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Fabrication of nickel oxide nanostructure prepared by the simple wet chemical method for sensor application

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Abstract: A novel approach was employed to synthesis of porous 3D honey comb structure of nickel oxide. The nanoporous network of nickel oxide (NiO) has been synthesized by a facile chemical bath deposition method (CBD) at various deposition times. The X-ray diffraction (XRD) pattern of annealed NiO films revealed low intense peeks, confirming monocrystalline nature with cubic structure. The scanning electron microscope (SEM) images exhibited well-defined and nannoporous interconnected network. Optical absorption study revealed direct band gap energy of 3.2 eV and indirect band gap 3.5eV. Porous honeycomb structure can be used as sensing element due to oxygen trap pocket.

Key word: Honey comb structure, nickel oxide, CBD.

1. Introduction:

Nanotechnology is a rapidly growing methodology with huge potential to develop new materials with exceptional properties and to create new and improved products for various applicative fields. Numerous nano-based products are commercially available such as electronic materials, automotive parts, sporting goods and personal care. In the near future, nanotechnology enable-materials are expected to represent a bulk market in chemical, pharmaceutical and healthcare industries which will be major nanotechnology sectors. However, there are many concerns about the impact of nanomaterials on both the human health and environment [1]. Although the term "nanotechnology'' was first coined by the Japanese scientist Norio Taniguchi in 1974 to describe precision processes in semiconductor engineering [2], but the idea of creating, manipulating, and controlling materials on small scale was introduced by Richard Feynman in his famous talk "There's Plenty of Room at the Bottom'' in 1959 [3]. Therefore, the research and development in nanotechnology fields are greatly influenced by the fabrication of new nanomaterials with improved properties. In the current interdisciplinary age of nanotechnology, metal oxide semiconductor nanomaterials have gained substantial interest due to their promising applications in electronics, optoelectronics, bio-chemical sensors, coating systems, and chemical catalysis. From the last decade many research groups motivated the development of controlled synthesis and functionality of oxides nanomaterials for their diverse applications and recognized that the properties of metal oxide nanomaterials are significantly different from their counterpart bulk materials due to the relatively large surface area. Nickel has two known stable oxides, nickel (III) oxide (Ni_2O_3) and nickel (II) oxide (NiO). The physical properties of these two nickel oxides are different since they have different crystal structures, optical and electronic properties. In the recent years, inexpensive synthesis of nickel oxide nanomaterials has grown substantially due to

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its direct band-gap and intrinsic p-type behavior with good electrochemical properties. These interesting properties made NiO among the best materials for electrical, optical, catalytic, and sensing applications [4-8]. Moreover, high ionic behavior of Ni-O bonds in NiO, found considerable attention for applications in catalysis, gas sensors, and solar cells. Among other compound semiconductors, nickel oxide is of great interest in semiconductor physics. NiO has monoclinic structure belong to space group C2/c, which displays a wealth of interesting properties, abundant in nature, nonhazardous materials, and can be prepared by inexpensive methods which are the key issues for sensing applications. It has narrow band gap around 3.2-3.6 eV for p-type semiconductor in bulk [9-12]. As mentioned before, nanostructures exhibit many features that are not present in bulk material because they have high surface area to volume ratio. CuO nanostructures have a wide range of applications [13-14]. NiO is transition metal oxides that have several prospective applications, such as smart material [15] solar heat digester [16] electrode for dry cell applications [17] and volatile or nonvolatile gas sensing [18]. Adjusting the morphology in nano structure materials is a typically employed approach to optimize their performance due to their size and structure dependent properties [19].

2. Materials and Methods:

2.1 Preparation of NiO nano structure.

All the reagent procure from SRL chemical Pvt and were used without any further purification. Solution for chemical bath deposition was prepared by mixing of 40 ml of 1M Nickel sulphate, 30 ml of 0.25 M potassium persulphate and 20 ml of deionized water in 500 ml of borosile glass biker and biker was carried out by a magnetic stir bar at 300 rpm for 10 min. The chemically clean glass substrate were immersed vertically in the solution at room temperature and taken off after time interval of 20, 30, 40 min and subsequently absorb as NiO_{10}, NiO_{20}, NiO_{30} , respectively. The nickel oxide (NiO) deposited glass slide rinsed with DI water to remove unbound NiO particles and all the glass slide annelid at $300^{O}C$ for 90 min in open furnish.

