RESEARCH PAPER

A Review Study of Structure Analysis on Signal Warning Detector (SWAD) by Employing Nanosensors

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ABSTRACT

Nanosensors with high sensitivity utilize electrical, optical, and acoustic properties to improve the detection limits. The unique and exceptional properties of nanomaterials (large surface area to volume ratio, composition, charge, reactive sites, physical structure and potential) are exploited for sensing purposes. The concern about the safe environment on the road, especially during the maintenance and repairing process, the application of Signal Warning Detector (SWAD) be applied to help reduce the percentage of having a fatal accident that involves the maintenance worker and the highway users. This system was created to alert the workers from the danger that will warn them through 3 ways, such as sound, vibration and visual. It is important to develop the transmitter device and the receiver device that can be connected as a wireless system to ensure the worker can move freely while working and not being constructed by the connecting wire. This system is one of the safety procedures for workers while working the highway emergency lanes. The model of the casing is drawn by SolidWorks and static analysis was used to analyze the stress, displacement and strain on the device's casing suitable with the environment working field to get an appropriate material and mechanical structure design. The analysis for the system based on the design of experiments and demonstration in real situations.

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INTRODUCTION

Advances in the era of nanotechnology are moving towards the fabrication of nanosensors that are flexible, specific, versatile and sensitive. The objective of nanosensors is to screen and measure any chemical, mechanical and physical changes that are related to a marker of interest. Different sensing approaches can be assimilated into other systems like labs-on-a-chip to simplify any kind of detection. The number of cars on the road is increasing steeply because people see cars as a necessary addition to their life. About 1.2 million people each year around the world involved in a road traffic accident would result in the death and the increasingly serious global issue [1]. Rear-end collisions are responsible for a large number of cases involving highway worker, usually occurring at speed up to 140 km/h on

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the highway. In general, rear-end collisions occur more frequently in the work zone with increased road congestion and speed variability [2]. Road safety is the paramount and joint responsibility of all road users, which include driver and safety worker using different means of transport. In this situation, there is less concern about the safety of employees doing the maintenance job on the highway [3]. Three risks contributing to accidents such as due to underproduction or lack of protection, inadequate visibility problem and speeding through working zones [4]. There is no doubt rear-end collisions are common, and it brings a lot of loss of life and damage costs. The safety system is one of the most important requirements to make sure employees are always safe and are not exposed to any danger [5].

Most of the accidents that occurred on the highway involved user and worker vehicle within the work zone [6,7]. Factors that cause construction at night are dangerous due to night vision problems among highway users and highway workers[8]. The higher numbers of night-time accidents were caused by fatigue, drugs, alcohol and blurred vision that related to age [9]. Besides, other major causes included miscommunications among the various project participants, driving behaviour without supervision, lack of coordination with other nearby projects and vehicle delays and congestion in the working zone [10]. Moreover, as stated in the annual police road traffic accident reports, there are more than 10 types of road defects that caused road accident [11]. One of the road defects that caused an accident is the lack of street lighting, especially at night time. The lack of lighting can cause the driver cannot see another surrounding vehicle. Several strategies for improving the safe operation of equipment within the work zone is the use of electronic warning systems or detectors to alert workers of equipment in the immediate work area. The research was done by Zhang [12], they present a warning system for automobile collision avoidance based on LabVIEW. It will give a signal when a collision danger is detected, and it will assist the driver control the brakes, so some collision accidents can be prevented. Another researcher had discussed and study vehicle rear-end collision avoidance system [13]. Based on the research that has been made, The Danger Detection Module can be used in such settings as network traffic incident detection, system call analysis, smart home safety, etc [14]. Also, sensors are advanced devices that are mostly used to detect and respond to electrical or optical signals. The use of ultrasonic sensors has been widely used for various purposes, such as surface structure determination, position measurement and object speed calculation [15]. As due to technological development, Wireless Sensor Network (WSN) is originated from wireless networking, which is the interconnection of nodes that do not require any form of cable [16].

Sensing techniques

Sensors can be classified either based on signal production or by the different methods they employ for signal transduction. Transduction can take place through a number of approaches. There are presently three main transduction approaches categorized based on detection mechanisms: (1) electrochemical detection, (2) optical detection and (3) acoustic/mechanical detection. On the other hand, there is constant progress in designing and optimizing new detection mechanisms of transducers to fabricate new types of sensors. There are different subtypes based on the principle of three main transduction approaches. A number of transduction systems are available in combination with other techniques. In the following, we give a brief description of the detection systems that are currently available.

The low-cost distance sensor capable of adapting itself to environmental conditions as shown in Fig. 1 [17]. Arduino is an open-source microcontroller which can be easily programmed, deleted and reprogrammed [18]. The Arduino board senses the environment by receiving input from a range of sensors and can affect its surroundings by controlling LCDs, speakers' motors and GS modules. This kind of technology able to maximizes the level of safety of use. The distance between ultrasonic sensors can be varied to improve the accuracy of the measurement or to meet the needs of the user [19].

