List of Figures

Figures	Title	Page
1.1	Basic design of an electrochemical gas sensor (Source: Electrochemical Sensors, (www.intlsensor.com))	3
1.2	Schematic diagram of SAW gas sensor (Source: Liu et al., 2018)	4
1.3	Schematic diagram of NDIR gas sensor (Source: Hodgkinson et al., 2013)	4
1.4	Basic device structure of capacitive gas sensors (a) MOS (b) MOM (Source: Bindra <i>et al.</i> , 2018)	5
1.5	Schematic representations of catalytic gas sensors in clean air and combustible gas (Source: https://instrumentationtools.com/catalytic-type-gas-sensor-principle)	6
1.6	Schematic diagram of FET based gas sensor where nanowire (1D nanostructure) is placed in between the source and drain (Source: Huang <i>et al.</i> , 2009)	9
1.7	Schematic device structures of metal oxide gas sensors (a) ceramic tube (Taguchi type) (b) Planner type gas sensors (Source: Sung <i>et al.</i> , 2012)	9
1.8	Gas sensing mechanism of ZnO nanofibers under UV illumination: (a) ZnO nanoplates and (b) ZnO nanoflowers in the presence of HCHO (Source: Cui <i>et al.</i> , 2016)	11
1.9	Schematic diagram of the effect of grain size of MOx for gas sensing response (Sun <i>et al.</i> , 2012)	12
1.10	(a) Gas response with different Co doping concentration at 300°C, (b) gas response of all sensors for different H2 concentration at 300°C, and (c) gas sensing mechanism of undoped and Co-doped ZnO NRs (Source: Sett <i>et al.</i> , 2017)	14
1.11	Dynamic response of gas sensor under different concentrations of NO ₂ for pure ZNWs (150°C) and Pd-ZNWs (100°C) at (a) 30% RH and (b) 60% RH and (c-d) corresponding gas sensor response at (c) 30% RH and (d) 60% RH (e) gas sensing mechanism for Pd-ZNWs under NO ₂ and reducing gases (Source: Chen <i>et al.</i> , 2019)	16
1.12	(a) Sensors response of 5 ppm NO ₂ with different temperatures, (b) sensors response of 5 ppm NO ₂ with different RGO concentrations at 400°C, (c-d) sensing mechanism of pure n- 7nO NFs and RGO-7nO beterojunctions (Source: Abideen <i>et al.</i> , 2015)	18
1.13	FESEM images of all samples: (a,b) pure ZnO, (c,d) 0.125:1 CuO/ZnO, (e,f) 0.25:1 CuO/ZnO and (g,h) 0.5:1 CuO/ZnO, (i) sensing response of all samples for 100 ppm ethanol at different temperatures, and (j,k) sensing mechanism using band bending diagram (Source: Zhang et al. 2014)	20
1.14	(a-c) Comparison of sensing responses for sensors with and without UV irradiation at different temperatures, (d) dynamic responses of sensors under UV irradiation, (e-g) sensing mechanism of Au/rGO/ZnO sensor in (e) air (f) air with UV, and (g) in H ₂ gas with UV irradiation (Source: Drmosh <i>et al.</i> , 2019)	22
1.15	(a) Normalized dynamic resistances of ZnO NF with different doses of e-beam for 0.1, 1, and 10 ppm H ₂ at 350°C, (b) calibration curves, (c-f) sensing mechanism of e-beam irradiated H ₂ sensor (Source: Kim <i>et al.</i> , 2019)	24
2.1	Crystal structure of (a) anatase (b) rutile (Source: Jia <i>et al.</i> , 2016)	29
2.2	Different types of crystal structures of ZnO (Source: Özgür et al., 2005)	30
2.3	(a) Schematic diagram of sputtering process (Source: Yasrebi <i>et al.</i> , 2014) (b) Experimental setup of RF sputtering system at IIT Jodhpur	32
