

Figures 1 and 2 show the performances of absorbance and transmittance of PVA–ZrO_2–Sb_2O_3 nanostructures with wavelength respectively. As shown in these figures, the absorbance is high at low wavelength (UV-region) due to the high energy at this region. The absorbance reduces and transmittance increases with increasing wavelength. The absorption of PVA rises, while the transmittance reduces, when the ZrO_2–Sb_2O_3 NPs content rises, which may be due to increase in the number of charge carriers. This enhancement in the absorption of PVA by doping with ZrO_2–Sb_2O_3 NPs can due to improve of other intermolecular bonds between cations and anions creating defects over the entire polymer medium. The reduced transmittance is due to the rise in scattering processes of the incident photons by denser NPs' filling the polymer matrix [53–65].

Figure 3 demonstrates the variation of absorption coefficient for PVA–ZrO_2–Sb_2O_3 nanostructures with photon energy. From this figure, the values of absorption coefficient are less than 10^4 cm^{-1} that indicates to the indirect transition.

Figures 4 and 5 illustrate the energy gap values for the allowed and forbidden transitions of PVA–ZrO_2–Sb_2O_3 nanostructures. The

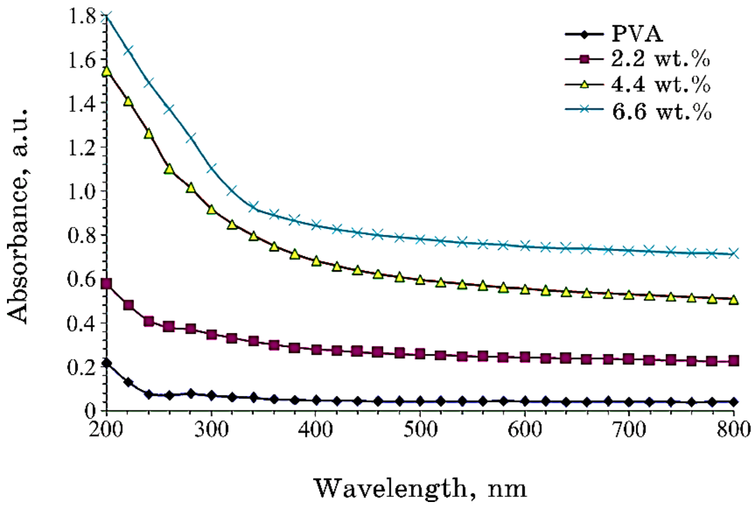

Fig. 1. Performance of absorbance for PVA–ZrO_2–Sb_2O_3 nanostructures with wavelength.

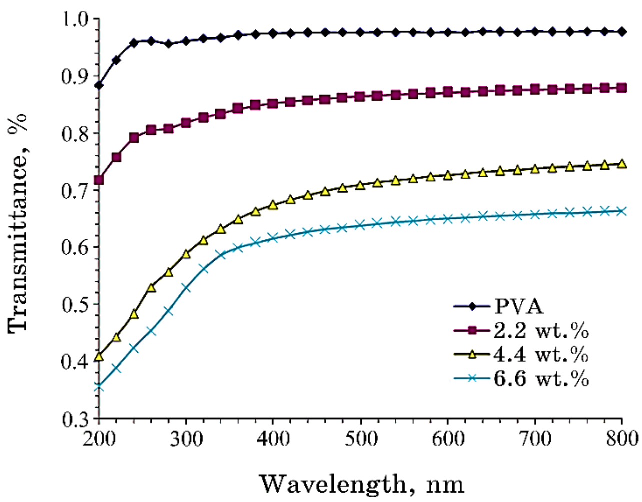

Fig. 2. Transmittance variation of PVA–ZrO_2–Sb_2O_3 nanostructures with wavelength.

energy gap of PVA is reduced with rising ZrO_2–Sb_2O_3 content; this behaviour can be due to the creation of new energy levels, which create the energy band gap. The reduced energy gap selects that the charge transfer complexes presence relate the form of defects in the polymer matrix. These defects create the localized levels in the energy gap [66–72].