A programmable logic controller (PLC) is a single-processor, computer-based, solid-state device that is a specialized computer used to control and process machines. PLC is commonly used in most industrial automation, not just because of its economic benefits, but also because of its role in providing a reliable quality-guaranteed product [20]. The PLC system was used to integrate materials handling and processing into automated manufacturing systems. PLC has been commonly

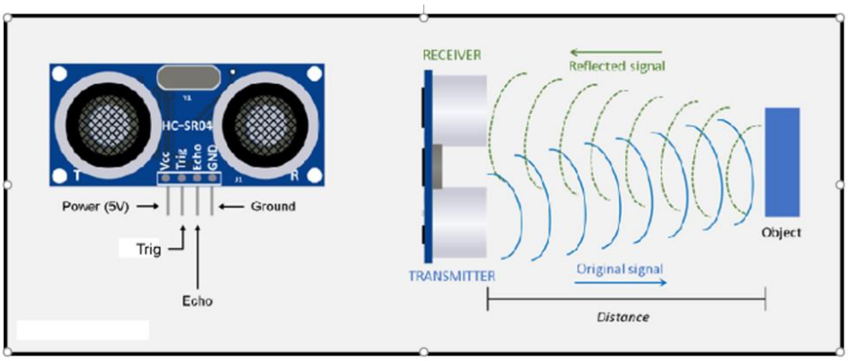

Fig. 1. Ultrasonic sensor [17].

used for sequential logic control in manufacturing environment [21].

The purpose of the structural analysis is to design a structure that has suitable strength, rigidity and safety. In other words, the finite element is the most practical method for the analysis of all types of machine structure structures due to realistic assumptions [22]. The structural analysis is a science that ensures that the structures are safe and meet the functions for which they have been designed [23]. The structural analysis is an important step in determining the residual life of composite laminates [24]. In this analysis, loads are applied to a body or model due to which the body part deforms and the effects of the loads are transmitted through the body.

In the numerical analysis of the mechanical performance of deformable bodies uses of the finite element method has been reliably and extensively [25]. Static analysis refers to the calculation of displacement, stress, strain and error estimates under various loading conditions, based on certain assumptions. The finite element method was used to analyze the stress, strain and deformation as a result of the pressure that existed [26]. The structural analysis combines the disciplines of mechanics, dynamics and failure theories to estimate internal forces and stress on the structures to be designed. Some researchers have done a large number of simulation analyses using FEM software [27].

All aspects of engineering design are important for material selection [28]. Improper selection of materials can have a significant impact on the safety and application of the product to be produced. When determining a material for a particular use, sufficient and suitable testing shall be carried out to ensure that the material remains suitable for application over the life of the product [29]. There are several different factors involved in determining the selection criteria, such as mechanical properties, chemical properties, physical properties, electrical properties and cost.

Nylon 6 is commonly used in many applications and is an important engineering thermoplastic material with properties such as high toughness, abrasion resistance, low density and low friction coefficient [30]. It is available in a range of grades and forms to suit with many applications. Nylon 6 competing with metal in the advanced material engineering exhibit improved and better characteristics [31]. These thermoplastic polymers have been commonly used as high potential materials for automotive, industrial and construction applications [32]. The physical properties of nylon 6 polymers, such as impact strength, tensile strength, density, thermal expansion coefficient, melting and boiling points, as well play an important role in CNC turning capabilities [33].

MATERIALS AND METHODS

This project was presented with a design procedure of SWAD casing by applying SolidWorks. The Fig. 2 shows the process of the project was done as shown in the flow chart.

Static study function was selected in this simulation and had been carried out to get the maximum value of stress, displacement, and strain by applied the force in the one direction. Type of material, fix geometry, meshing and components connection was set up for the analysis. Then, apply force for performing and setting parameters. The analysis was performed for both of the model design. The result of both casing designs was compared to find the best design.