2.4	Mask Aligner setup for photolithography at IIT Jodhpur	33
2.5	Schematic diagram of fabrication steps in the drop cast method	34
2.6	(a) Basic diagram of thermal evaporation (Source: Lakhtakia <i>et al.</i> , 2013) (b) Thermal evaporation system at IIT Jodhpur	34
2.7	Schematic diagram of Bragg's Law (Source: https://wiki.anton-paar.com/en/x-ray- diffraction-xrd/)	35
2.8	Powder XRD machine at IIT Jodhpur	36
2.9	(a) Schematic diagram of scanning electron microscopy (Source: https://sites.google.com/site/frontierlab2011/scannig-electron-microscope/principie-of-sem) (b) SEM facility available at IIT Jodhpur	37
2.10	Schematic diagram of various information generated from the sample (upto depth ~ 5µm) during interaction of primary electron (Source:	37

	https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Book%3A_Physical_	
	Methods_in_Chemistry_and_Nano_Science_(Barron)/09%3A_Surface_Morphology_and_	
	Structure/9.3%3A_SEM_and_its_Applications_for_Polymer_Science)	
2.11	(a) Basic diagram of the working principle of AFM (Source: Guo et al., 2013) (b)	38
	Experimental set up of AFM facility at IIT Jodhpur	
2.12	Basic diagram of UV visible spectrophotometer	39
	(Source:https://commons.wikimedia.org/wiki/File:Schematic_of_UV_visible_	
	spectrophotometer.png)	
2.13	Block diagram of Raman spectrometer (Source: Li <i>et al.,</i> 2014)	40
2.14	Schematic illustration of photoemission process (Source:	41
	http://www.coretechint.com/technical_info-xps.php)	
2.15	Schematic diagram of basic instrumentation of FTIR spectrometer	42
	(https://chemistry.oregonstate.edu/courses/ch361-464/ch362/irinstrs.htm)	
2.16	Experimental set up for electrical measurement at IIT Jodhpur	43
2.17	Customized gas sensing chamber used in IIT Jodhpur (Inset Figure shows the sample	44
	platform inside the gas chamber	
3.1	Schematic diagram of M/TiO_2 device	46
3.2	XRD spectra of TiO ₂ nanoplates	47
3.3	FESEM images of TiO2 nanoplates (a) Top view and (b) Tilted view	47
3.4	Current-Voltage (I-V) characteristics of Au/TiO ₂ , Al/TiO ₂ , Ag/TiO ₂ , Ni/TiO ₂ in (a) air and (b)1%	48
	hydrogen at 17 ⁵ C	-
3.5	Current density versus square root of reverse voltage for Au/TiO, in hydrogen at 175°C	49
3.6	Temperature dependent barrier height modulation in air to hydrogen atmosphere	49
3.7	Relative response curve of Al/TiO ₂ , Ag/TiO ₂ , Ni/TiO ₂ , and Au/TiO ₂ at 175°C to 1% hydrogen	50
3.8	Temperature dependent hydrogen sensing curves of (a) AI/TiO_2 (b) Ag/TiO_2 (c) Ni/TiO_2 and	51
<u> </u>	(d) Au/TiO ₂	
3.9	Base resistance as a function of temperature at fixed 1 μ A current	51
3 10	Variation of (a) response time and (b) recovery time with temperature	57
3 11	Relative response of M/TiO structure with temperature	53
2 17	Schematic illustration of hydrogen sensing mechanism in (a-h) Energy hand diagram of	54
5.12	$M/TiO_{in}(c)$ (e) and (g) for air and (d) (f) and (b) for hydrogen	54
4.1	Schematic diagram of $7nO$ target	56
4.1	XBD pattern of (a) undoped (b) 2% Ni-doped (c) 4% Ni-doped and (d) 6% Ni-doped $7nO$	50
4.2	nanostructures)/
