

Design and Development of Graphene - Zinc Oxide Composites and their Radiation Sensing Characterization

Rajesh Kumar¹, A. Singh², Sunita Mishra²

Ph.D. Research Scholar, Lovely Professional University, Phagwara, Jalandhar, Punjab, India¹

Project Engineer, Indian Institute of Science Education & Research, Mohali, Punjab, India²

Principal Scientist, Central Scientific Instrumentation Organization, Sector-30, Chandigarh, India³

ABSTRACT: In this paper, the quantum properties of Zinc Oxide and Graphene composites are discussed and analyzed. It is further explored that the Graphene and Zinc oxide based sensors can be very effective in the very sensitive environment like radiations. The synthesis of graphene sheets via chemical routes poses the potential challenges. Therefore, effective efforts are required for achieving an understanding of the intercalation, oxidation, exfoliation, reduction, functionalization and dispersion processes. For developing new suitable compositions, all the starting materials and reaction routes are needed to be thoroughly reviewed. These composite based devices, sensors, memory elements and switches can be very useful in the technological advancements. Due to its unique properties, the necessary and relevant properties of Zinc Oxide and Graphene composites are also analyzed in this work..

KEYWORDS: Graphene, Nano sensor, Zinc Oxide, Synthesis, Properties, Composite Materials, chemical sensors, Radiations.

I. INTRODUCTION

The history of development and technology of macroscopic synthesis of fullerenes, and their physico-chemical properties are already being explored by many, and it is well proven that the plenty of room is there at bottom means at nanoscale [1, 4]. Every atom of graphene may be considered as a surface atom, capable of interacting even with a single molecule of the target gas or vapor species, which eventually results in the ultrasensitive sensor response. The electrical conductivity of graphene changes definitely upon introduction to and ensuing adsorption of the objective compound species attributable to change in free electron focus (fixation builds/diminishes if the objective species go about as giver/acceptor) [23– 27, 30– 34]. As of now checked on by Kim, the dimension of cooperation between target gas/vapor particle may achieve the lower furthest reaches of even a solitary atom [3]. In this way, the littlest quantum of resultant change in conduction can be estimated in graphene [23, 24]. The purpose for the ultra affectability of graphene based sensor was pleasantly clarified by Prof. Andre Geim, University of Manchester and Noble prize victor in Physics (2010), who stated, "Graphene has a definitive affectability on the grounds that on a basic level it can't be beaten - you can't get more delicate than a solitary atom" [1]. Along these lines, on a basic level the dynamic scope of recognition (gas/vapor fixation level) may cover from a solitary particle to a high focus level, which is unthinkable with the ordinarily utilized 3D gas detecting materials. In any case, the issue with inborn graphene is that it has no dangling bonds on its surface (required for gas/vapor adsorption) and subsequently to upgrade the chemisorptions on graphene surface it should be functionalized with polymers, metals or different modifiers [29-31]. The surprising physico-chemical properties of fullerenes and Zinc Oxide and Graphene composites (ZnO -Graphene composites) offer new prospects for the development of nanotechnologies. The range of nano-cluster applications is very wide.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 12, December 2018

II. RELATED WORK

The thin covering of functionalizing materials carries on as catching habitats for target species and the adsorption presents a nearby change in electrical obstruction of graphene sensors. In spite of the fact that comparative methodology has been now settled in concoction sensor look into, the remarkable favorable position in the event of graphene is its to a great degree high electrical conductivity (notwithstanding when couple of bearers are available) alongside low commotion which rolls out this improvement in opposition noticeable even to sub ppm level [30]. Moreover, “graphene also allows for the fabrication of four-probe devices on mono-crystals which ensures that any influence of the contact resistance in limiting sensitivity is eliminated [33].