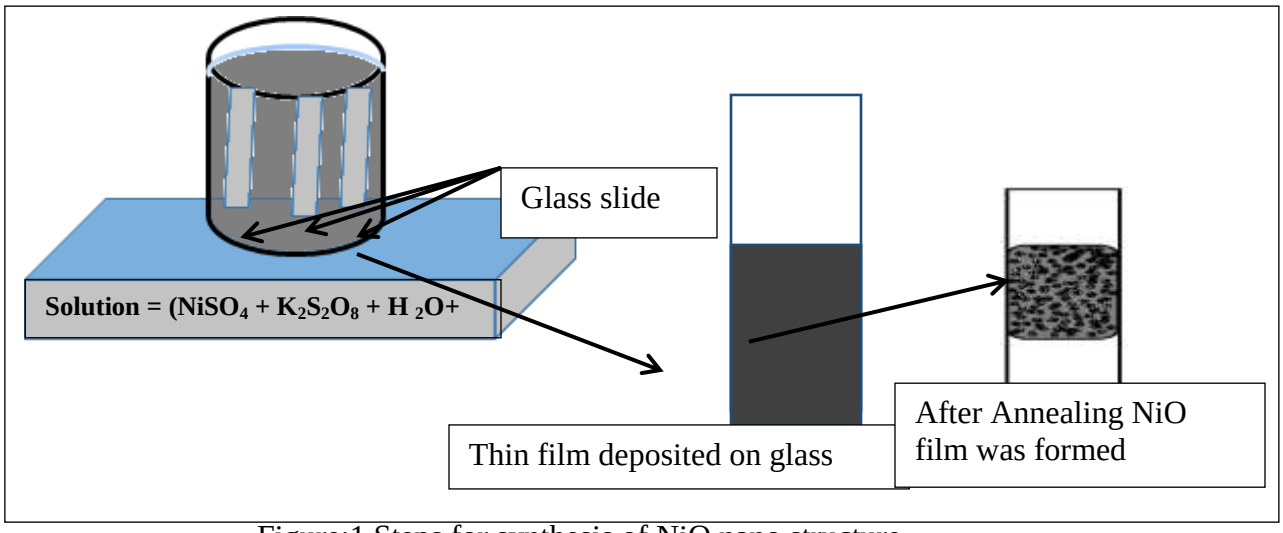

Figure:1 Steps for synthesis of NiO nano structure.

2.2 Growth mechanism-

Figure 1a shows that a typical 3D structure grown on top of the glass slide. The 3D structure can be grown by three different phages. During the initial induction phage of the process, no nucleation is observed. This period lasting only few second, after that heterogynous nucleation occurred and it's appear as a thin film. Film thickness also increases proportionally with deposition time due to formation of honey comb 3D structure. After a few minutes, a depletion growth regime is entered in which film growth rate drop quickly to near zero and final film thickness is attained. We found the growth rate and final film thickness were strongly depend on the mixing condition. The result could be interpreted by competition of between heterogeneous film growth on the substrate and homogeneous growth, and aggregation leading to particle formation. The resulting terminal thickness would then be determined by the relative rate of the reactions. Since linear growth rate were relatively independent of stirred rpm, film growth due to the formation of nanoparticles in the solution through the orthogenetic mechanism[8].We observed no film were formation when used ammonium per-sulfate in replaced of aqueous ammonia because aqueous ammonia used as a reducing agent. Potassium per sulfate also play major role to formation of crystalline particles. Initially, It was proved that by Bhowmik and Bhattacharya[12] that NiO phase formation proceeded via two steps

$NiSO_4 + xK_2S_2O_8 + 2(1+x)\ OH^-$

$NiO_{1+}x + xK_2SO_4 + (1+x)\ SO_4^{2-} + (1+x)\ H^2O$ ------- [1]

$NiO_{1+}x + 2x/3\ NH_3 \longrightarrow NiO + x/3N_2 + H_2O$ ---------- [2]

The first steps reaction involved the deposition of higher valency of nickel oxide (mixed valency 2 or 3). The higher valiancy Ni is then reduced by ammonia to normal oxidation state according to reaction 2.