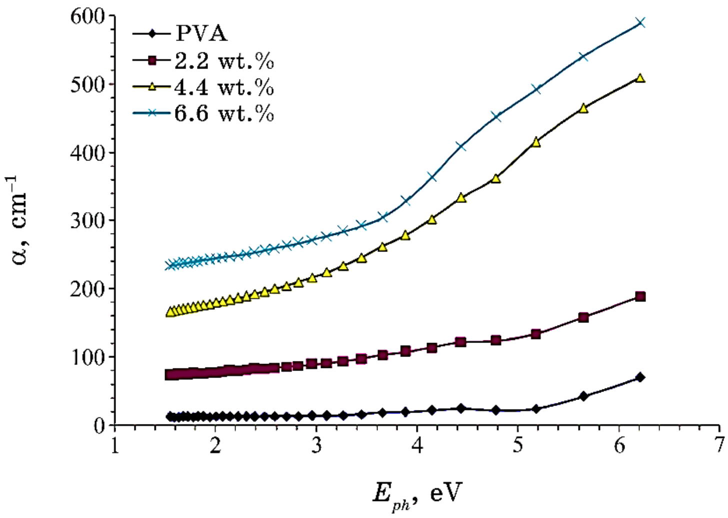

Fig. 3. Variation of absorption coefficient for PVA–ZrO_2–Sb_2O_3 nanostructures with photon energy.

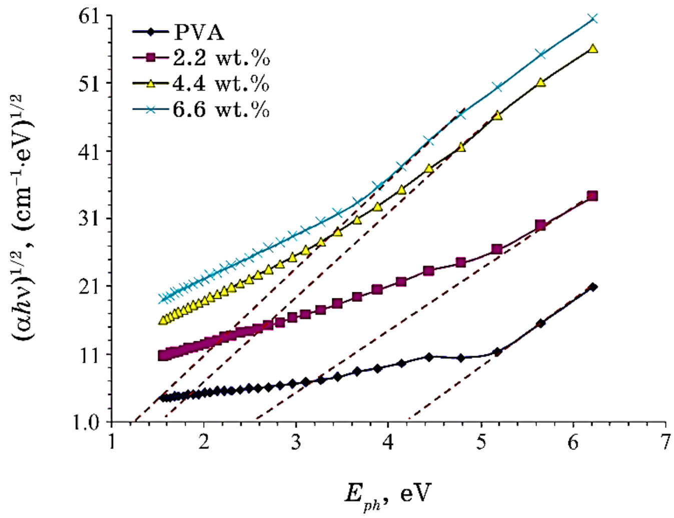

Fig. 4. Energy gap values for allowed transition for PVA–ZrO_2–Sb_2O_3 nanostructures.

4. CONCLUSION

This paper includes synthesis of PVA–ZrO_2–Sb_2O_3 nanostructures to use in low-cost nanoelectronics fields. The experimental results showed that the absorbance and absorption coefficient of PVA are

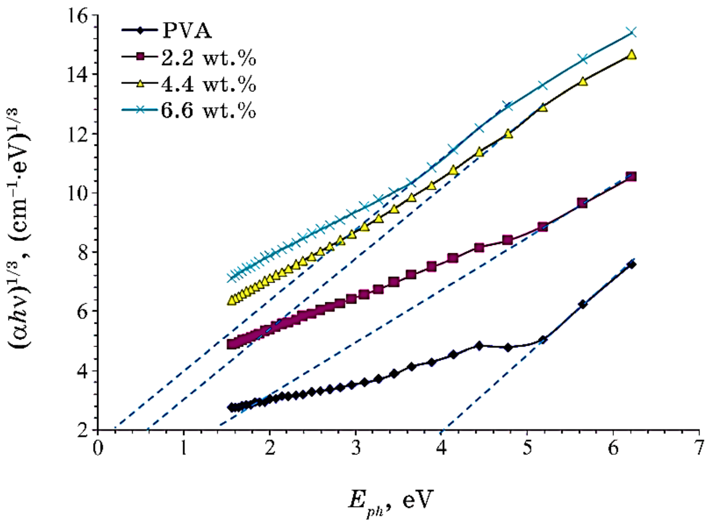

Fig. 5. Energy gap values for forbidden transition for PVA–ZrO_2–Sb_2O_3 nanostructures

increased with increasing of ZrO_2–Sb_2O_3-NPs' content. The transmittance and energy gap are decreased with increasing of the ZrO_2–Sb_2O_3-NPs' content. Finally, the results demonstrated that the PVA–ZrO_2–Sb_2O_3 nanostructures can be considered as promising materials for nanoelectronics fields.