Table-1

Some of the mechanical and electrical/electronic properties of graphene useful for gas and vapor sensors [1-26]

Property	Value
Density	0.77 mg/m ²
Young's Modulus	0.05 TPa
Carrier Density	10 ¹² /cm ²
Resistivity	10 ⁻⁶ Ω cm
Electron Mobility at 300k	20,000 cm ² V ⁻¹ s
Thermal conductivity (at 27 °C)	5000 W/mK

a. Preparation of functionalized ZnO particles

The composite are created utilizing numerous means in succession. At first, the Zinc acetic acid derivation (0.125 M) and 0.25 M sodium hydroxide arrangement were broken down in progression into methanol warmed to 65°C under persistent mixing. At that point, 10 mL of the sodium hydroxide - methanol arrangement was gathered in a 20 mL syringe and infused into a response container containing 10 mL zinc acetic acid derivation. The flow rate was 330 μL/min (kept up by the syringe siphon). The arrangement was blended at 800 rpm and kept up at a temperature of 65°C as appeared in the stage 1 beneath. This above advances are delineated in the accompanying figures in detail.

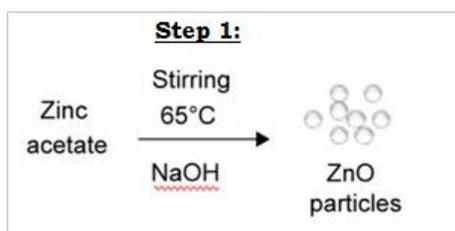
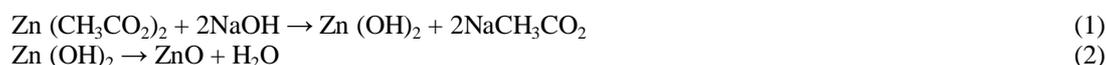


Fig. 1. The chemical process of ZnO particle manufacturing.

The figure 1 above shows the chemical manufacturing process of the Zinc-oxide particle formation. The Zinc acetate is stirred at 65 °C with the presence of NaOH. The process generates the tinny particles of Zinc-oxide, which in the solidification state behaves like a powdered material. The chemical process is as follows:



International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 12, December 2018

An extra 10 mL sodium hydroxide arrangement was added to the blend drop-wise, and mixing proceeded for 30 minutes. The subsequent white accelerate was isolated by means of centrifugation and washed multiple times with anhydrous ethanol in a ultrasonication shower. The arrangement containing ZnO particles was dried in a sight-seeing oven at 60°C for 24 hours.

b. Synthesis of graphene oxide sheets

Graphene oxide was synthesized according to the modified Hummer method with graphite powder as a precursor. The graphite powder (2 g) was dissolved in 30 mL sulfuric acid (98%, mass percent) under strong stirring for 1 hour. Potassium permanganate (6 g) was added gradually with stirring and the solution was kept at 35°C in an ice bath for 1 hour. The mixture was carefully diluted with 100 mL distilled water under vigorous stirring. Subsequently, 100 mol water and 10 mL 30% hydrogen peroxide solution were added under continuous stirring for 2 hours. The second stage is depicted in the following figure in detail.

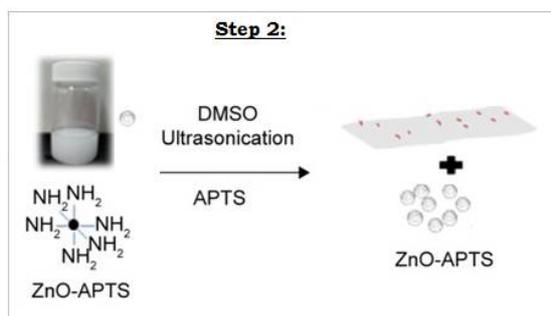


Fig. 2. The chemical process of ZnO-APTS particle formation.

The figure 2 above shows the chemical particle formation process of the Zinc-Oxide-APTS. The Zinc-Oxide-APTS composition is ultrasonicated with DMSO, which generates the powdered ZnO-APTS material formation. The chemical process is very fast and generates no residue.