3. Results and discussion

3.1 XRD pattern of NiO nano particles

When potassium persulfate ($K_2S_2O_8$) and arouse ammonia added into the solution of nickel sulfate, NiO particles were formed in the chemical bath and the color either black or green in appearance and after few second its deposited as a film on glass slide. We also observed only nano particle formation in absent of potassium per-sulfate. The XRD pattern (Figure:2) of NiO nanoparticle exhibited diffraction peaks due to pure face center cubic structure(JCPDS no 47-1049). The pattern of particles without adding K2S2O8 and addition of perselfate and anneal at 300^OC were shown fig. 1. respectively three peaks at 2Ø value of 37.249, 43.276 and 62.879 match the (111), (200) and (220) peaks of cubic NiO phase (JCPDS No: 47-1049) The particle formed without potassium per-sulfate, however, showed worse crystallinity then the particle formed with potassium peroxide.

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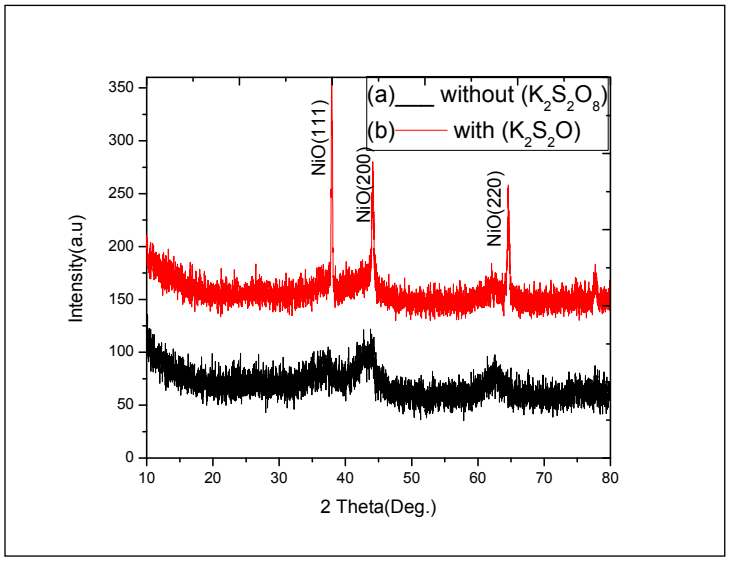

Figure 2. X-ray difraction (XRD) pattern of (a) filter particles of without adition of $K_2S_2O_8$ (b) filter particles of with the addition persulphate.

3.2 XRD pattern of NiO 3D structure in glass slide.

The XRD patren of 3D nano strcuture are shown in figure 3. The spectra consist of five peaks at 37.249, 43.276, 62.879 and 79.416. corrosponding to (111), (200), (220) and (222) planes. Confirming face cener cubic phase of NiO (JCPDS No: 47-1049). In low chemical bath deposition time, the peak intensity is lower due to porouse and less crystaline structure.

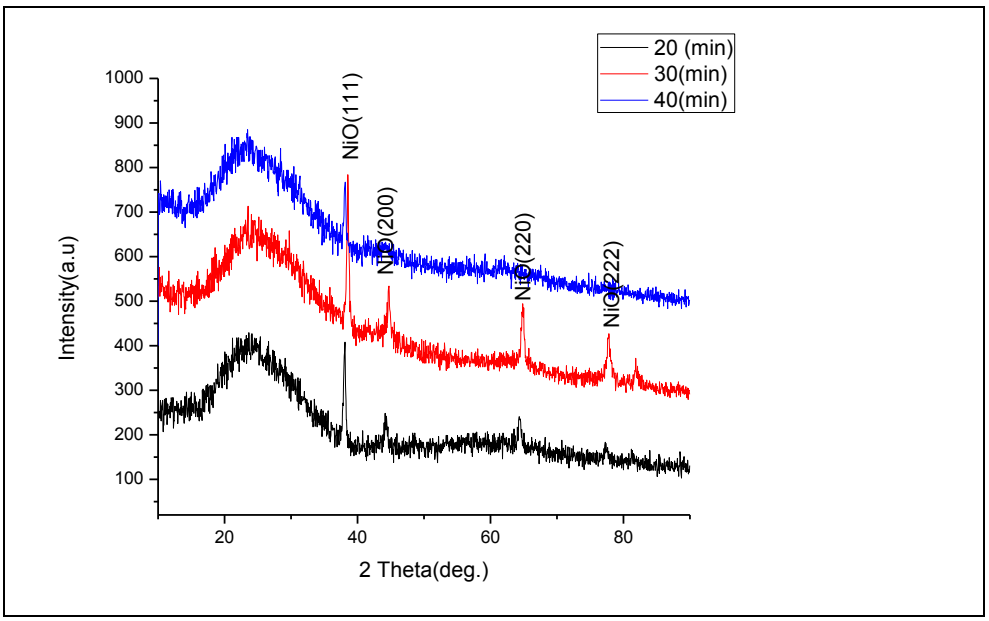

Figure 3. XRD pattren of (a) annealing time 20 min (b) anneling time 30 min (c) anneling time 40 min.

