CHAPTER 6

Conclusion and future direction

CHAPTER 6

Conclusion and future direction

6.1 Conclusion

Quantum dots of ZnO, SnO_2, and Fe_2O_3 have been synthesized by quenching method followed by their characterizations[1-15] using various techniques viz UV/Vis spectroscopy, XRD and HRTEM. From the blue shift of UV/VIS spectroscopy, using hyperbolic band model approximate quantum dot size has been estimated while from XRD the crystalline structures as well as the sizes of quantum dots have been obtained. HRTEM provides the pictorial views of quantum dots along with their sizes and shapes. The sizes of ZnO/PVA, ZnO/PVP, SnO_2/PVP, and Fe_2O_3/PVP quantum dots are 12nm, 10nm,13nm and 14nm respectively and these are elliptical /circular in shape. However, it has been observed that quantum dots on PVA matrix is less stable for six months or so while quantum dots on PVP matrix are stable for 2 years or so. The characterizations are summarized in the following table.

	Data From Characterization					
Type of Quantum dots Sample	UV-VIS spectroscopy Study	XRD Study	HRTEM Study	Average Size of Quantum dots	Shape of Quantum dots	Structure
ZnO/PVA	12nm	11nm	11nm	Within 12 nm	elliptical	wurtzite
ZnO/PVP	10 nm	9nm	10 nm	Within 10 nm	Circular	wurtzite
SnO_2/PVP	13 nm	12 nm	12 nm	Within 13 nm	Circular	Rutile
Fe_2O_3/PVP	15 nm	14 nm	15 nm	Within 15 nm	Circular	wurtzite

Table 6.1: Data from characterizations

Further, the prepared quantum dots have been tested for their applications for sensing reducing gases namely acetone, ethanol and methanol and following information has been obtained from the studies:

1. PVA embedded ZnO quantum dots[7,8] has lower acetone sensitivity in compare to PVP embedded ZnO quantum dots. But both the response time and recovery time are large in case of ZnO quantum dots embedded in PVP in comparison to that in PVA .
2. ZnO quantum dot acetone sensor[7] has higher sensitivity in compare to Fe_2O_3 quantum dot acetone sensor but it is comparable with that of SnO_2 quantum dots Further ZnO quantum dots are very sensitive to acetone even at lower concentration e.g 100 ppm.
3. Response time and recovery time is less in case of SnO_2 quantum dot acetone sensor in compare to that of ZnO and Fe_2O_3 quantum dot acetone sensor .
4. SnO_2 quantum dots ethanol sensor[1] has higher sensitivity, in comparison to that of ZnO and Fe_2O_3 quantum dots ethanol sensors[3] ..But ZnO quantum dots ethanol sensor has less response and recovery time in comparison to SnO_2 and Fe_2O_3 quantum dots ethanol sensors
5. Furthermore, SnO_2 quantum dots methanol sensor has higher sensitivity, less response and recovery time in compare to ZnO and Fe_2O_3 quantum dot methanol sensor[2,4].

The sensing properties of quantum dots towards different reducing gas/vapors are summarized in the following tables.

	Data From Experimental Work											
	ZnO Q.D Embedded on PVA			ZnO Q.D Embedded on PVP			Fe_2O_3 Q.D Embedded on PVP			SnO_2 Q.D embedded on PVP		
	Acetone Concentration			Acetone concentration			Acetone concentration			Acetone Concentration		
	100 ppm	300 ppm	500 ppm	100 ppm	300 ppm	500 ppm	100 ppm	300 ppm	500 ppm	100 ppm	300 ppm	500 ppm
Response in %	13	42	65	62	82	88	40	55	70	20	65	88
Operating temperature (^{0}c)	290	290	290	300	300	300	300	300	300	250	250	250
Response time(sec)	85	55	35	110	85	60	110	70	50	96	46	35
Recovery time(sec)	60	50	40	175	140	120	120	43	40	65	40	16

Table 6.2: Experimental Data from Acetone Sensing

	Data From Experimental Work								
	ZnO Q.D Embedded on PVP			Fe_2O_3 Q.D Embedded on PVP			SnO_2 Q.D Embedded on PVP		
	Ethanol Concentration			Ethanol concentration			Ethanol concentration		
	100 ppm	300 Ppm	500 ppm	100 ppm	300 ppm	500 ppm	100 ppm	300 ppm	500 ppm
Response in %	37	45	60	40	50	75	45	60	85
Operating temperature (^{0}c)	300	300	300	290	290	290	275	275	275
Response time(sec)	80	50	40	162	124	85	150	100	50
Recovery time(sec)	17	12	7	150	100	80	110	70	50

Table 6.3: Experimental Data from Ethanol Sensing

	Data From Experimental Work								
	ZnO Q.D Embedded on PVP			Fe_2O_3 Q.D Embedded on PVP			SnO_2 Q.D Embedded on PVP		
	Methanol Concentration			Methanol concentration			Methanol concentration		
	100 ppm	300 ppm	500 ppm	100 ppm	300 ppm	500 ppm	100 ppm	300 ppm	500 ppm
Response in %	48	67	75	50	70	80	53	77	90
Operating temperature (^{0}c)	290	290	290	300	300	300	250	250	250
Response time(sec)	140	120	80	138	110	50	100	66	45
Recovery time(sec)	130	90	80	110	80	55	100	70	40

Table 6.4: Experimental Data from Methanol Sensing

6.2. Future research direction

The present work is an attempt to study sensing properties of three semiconductor quantum dots for three reducing gases. In this study, only quenching technique has been adopted for quantum dot synthesis on two non-conducting matrices Therefore, the present work may be extended in the following directions.