The dull darker arrangement was then separated and washed with 5% hydrochloric corrosive answer for expel metal particles. At long last, the suspension was washed by centrifuging with refined water until the pH of the arrangement was unbiased. After this the water (100 mL) was added to the filtered graphene oxide hasten, and the blend was firmly sonicated in a test type sonicator for a hour and a half to acquire a uniform graphene oxide arrangement. The graphene oxide liquid was dried in a hot-air oven at 60°C for 24 hours.

c. Fabrication of ZnO/graphene oxide composites

The prepared ZnO (0.50 g) was broken up in 10 mL DMSO and ultra-sonicated for 60 minutes. APTS (10 mL) was added to the arrangement and sonicated for 2 hours to finish the response. The amino-functionalized ZnO was isolated from the arrangement by means of centrifugation, washed with total ethanol, and dried in a stove. The ZnO-APTS particles (0.10 g) and graphene oxide powder were disintegrated in dimethyl-formamide. The arrangement was blended and sonicated for 2 hours to acquire uniform scattering. At long last, ZnO/graphene oxide composites were recuperated through centrifugation and washed multiple times with liquor, and dried in a broiler for sometime later. Figure 1 demonstrates the creation steps quickly. The last structure is acquired according to the outline beneath.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 12, December 2018

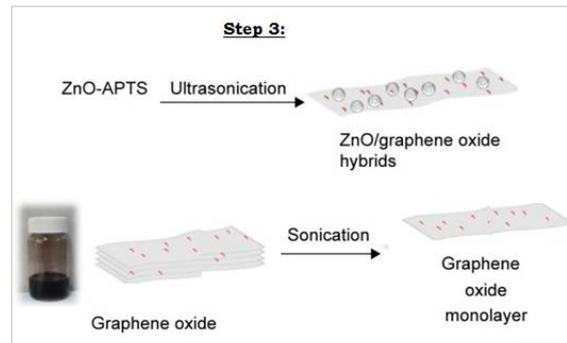


Fig. 3. The chemical process of Graphene oxide monolayer formation.

The figure 3. above shows the chemical process of Graphene oxide monolayer formation. The ZnO-APTS after the ultrasonication generates ZnO hybrid sheets which after the sonication generates the monolayers as shown above. The Zinc-Oxide-APTS composition is ultrasonicated with DMSO, by graphene oxide is sonicated which generates the oxide monolayer formation. The chemical process is highly sensitive and requires high level of quality assurance of the compositions. In the earlier years, work was centered on enhancing the film producing advances. Examination of the writing demonstrates that the emanation attributes of our cathodes are high. The base limit electric field for the film tests which we consider to be great is from 0.5 to 1 V/ μm , the working field is from 5 to 10 μV , and the flow thickness achieves 0.5 A/cm². For fixations over 60 mM, development of nanotubes is hindered, and the printed format is secured by undefined carbon particles. To begin with, permeable silicon was shaped on the surface of a silicon substrate by anode drawing and afterward the ferrum film was kept on the last through the shadow cover by electron pillar vanishing [13]. At that point nanotubes were developed because of acetylene deterioration in argon stream at 700 °C.

III. OBSERVATIONS

It is observed that different methods, different technologies yield totally altered films of both well oriented and strongly entangled tubes. The FET based design is proposed and manufactured in this present work. We know that ISFET is generally used to measure ion concentrations in solutions. When the ion concentration, such as pH, changes, the current through the transistor will change accordingly. Here, the solution is used as the gate electrode instead of the traditional metal gate. The voltage between substrate and oxide surfaces arises due to an ions sheath. Actually, an ISFET's source and drain are constructed similarly as a Metal-oxide Semiconductor Field-Effect Transistor (MOSFET) [8]. Although an ISFET is very similar to a MOSFET, there are still some differences. As shown in Fig.1, the metal gate is replaced by the metal of a reference electrode, whilst the target liquid in which this electrode is present, which makes contact with the bare gate insulator. Both of them have the same equivalent circuit, so the devices with this structure can be applied to pH measurement [7]. However, the final objective of our work on Nano pH sensor is to enhance the inversion layer with Graphenes as nano wire to conduct electrons between the drain and source, the drain current might be much greater under the same gate voltage. Furthermore, the semiconducting Graphenes are able to be fabricated as transistors. If all of these conditions are verified, these gadgets could be created and made. This may prompt shoddy winning to graphene's one of a kind mechanical and electrical properties, for example, high flow conveying abilities. One of such FET structure is proposed as under:

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 12, December 2018

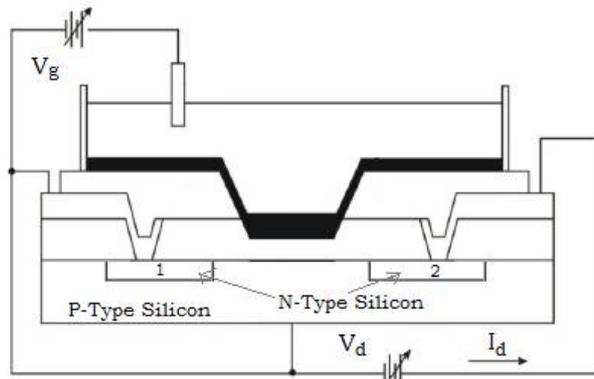


Fig. 4. Schematic diagram of proposed dielectric FET with various silicon substrates.

As proposed above, the same FET was fabricated by keeping the graphene in observation and focus. This is depicted in figure 4 below. The diagram of figure 4 above shows the three doped regions, out of which two regions are n-type silicon and another is the p-type silicon material. The potential is applied between the source and substrate and source and drain.

IV. RESULTS AND ANALYSIS

As it is well known that a single-wall nanotube is located on a substrate such that it connects two electrodes, then one electrode is a source, another electrode is a drain and the substrate is a gate. Such a device is appeared in an embed in Fig. 2. Two standards of conduct are recognized when the reliance of the cylinder conductivity G on the door voltage is estimated. In one case, the entryway voltage V_g pitifully impacts the conductivity G , which relates to a metallic cylinder. For another situation, solid reliance of G on V_g is watched, which relates to semiconducting cylinders. The Field-impact transistor dependent on a semiconducting single-divider nanotube Semiconductor properties of Zinc Oxide and Graphene composites were considered for the first time by Tans et al. in 1998 [20]. After that the little research is done in the field of gadget structuring and manufacture utilizing these syntheses because of the vast property varieties at nano-scale.

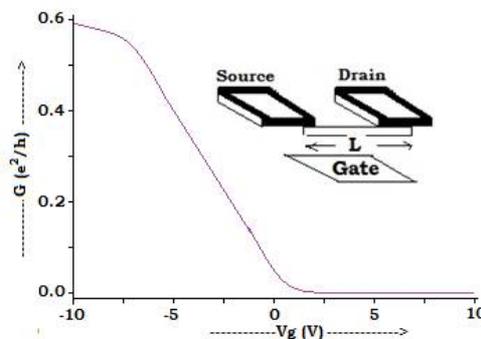


Fig. 2. Zinc Oxide and Graphene composites conductivity G as a function of the gate voltage V_g for a p-type FET.

The figure 2 above shows that the Zinc Oxide and Graphene composites conductivity G acts as a function of the gate voltage V_g for a p-type FET. Likewise, hypothetically the conductivity of an ideal single-divider nanotube with ballistic transport of electrons is $4e^2/h = 0.155$ mS, which relates to an obstruction of 6.5 k ω . The figure 3 shows the

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 12, December 2018

architecture of Zinc oxide and Graphene based transistor array: Array element located at the cross point of the upper and lower electrodes.