REFERENCES

1. N. E. Guimarãea, É. R. B. Ximenes, L. A. D. Silva, R. F. D. S. Santos, E. S. Araújo, and K. A. D. S. Aquino, *Materials Research*, **26**: 1 (2023); https://doi.org/10.1590/1980-5373-MR-2022-0308
2. S. H. Zyoud, T. H. AlAbdulaal, A. Almoadi, M. S. Alqahtani, F. A. Harraz, M. S. Al-Assiri, I. S. Yahia, H. Y. Zahran, M. I. Mohammed, and M. S. Abdel-wahab, *Crystals*, **13**: 1(2023); https://doi.org/10.3390/cryst13040608
3. M. Q. A. Al-Gunaid, G. H. Maheshwarappa, S. B. Shivanna, M. A. H. Dhaif-Allah, W. A. Ahmed, and F. H. Al-Ostoot, *European Journal of Chemistry*, **14**, No. 3: 1 (2023); https://doi.org/10.5155/eurjchem.14.3.401-413.2439
4. A. Abou Elfadl, *Arab. J. Nucl. Sci. Appl.*, **52**, No. 4: 145 (2019); doi:10.21608/ajnsa.2019.8081.1177
5. J.-L. Xu, Y.-G. Lin, W.-L.Yang, C.-H. Kang, and L. Niu, *Materials Research*, **23**: 1 (2020); https://doi.org/10.1590/1980-5373-MR-2020-0316
6. D. Hirani, K. Shah, and B. S. Chakrabarty, *International Journal of Scientific & Technology Research*, **8**, Iss. 12: 4001 (2019).
7. B. Mohammed, H. Ahmed, and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **21**, Iss. 1: 113 (2023);

https://doi.org/10.15407/nnn.21.01.133
8. A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, Iss. 3: 647 (2021); https://doi.org/10.15407/nnn.19.03.647
9. A. Hazim, A. Hashim, and H. M. Abduljalil, *Nanosistemi, Nanomateriali, Nanotehnologii*, **18**, No. 4: 983 (2020); https://doi.org/10.15407/nnn.18.04.983
10. A. Hashim and Z. S. Hamad, *Nanosistemi, Nanomateriali, Nanotehnologii*, **18**, No. 4: 969 (2020); https://doi.org/10.15407/nnn.18.04.969
11. A. Hazim, A. Hashim, and H. M. Abduljalil, *Egypt. J. Chem.*, **64**, No. 1: 359 (2021); doi:10.21608/EJCHEM.2019.18513.2144
12. H. Ahmed and A. Hashim, *Journal of Molecular Modeling*, **26**: 1 (2020); doi:10.1007/s00894-020-04479-1
14. H. Ahmed and A. Hashim, *Silicon*, **14**: 4907 (2022); https://doi.org/10.1007/s12633-021-01258-2
15. A. Hashim, *Opt. Quant. Electron.*, **53**: 1 (2021); https://doi.org/10.1007/s11082-021-03100-w
16. H. Ahmed and A. Hashim, *Trans. Electr. Electron. Mater.*, **23**: 237 (2022); https://doi.org/10.1007/s42341-021-00340-1
17. H. Ahmed and A. Hashim, *Silicon*, **14**: 7025 (2021); https://doi.org/10.1007/s12633-021-01465-x
18. A. Hazim, A. Hashim, and H. M. Abduljalil, *Trans. Electr. Electron. Mater.*, **21**: 48 (2019); https://doi.org/10.1007/s42341-019-00148-0
19. A. F. Kadhim and A. Hashim, *Opt. Quant. Electron.*, **55**: 432 (2023); https://doi.org/10.1007/s11082-023-04699-8
20. H. Ahmed and A. Hashim, *Opt. Quant. Electron.*, **55**: 280 (2023); https://doi.org/10.1007/s11082-022-04528-4
21. G. Ahmed and A. Hashim, *Silicon*, **15**: 3977 (2023); https://doi.org/10.1007/s12633-023-02322-9
22. M. H. Meteab, A. Hashim, and B. H. Rabee, *Opt. Quant. Electron.*, **55**: 187 (2023); https://doi.org/10.1007/s11082-022-04447-4
23. H. Ahmed and A. Hashim, *Silicon*, **14**: 6637 (2022); https://doi.org/10.1007/s12633-021-01449-x
24. H. Ahmed and A. Hashim, *Silicon*, **13**: 4331 (2020); https://doi.org/10.1007/s12633-020-00723-8
25. O. B. Fadil and A. Hashim, *Silicon*, **14**: 9845 (2022); https://doi.org/10.1007/s12633-022-01728-1
26. H. Ahmed and A. Hashim, *Silicon*, **15**: 2339 (2023); https://doi.org/10.1007/s12633-022-02173-w
27. H. B. Hassan, H. M. Abduljalil, and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, Iss. 4: 941(2022); https://doi.org/10.15407/nnn.20.04.941
28. H. A. Jawad and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, Iss. 4: 963 (2022); https://doi.org/10.15407/nnn.20.04.963
29. H. Ahmed and A. Hashim, *Transactions on Electrical and Electronic Materials*, **22**: 335 (2021); https://doi.org/10.1007/s42341-020-00244-6
30. N. AH. Al-Aaraji, A. Hashim, A. Hadi, and H. M. Abduljalil, *Silicon*, **14**: 10037 (2022); https://doi.org/10.1007/s12633-022-01730-7
31. H. Ahmed and A. Hashim, *Opt. Quant. Electron.*, **55**: 1 (2023); https://doi.org/10.1007/s11082-022-04273-8