4.3	(a-h) Top view and cross sectional view of FESEM images for (a-h) undoped. (c-d) 2% Ni-	58
U	doped. (e-f) 4% Ni- doped and (g-h) 6% Ni- doped 7nO panostructures	٦
11	(a-c) EDX spectra of 2% 1% and 6% Ni -doped ZnO nanostructures respectively	50
4.4 1 E	($a \in EX$ spectra of 2%, 4%, and 0% ($a \in C$ apped 2no nanostructures at BT	59
4.5	(a) Schematic diagram of Sensor device. (b-e) LV characteristics of undoped 3% Ni-doped	59
4.0	4% Ni-doped and $6%$ Ni-doped $7nO$ papestructure in presence of air as well as $4%$ hydrogen	00
	4% NF doped, and 0% NF doped 2no hanost deture in presence of all as well as 1% hydrogen at 45.0° C	
47	a (1) C	61
4.7	with increasing operating temperature ranging from RT to 150°C for 1% hydrogen	01
	concontration	
4 9	Concentration Relative response of undered and Ni, denod $7nO$ papeetructures based concernation C	65
4.0	Long term stability surve of 4% Ni, dened 7nO papenlates for 450 days	62
4.9	tong term stability curve of 4% NF doped 2no hanoplates for 150 days	62
4.10	4% NF doped 210 based sensor relative response with increasing hydrogen concentration	03
	(a, d) Temperature dependent resistance what impacture for undependent 2% 4% and 6% Ni	(2)
4.11	(a-d) remperature dependent resistance v/s time curve for undoped, 2%, 4%, and 6% Ni-	63
	doped 2no nanostructures based sensor on exposure of 1% hydrogen with operating	
	temperature ranging from KT to 150 °C.	<i>c</i> .
4.12	(a-d) Rate of change in resistance with temperature for undoped, 2%, 4%, and 6% NI- doped	64
	And nanostructures, respectively	-
4.13	Activation energy plot for undoped and NI- doped ZnO nanostructures	64
4.14	Selectivity test of different target gases for 5 ppm concentration at 150°C operating	65
	temperature	
5.1	Schematic diagram for gas sensor fabrication which includes (a) Ni doped ZhO	71
	nanostructure deposited on p-SI substrate using KF sputtering with IDEs (b-c) Drop cast	
	method used to decorate rGO over NI doped ZnO hanostructures	

5.2	(a-b) XRD spectra of Pristine and 0.75 wt% rGO loaded Ni doped ZnO nanostructures (a-b) Raman spectra of pristine and 0.75 wt% rGO samples	71 72
5.4	(a) Digital photograph of the gas sensor with Cr /Au IDEs structure for gas sensing	72
7.4	applications and the magnified SEM images (b-d) Two Cr /Au electrodes lines of IDEs	/2
	structures. Ni doped ZnO nanostructures, and 0.75 wt% rGO loaded ZnO, respectively	
5.5	Room temperature I-V characteristics of various concentration (0.25 wt% to 0.75 wt%) of	73
	rGO loaded sensor and highest concentration of rGO (1.5 wt%) sample, respectively	
5.6	Sensor's relative response for pristine and rGO loaded ZnO for 100 ppm hydrogen gas at	74
	150°C operating temperature	
5.7	Sensor's relative response from 1ppm to 100 ppm at 150 $^\circ$ C operating temperature for (a)	75
	0.75 wt% rGO loaded sensor and (b) comparative studies for all rGO loaded sensors and	
	where, the inset figure represents the enlarged linear fitted hydrogen gas sensing response	
	from 1 to 10 ppm	
5.8	Selectivity histogram for Pristine and rGO loaded Ni doped ZnO nanostructures based	76
	sensor	