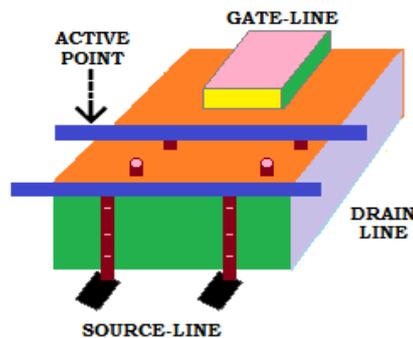


Fig. 5. Architecture of Zinc oxide and Graphene based transistor array: Array element located at the cross point of the upper and lower electrodes.

The term of contact amid the printing was 3s. Nanotube affidavit was finished by the CVD technique in a standard stream reactor at a temperature of 720°C. For the acquired examples, the flow thickness was 10 mA/cm² for the electric field from 4 to 4.5 V/μm. As an unfathomably growing field, the utilization of carbon strips, cylinders or chains in nano-gadgets shows a progression of favorable circumstances as for the flow semiconductor innovation: inborn low-dimensionality, mechanical strength and flexibility, uncommon electrical, optical and warm properties to give some examples. Figure 5 underneath demonstrates that variety in the conductivity of a semiconducting single-divider nanotube with the door voltage provided to the leading substrate. The cylinder conducts for negative V_g and is cut off for positive V_g. Semiconducting single-divider nanotubes are for the most part of the p type in view of the nearness of contacts and concoction added substances, specifically, adsorbed oxygen acting as a weak admixture of the p type.

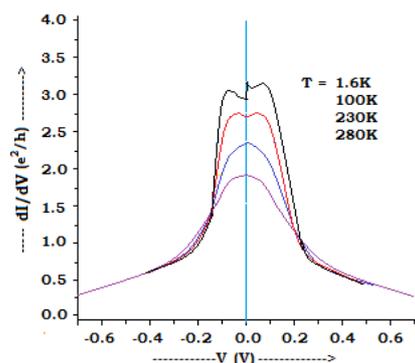


Fig. 6. Differential conductivity dI/dV of a Zinc Oxide and Graphene composites as a function of V_{sd} for different temperatures.

The Figure 6 shows the differential conductivity of the Zinc oxide and Graphene composites. The diagram also demonstrates that the differential conductivity dI/dV of metallic single-divider nanotube with a length of the request 1 μm as a component of voltage V_{ds} provided to the cylinder closes at various temperatures. The conductivity moving toward the hypothetically anticipated esteem $G = 4e^2/h$ was additionally tentatively gotten in above adjusted blends. It very well may be demonstrated that the electron mean free way in a nanotube surpasses 1 μm at room temperature, is as yet more noteworthy if the cylinder is cooled. This esteem adds up to several nanometers for ordinary metals at room temperature. The symmetric conduct of the current-voltage outline for zero inclination at the door is seen at nearly up

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 12, December 2018

to 30 K. The acquired transistors can be coordinated into a huge cluster with a thickness of around 2 nm. On the mechanical ground, 1011 components for each square centimeter and are portrayed by a low expended power. It is simple seen that the each cylinder is in contact with metal terminal. Computations demonstrate that the ideal opportunity for perception amid activity ought to be in any event 10–15 s. This will give most extreme recompense to the nanotube latency (nanotubes still have mass) and electrical capacitance of the lines created in the substrate. Finally it should be noted that a further effort in order to design and implement scaling and optimization techniques in transport carriers requires stability analysis. These are necessary for a more efficient application of theoretical models over experimental data.