32. W. O. Obaid and A. Hashim, *Silicon*, **14**: 11199 (2022); https://doi.org/10.1007/s12633-022-01854-w
33. A. Hashim and N. Hamid, *Journal of Bionanoscien*ce, **12**, No. 6: 788 (2018); doi:10.1166/jbns.2018.1591
34. B. Abbas and A. Hashim, *International Journal of Emerging Trends in Engineering Research*, **7**, No. 8: 131 (2019); https://doi.org/10.30534/ijeter/2019/06782019
35. K. H. H. Al-Attiyah, A. Hashim, and S. F. Obaid, *Journal of Bionanoscience*, **12**: 200 (2018); doi:10.1166/jbns.2018.1526
36. H. A. J. Hussien, A. Hadi, and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, Iss. 4: 1001 (2022); https://doi.org/10.15407/nnn.20.04.1001
37. A. Hashim and Z. S. Hamad, *Journal of Bionanoscience*, **12**, No. 4: 488 (2018); doi:10.1166/jbns.2018.1551
38. A. Hashim and Z. S. Hamad, *Journal of Bionanoscience*, **12**, No. 4: 504 (2018); doi:10.1166/jbns.2018.1561
39. H. Ahmed and A. Hashim, *International Journal of Scientific & Technology Research*, **8**, Iss. 11: 1014 (2019).
40. B. Mohammed, H. Ahmed, and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, Iss. 1: 187 (2022); https://doi.org/10.15407/nnn.20.01.187
41. A. Hashim and A. Hadi, *Sensor Letters*, **15**, No. 10: 858 (2017); https://doi.org/10.1166/sl.2017.3900
42. H. Ahmed and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, Iss. 4: 951 (2022); https://doi.org/10.15407/nnn.20.04.951
43. A. S. Shareef, F. Lafta R., A. Hadi, and A. Hashim, *International Journal of Scientific & Technology Research*, **8**, Iss. 11: 1041 (2019).
44. A. Hadi, A. Hashim, and D. Hassan, *Bulletin of Electrical Engineering and Informatics*, **9**, No. 1: 83 (2020); doi:10.11591/eei.v9i1.1323
45. A. Hashim, I. R. Agool, and K. J. Kadhim, *Journal of Bionanoscience*, **12**, No. 5: 608 (2018); doi:10.1166/jbns.2018.1580
46. O. B. Fadil and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, Iss. 4: 1029 (2022); https://doi.org/10.15407/nnn.20.04.1029
47. W. O. Obaid and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, Iss. 4: 1009 (2022); https://doi.org/10.15407/nnn.20.04.1009
48. M. H. Meteab, A. Hashim, and B. H. Rabee, *Nanosistemi, Nanomateriali, Nanotehnologii*, **21**, Iss. 1: 199 (2023); https://doi.org/10.15407/nnn.21.01.199
49. M. H. Meteab, A. Hashim, and B. H. Rabee, *Nanosistemi, Nanomateriali, Nanotehnologii*, **21**, Iss. 2: 451 (2023); https://doi.org/10.15407/nnn.21.02.451
50. A. Hazim, A. Hashim, and H. M. Abduljalil, *International Journal of Emerging Trends in Engineering Research*, **7**, No. 8: 68 (2019); https://doi.org/10.30534/ijeter/2019/01782019
51. A. Hazim, H. M. Abduljalil, and A. Hashim, *International Journal of Emerging Trends in Engineering Research*, **7**, No. 8: 104 (2019); https://doi.org/10.30534/ijeter/2019/04782019
52. A. A. A. Ahmed, A. M. Al-Hussam, A. M. Abdulwahab, and A. N. A. A. Ahmed, *AIMS Mater. Sci.*, **5**, Iss. 3: 1 (2018);