5.9	(a-b) Schematic diagram of gas sensing mechanism in presence of air and hydrogen for	78
	rGO loaded 4% NI-ZnO nanostructures and (c-e) The band diagram illustration of rGO/ZnO	
5.40	Schematic diagram of various fabrication store for final dovise	80
5.10	Optical image of IDE pattern on V.O. thin film	80 81
5.11	XBD pattern of the V.O. thin film	81
5 12	XPS spectra of rGO-decorated V O, thin films: (a) V p_{a} and O s_{a} and (b) C s_{a}	87
5 1/l	AFM images of V.O. thin film	82
5.15	Contact potential difference (V_{cm}) of (a) rGO and (b) $V_{s}O_{c}$ thin film as a function of number	83
J., J	of points taken during the work function estimation	ر پ
5.16	Room-temperature I–V characteristics of (a) V_2O_3 thin film and rGO-decorated V_2O_3 thin film	83
-	and (b) rGO thin film/IDE/glass substrate	-
5.17	Relative response of V_2O_5 thin film towards NO ₂ gas from 1 to 100 ppm at different	84
	temperatures (room temperature to 150 $^{\circ}$ C)	
5.18	Comparison of relative response for V_2O_5 thin film towards 100 ppm of NO $_2$ gas at different	85
	temperatures	
5.19	Relative response for NO $_2$ gas at 150 °C: (a) rGO-decorated V $_2O_5$ thin film and (b) rGO thin	85
	film/IDE/glass substrate	
5.20	Response and recovery time calculation for rGO decorated V_2O_5 thin film for 100 ppm NO ₂	86
/	gas at 150 °C.	0.0
5.21	Comparison of relative response for V_2O_5 thin film, rGO film, and rGO-decorated V_2O_5 thin film for too norm NO, goe at too $%$	86
5 22	$\frac{1}{100} \text{ for 100 ppm NO}_2 \text{ gas at 150 C}$	00
5.22	100°	00
5 72	Schematic diagram of the sensing mechanism in the presence of air and NO. for rCO-	80
5.25	decorated V ₂ Ω_2 thin film showing (a)–(c) band diagram illustrations of the p–n	09
	heteroiunction before and after contact	
6.1	Schematic diagram of CNF/ZnO nanostructures based device	92
6.2	Optical image of (a) pure CNF and (b-f) different concentration of CNF (0.1-0.5 wt%)/ZnO	93
	nanostructures	
6.3	XRD pattern of (a) CNF (b) ZnO nanostructures (c) different concentrations of CNF (0.1–0.5	93
	wt%) loaded on ZnO nanostructures	
6.4	Raman Spectra of CNF	94
6.5	FESEM images of (a) CNF (b) ZnO (c) CNF decorated on ZnO (d) 0.1 wt% CNF/ZnO (e) 0.2	95
	wt% CNF/ZnO (f) 0.3 wt% CNF/ZnO (g) 0.4 wt% CNF/ZnO (h) 0.5 wt% CNF/ZnO	
6.6	FTIR spectra of (a) CNF (b) pristine ZnO and CNF loaded on ZnO nanostructures	96
6.7	Room temperature I–V characteristics of (a) CNF/SiO ₂ versus SiO ₂ (b) ZnO versus (0.1-0.5	97
	wt%) CNF/ZnO	
6.8	Comparison of relative response; (a) Dynamic sensing response (b) Maximum relative	98
6.0	response for all sensors for 100 ppm hydrogen gas at 150 °C	- 0
б. <u>9</u> б.10	Response unite and recovery time for 0.2 wt% CNF loaded ZnO nanostructures Relative response curve for 0.2 wt% CNE/ZnO papestructures from 4 to 400 ppm bydrogon	98
0.10	as at 150 °C	99
6.11	Repeatability curve of 0.2 wt% CNF/ZnO nanostructures based sensor for 100 ppm	ga
		,,

hydrogen gas at 150 °C Band diagram demonstration of CNF/ZnO nanostructures (a) before contact and (b–c) after contact (presence of air and hydrogen) and (d–e) schematic diagram for hydrogen sensing 6.12 mechanism

101