V. CONCLUSION

In this field, expectations are very high. In this paper, we have proposed a novel idea for developing graphene and Zinc oxide based radiation sensor based on fabricated ISFET. The figure shows that the differential conductivity dI/dV of metallic single-divider nanotube with a length of the request $1\ \mu\text{m}$ as an element of voltage V_{ds} provided to the cylinder closes at various temperatures. The conductivity moving toward the hypothetically anticipated esteem $G = 4e^2/h$ was likewise tentatively gotten in above altered blends. It tends to be demonstrated that the electron mean free way in a nanotube surpasses $1\ \mu\text{m}$ at room temperature, is as yet more prominent if the cylinder is cooled. This esteem adds up to several nanometers for regular metals at room temperature. The symmetric conduct of the current-voltage chart for zero inclination at the door is seen at nearly up to 30 K. The obtained transistors can be coordinated into a huge cluster with a thickness of around 2. On the innovative ground, 1011 components for each square centimeter and are described by a low expended power. It is simple seen that the each cylinder is in contact with metal cathode. Counts demonstrate that the ideal opportunity for perception amid task ought to be at any rate 10–15 s. This will give most extreme recompense to the nanotube idleness (nanotubes still have mass) and electrical capacitance of the lines created in the substrate. The Zinc Oxide and Graphene composites are the state-of-the-art materials for the future innovations, sensor and device fabrications. In this field, expectations are very high. The development of Zinc Oxide and Graphene composite-based sensors has tremendous scope in the future to come and is going to be a potential field to be explored further.

REFERENCES

- [1] Novoselov, K.S., Geim, A.K., Morozov, S.V., Jiang, D., Katsnelson, M.I., Grigorieva, I.V., “Two-dimensional gas of mass less Dirac fermions in grapheme”, Nature, 438:197–200, 2005.
- [2] Zhang, Y., Tan, Y.W., Stormer, H.L., Kim, P., “Experimental observation of the quantum Hall effect and Berry’s phase in grapheme”, Nature, 438:201–4, 2005.
- [3] Kim, K.S., Zhao, Y., Jang, H., Lee, S.Y., Kim, J.M., Kim, K.S., “Large-scale pattern growth of graphene films for stretchable transparent electrodes”, Nature, 457:706–10, 2009.
- [4] Balandin, A.A., Ghosh, S., Bao W, Calizo I, Teweldebrhan, D., Miao, F., “Superior thermal conductivity of single-layer grapheme”, Nano Lett., 8:902–7, 2008.
- [5] Rahman, S.F.A., Kasai, S., Hashim, A.M., “Room temperature nonlinear operation of a grapheme-based three-branch nanojunction device chemical doping”, Appl Phys Lett., 100:1931–61, 2012.
- [6] Oberlin, A., Endo, M., Koyama, T., “ Filamentous growth of carbon through benzene decomposition”, J. Cryst. Growth 32, 335–349, 1976.
- [7] Meyer, J.C., Kisielowski, C., Erni, R., Rossell, M.D., Crommie, M.F., “Behaviour of Nano devices, a brief overview”, Nano Lett., 8, 3582, 2008.
- [8] Lin, Y., Jenkins, K.A., Valdes-Garcia, A., Small, J.P., Farmer, D.B., Avouris, P., “Photoluminescence and field-emission behavior of nano arrays”, Nano Lett., 9, 422, 2009.
- [9] Endo, M., Kim, Y.A., Fukai, T., Hayashi, T., Oshida, K., Terrones, M., Yanagisawa, T., Higaki, S., Dresselhaus, M.S., “Structural characterization of cup stacked type nanofibers with an entire hollow core”, Appl. Phys. Lett., 80, 1267–1269, 2002.
- [10] Mengxing, O., “Constant- Power Operation of Functionalized Carbon Nanotube Sensors for Alcohol Vapor Detection”, 3rd IEEE International conference on Nano/Micro Engineered and Molecular Systems, 2008.
- [11] Ahmad, M., Sun, H., Zhu, J., “Enhanced photoluminescence and field-emission behavior of vertically well aligned arrays of In-doped ZnO nanowires”, ACS App. Matter Interfaces”, 3:1299-305, 2011.
- [12] Iijima, S., “Helical microtubules of graphitic carbon”, Nature, 354, 56–58, 1991.
- [13] Tibbetts, G.G., “Vapor-grown carbon fibers: Status and prospects”, Carbon, 27, 745–747, 1989.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 12, December 2018