doi:10.3934/matersci.2018.3.533
53. T. A. Baset, M. Elzayat, and S. Mahrous, *Int. J. of Polym. Sci.*, **2016**: 1 (2016); http://dx.doi.org/10.1155/2016/1707018
54. Z. K. Heiba, M. B. Mohamed, and S. I. Ahmed, *Alexandria Engineering Journal*, **61**, Iss. 5: 3375 (2022); https://doi.org/10.1016/j.aej.2021.08.051
55. P. O. Amin, K. A. Ketuly, S. R. Saeed, F. F. Muhammadsharif, M. D. Symes, A. Paul, and K. Sulaiman, *BMC Chemistry*, **15**: 1 (2021); https://doi.org/10.1186/s13065-021-00751-4
56. A. Hashim, M. H. Abbas, N. A.-H. Al-Aaraji, and A. Hadi, *J. Inorg. Organomet. Polym.*, **33**: 1 (2023); https://doi.org/10.1007/s10904-022-02485-9
57. A. Hashim, M. H. Abbas, N. A.-H. Al-Aaraji, and A. Hadi, *Silicon*, **15**: 1283 (2023); https://doi.org/10.1007/s12633-022-02104-9
58. M. H. Meteab, A. Hashim, and B. H. Rabee, *Silicon*, **15**: 1609 (2023); https://doi.org/10.1007/s12633-022-02114-7
59. N. Al-Huda Al-Aaraji, A. Hashim, A. Hadi, and H. M. Abduljalil, *Silicon*, **14**: 4699 (2022); https://doi.org/10.1007/s12633-021-01265-3
60. S. Hadi, A. Hashim, and A. Jewad, *Australian Journal of Basic and Applied Sciences*, **5**, No. 9: 2192 (2011).
61. F. A. Jasim, A. Hashim, A. G. Hadi, F. Lafta, S. R. Salman, and H. Ahmed, *Research Journal of Applied Sciences*, **8**, Iss. 9: 439 (2013).
62. F. A. Jasim, F. Lafta, A. Hashim, M. Ali, and A. G. Hadi, *Journal of Engineering and Applied Sciences*, **8**, No. 5: 140 (2013).
63. A. Hashim and A. Hadi, *Sensor Letters*, **15**, No. 10: 858 (2017); https://doi.org/10.1166/sl.2017.3900
64. A. Hashim, M. A. Habeeb, A. Khalaf, and A. Hadi, *Sensor Letters*, **15**, No. 7: 589 (2017); https://doi.org/10.1166/sl.2017.3856
65. I. R. Agool, F. S. Mohammed, and A. Hashim, *Advances in Environmental Biology*, **9**, No. 11: 1 (2015).
66. B. H. Rabee and A. Hashim, *European Journal of Scientific Research*, **60**, No. 2: 247 (2011).
67. A. Hashim, A. Hadi, and M. H. Abbas, *Opt. Quant. Electron.*, **55**: 642 (2023); https://doi.org/10.1007/s11082-023-04929-z
68. A. Hashim, A. Hadi, and M. H. Abbas, *Silicon*, **15**: 6431 (2023); https://doi.org/10.1007/s12633-023-02529-w
69. H. A. J. Hussien and A. Hashim, *J. Inorg. Organomet. Polym.*, **33**: 2331 (2023); https://doi.org/10.1007/s10904-023-02688-8
70. A. Hashim, A. Hadi, N. A. H. Al-Aaraji, and F. L. Rashid, *Silicon*, **15**: 5725 (2023); https://doi.org/10.1007/s12633-023-02471-x
71. G. Ahmed and A. Hashim, *Silicon*, **15**: 7085 (2023); https://doi.org/10.1007/s12633-023-02572-7
72. A. Hashim, A. Hadi, and N. A.-H. Al-Aaraji, *Opt. Quant. Electron.*, **55**: 1 (2023); https://doi.org/10.1007/s11082-023-04994-4
73. N. A.-H. Al-Aaraji, A. Hashim, H. M. Abduljalil, and A. Hadi, *Opt. Quant. Electron.*, **55**: 1 (2023); https://doi.org/10.1007/s11082-023-05048-5