1) **Synthesis of quantum dot using conducting matrix**: Quantum dots[9,10] may be synthesized by using conducting matrix e.g NAFION 117. In this case conducting matrix may replace the insulating matrix between any two quantum dots and the electrons from one quantum dot to another may drift faster through the conducting matrix which may result better sensing efficiency, small response and recovery time.

2) **Synthesis of quantum dots without matrix**: Quantum dots[12] may be synthesized without using any kind of matrix by controlling PH, stirring rate, and temperature during synthesis. In that case, free standing quantum dots may be obtained and thus effect of matrix may be nullified.

3) **Synthesis of quantum dot by electro deposition technique:** Quantum dot synthesis may be done by using electrodepositing[13] technique: Though the method is little costly, but quantum dots of better shape and smaller size may be obtained by this technique.

4). **Quantum dots of better Stability:** Quantum dots embedded in PVP matrix is stable for 2 years or so. After that they agglomerate resulting in property deterioration. To increase the stability, silica[11] may be coated around the quantum dots as shield which may prevent them from agglomeration.

5) **Gas sensing at low temperature:** Gas sensing at low temperature[14] (room temperature) is an important issue till date. Low temperature gas sensing may be an important future direction of the present work.

6) **Oxidizing gas sensing:** It is very important to sense the oxidizing gases[15] also. The present work may be extended to sense these gases.

References:

[1] Choudhury, M.; Nath, S.S. and Bhattacharjee, R., Ethanol sensing property of SnO_2 quantum dots embedded on PVP, *Journal of Nanotech. Prog INT.,* vol. 5, Issue1, 2014.

[2] Choudhury, M.; Nath, S.S. and Bhattacharjee, R., Methanol sensing property of Fe_2O_3 quantum dots embedded on PVP, *International Journal of Nanoscience and Nanotechnology ,* vol. 5, Number 1, pp. 101-108, 2014.

[3] Choudhury, M.; Nath, S.S. and Nath, R.K., ZnO: PVP Quantum dot Ethanol sensor, *Journal of sensor Technology,* Issue1, pp 86-90, 2011.

[4] Nath, S.S.; Choudhury, M. and Nath, R.K, Syntheses of PVP embedded ZnO quantum dots and the investigation of their methanol sensing properties, *J. Nanotechnology Progress International,* Issue 4,2011.

[5] Nath, S.S.; Choudhury, M.; Nath, R.K. and Gope, G., PVA embedded ZnO quantum dots for methanol sensing, *Nanotrends-A journal of nanotechnology and its application,*vol 8, Issue 3, p 1, 2010 .

[6] Choudhury, M.; Nath, S.S.; Nath, R.K.; Chakder, D.; Gope, G. and Das,R., ZnO quantum dots in SBR latex for methanol sensing, *Assam University journal of Sc. and Tech*., vol.6, No 2, pp 46-50, 2010.

[7] Nath, S.S; Choudhury, M.; Nath, R.K. and Gope, G., Acetone sensing property of ZnO quantum dots embedded on PVP, *Sensors and actuators B: Chemical*, vol. 148, pp 353-357, 2010.

[8] Choudhury, M.; Nath, S.S.; Nath, R.K.; Gope, G. and Chakder, D., Acetone Sensing of ZnO quantum dots embedded in PVA matrix, *Advanced Science Letter*., vol. 1, p. 6, 2010.

[9] Zhao, Lihua.; Zhou, Zhang-Lin.; Guo, Zengshan.; Pei, Jian. and Mao, Samuel., Development of New Polymer Systems and Quantum Dots – Polymer Nano composites for Flexible OLED Display Applications, HP Laboratories ,HPL-2011-68.

[10] Sumi, R.; Warrier, Anita R. and Vijayan, C., Visible-light driven photocatalytic activity of *β*-indium sulfide (In_2S_3) quantum dots embedded in Nafion matrix, *Journal of Physics D: Applied Physics,* vol.47, No. 10, 2014.

[11] Jeon, Jun-Hong.; Choi, Jin-Young.; Park, Won-Woong. and Moon, Sun-Woo., Crystalline Ge quantum dots embedded in SiO_2 matrix synthesized by plasma immersion ion implantation, *Nanotechnology,* vol. 22, No. 28,2011 .

[12] Heine, J.R.; Rodriguez-Viejo, J.; Bawendi, M.G. and Jensen, K.F., Synthesis of CdSe quantum dot*s* ZnS matrix thin films via electrospray organometallic chemical vapor deposition, *Journal of Crystal Growth*, vol.195, pp. 564-568, 1998.

[13] Ropp, Chad.; Cummins, Zachary.; Probst, Roland.and Qin,S., Positioning and Immobilization of Individual Quantum Dots with Nanoscale Precision, *Nano Lett.,vol. 10*, pp. 4673–4679, 2010.

[14] Tian, Shouqin.; Ding, Xiaohu.; Zeng, Dawen.; Wu, Jinjin.; Zhang, Shunping. and Xie, Changsheng., A low temperature gas sensor based on Pd-functionalized mesoporous SnO_2 fibers for detecting trace formaldehyde**,** *RSC Adv***.**, vol.3,pp. 11823-11831, 2013.

[15] F. Fine, George; Cavanagh, Leon M.; Afonja, Ayo. and Binions, Russell., Metal Oxide Semi-Conductor Gas Sensors in Environmental Monitoring, *sensors,2010*