- [14] Liu, Q.F., Ren, W.C., Cheng, Z.G., "Semiconducting properties of cup-stacked carbon nanotubes", Carbon, 47, 731–736, 2009.
- [15] Magna, A. La., Deretzis, I., Forte, G., Pucci, R., "Electronic transport in mesoscopic systems", Phys. Rev. B, 78, 153-205, 2008.
- [16] Endo, M., Kim, C., Nishimura, K., Fujino, T., Miyashita, K., "Recent development of carbon materials for Li ion batteries", Carbon, 38, 183–197, 2000.
- [17] Xie, J.L., Guo, C.X., Li, C.M., "Construction of one-dimensional nanostructures on graphene for efficient energy conversion and storage", Energy Environ Sci., 7:2559–79, 2004.
- [18] Shao, Y., Wang, J., Wu, H., Liu, J., Aksay, I.A., Lin, Y., "Graphene based electrochemical sensors and biosensors: a review", Electroanalysis, 22:1027–36, 2010.
- [19] Rusli, N.I., Tanikawa, M., Mahmood, M.R., Yasui, K., Hashim, A.M., "Growth of high-density zinc oxide nanorods on porous silicon by thermal evaporation", Materials, 5:2817–32, 2012.
- [20] Ahn, M.W., Park, K.S., Heo, J.H., Park, J.G., Kim, D.W., Choi, K.J., "Gas sensing properties of defect-controlled ZnO-nanowire gas sensor", Appl. Phys. Lett., 93:2631–43, 2008.
- [21] Yi, J., Lee, J.M., Park, W.I., "Vertically aligned ZnO nanorods and graphene hybrid architectures for high-sensitive flexible gas sensors", Sens. Actuat. B-Chem., 155:264–9, 2011.
- [22] Castro, A.H., Guinea, F., Peres, N.M.R., Novoselov, K.S., Geim, A.K., "Physico-chemical properties of fullerenes", Rev. Mod. Phys., 81, 109, 2009.
- [23] Dubois, S., Zanolli, Z., Declerck, X., Charlier, J., "Zinc Oxide and Graphene composites new prospects for the development, Eur. Phys. J. B., 72, 1, 2009.
- [24] Mahmood, K., Park, S.S., Sung, H.J., "Enhanced photoluminescence, Raman spectra and field-emission behavior of indium-doped ZnO nanostructures", J. Mater. Chemicals, 1:3138–49, 2013.
- [25] Huang, M.H., Wu, Y., Feick, H., Tran, N., Weber, E., Yang, P., "Catalytic growth of zinc oxide nanowires by vapor transport", Adv. Materials, 3:113–6, 2011.
- [26] Frackowiak, F., Beguin, F., "Electrochemical storage of energy in carbon nanotubes and nanostructured carbons", Carbon, 40, 1775–1787, 2002.
- [27] Weidong, D., Ryota, H., Kohei, O., "Analysis of PD-generated SF₆ Decomposition Gases Adsorbed on Carbon Nanotubes", IEEE Transactions on Dielectrics and Electrical Insulation, 13:637-40, 2006.
- [28] I. Kiminobu, D. Weidong, O. Kohei, S. Junya, H. Ryota, H. Masanori, Low-Temperature Fabrication Method of Carbon Nanotubes-Based Gas Sensor. IEEE Transactions on Dielectrics and Electrical Insulation, 14:137-40, 2007.
- [29] Chatchawal, W., "Nano - structured Gas Sensors by Electron Beam Evaporation", 8th International Conference in Electrical Engineering, Electronics, Computer, Telecommunications and Information Technology, ECTI, 2011.
- [30] Wong, F.R., Aziz, N.S.A., Yasui, K., Hashim, A.M., "Graphene as a template layer for the growth of Ga-based compound materials", International Conference on Solid State Devices and Materials, 338–339, 2014.
- [31] Thomsen, C., Reich, S., Maultzsch, J., "Zinc Oxide and Graphene composites: Basic Concepts and Physical Properties, Wiley-VCH Verlag GmbH, 2007.