4. Transmission Electron Microscopy:

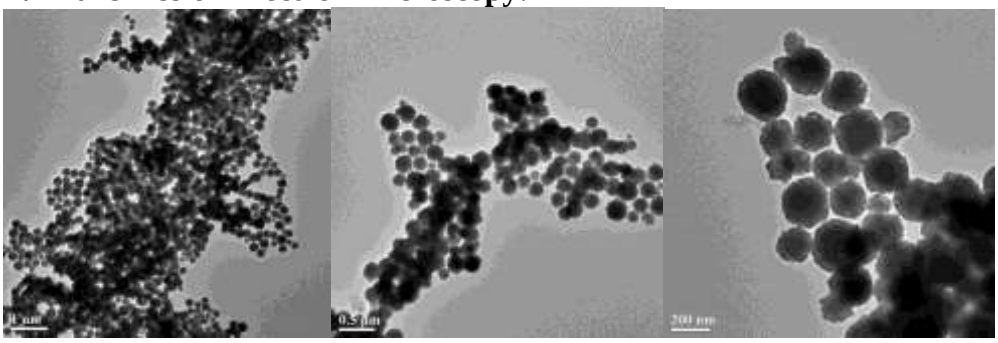

Figure: 4 TEM Micrograph nickels nanoparticles at different resolutions

The TEM micrographs (JEOL, JEM 2010) of the nickel nanoparticles was performed and the size distribution around 100-150, ± 5 nm were seen in the images figure 4. Nickel nanoparticles are suspended in slightly acidic solvent pH 6.30. The exact shape and morphology can be clearly obtained from these photographs. The spread nickel nanoparticles are almost round shape.

5. Scanning electron microscopy

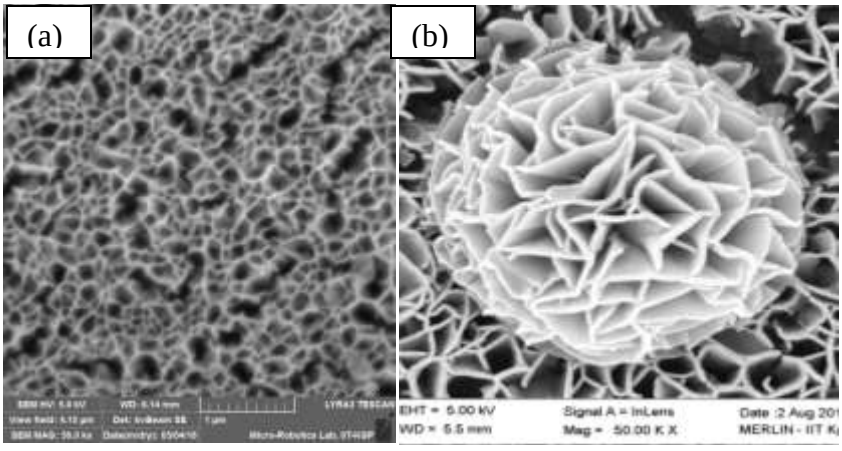

Figure: 5 FESEM micrograph of NiO

Figure:5 shows that the nickel oxide surface morphology is different under different deposition time on Si wafer. Figure (a) deposition time 10 minute and because of less growth time honeycomb structure formed. Figure (b) deposition time 40 minute and it was formed nano

flower that can be used as sensing materials.

6. Conclusion:

The growth of nickel oxide nanostructures were successfully achieved using two different sources glass slide and silicon wafer. The increase of temperature the orientation of NiO crystalline layer is little increased, due to increased thickness of the oxide layer. Upon heating the Ni film at 700^{o}C much larger and well developed Ni2O3 crystal were obtained from XRD analysis. The excess of oxygen may due to the formation of Ni^{3+} at 700^{o}C which needs extra oxygen for charge compensation.

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