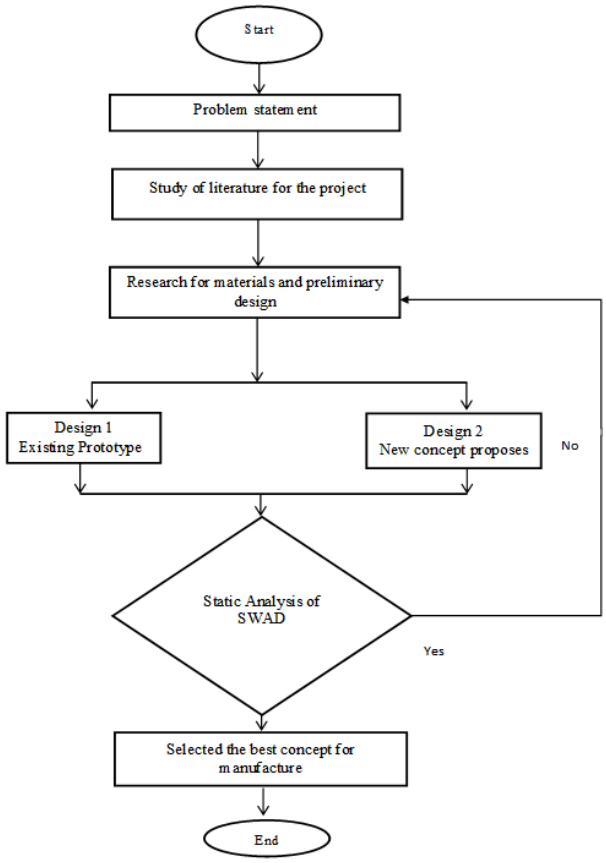

Fig. 2. Flow chart of overall research study

Von Mises produces a criterion stating that if the material stress under the load is equal to or greater than the yield limit of the same material under simple tension, which can be easily determined experimentally, then the material will yield. The results are expressed in MPa. Displacement is the primary unknown in the structural FEA, and stress is calculated on the base of the displacement results. Stress also rises with mesh refinement [34]. The solution of the mathematical model when proceeded to refine the mesh, it would seem that both the effects of displacement and stress converge to a finite value. The strain is a measure of geometric response and the change in shape due to applied forces. The strain is equal to a change in length from applying force or can be said as the original length [34].

For material improvement, the material of parts needs to change in improving the mechanical properties of the casing. The previous project used ABS for both casings. The ideas want to change ABS to the cast nylon by referring to the mechanical properties of these materials. The virtual design of the casing structure has been developed. Two types of casing designs were drawn, which the exact initial design was transferred to SolidWorks software. After finishing the designs of the casing, the casing design was produced by the 3 D printer as and advanced technology in Additive Manufacturing [35].

RESULTS AND DISCUSSIONS

This project target is to develop a new design of SWAD in making a new way to upgrade the level of safety for the maintenance worker during maintenance work at the highway or any site. This result can be accomplished if this device can detect the danger and transmit the signal to people surrounding. This is because SWAD was able to detect the vehicles coming from behind at a certain zone by using the distance sensor and able to give a vibration to the worker if the site is not safe for them. Besides that, it is expected to minimize the accidents or danger from an accident involving the worker, the highway users and road problem. Then, some innovation and modification were done in this project, such as redesign the structure and select the best material in developing the SWAD suitable to the working environment and to get a good mechanical structure design.

A conventional optical waveguide is characterized by cross-section such as J-J0 shown in Fig. 3(a). Optical waveguides are in general layed out such that the fluids flow orthogonal to the direction of optical wave propagation. Thus, as noted in the right image in Fig. 3(b), an air gap would exist between the PDMS layer (PDMS being the material of choice for microfluidic channels) and the bottom silicon dioxide cladding in a silicon-oninsulator (SOI) substrate. One typical solution to close the avenue for fluid leakage in silicon-chip-integrated waveguide sensor is introducing additional fabrication steps including but not limited to oxide deposition followed by planarization and selective oxide removal prior to microfluidic channel bonding. In the case of photonic-crystal sensors, such post-processing would necessitate removal of the oxide from the etched photonic-crystal patterns, which would result in additional etching of the bottom oxide cladding unless the process is very strictly controlled. A poor tolerance on the oxide removal processing would lead to uncertain resonance wavelengths in photonic-crystal biosensors.

A cascaded MMIs structure, whose top-view schematic is shown in Fig. 4(a), is utilized to build ultra-low-loss waveguide crossings on a SOI substrate (3-µm-thick buried oxide layer and 250-nm-thick top silicon layer) since it enables guiding of low-loss Bloch waves by periodic self-focusing sections offered by MMIs. Commercially available software FIMMWAVE (developed by Photon Design Ltd.) is used for simulation, and a side view schematic of the simulated structure is shown Fig. 4(b). Here the Wsi is chosen to be 0.6 µm to build a single-mode waveguide, and Wmmi is chosen as 1.2 µm to support only three quasi-TE modes (zeroth, first, and second). As the symmetry of this structure, the odd first-order mode has not been excited. Hence the selffocusing condition can be perfectly fulfilled by tuning Lin and Ls to eliminate the phase error between zeroth and second mode. Linear tapers (Lt 1 µm) are added to avoid sharp transition and at the same time to reduce the portion of the power in second-order mode in the MMI region that could improve the power transition.

Fig. 2a shows the current–voltage (I-V) characteristics of a device fabricated using ZnO-CNT networks with 2.0wt%CNT, showing double Schottky contacts formation and a high UV on/of current ratio. Figs 2b and S1e show the dynamic UV response of devices fabricated using pristine ZnO NW networks and networks which were functionalized with CNTs to three pulses of UV light with 10 s durations and 30 s periods, respectively. Te bias voltage applied on to the device structure was 10 V. Te addition of CNTs to ZnO NW networks (up to 2.0wt%) resulted in an increase of dark current (not shown) which can be attributed to the excellent electrical conductivity of CNTs. By adding 4.0wt% CNT, resistance of networks decreased dramatically leading to a higher dark current and poor UV detection properties

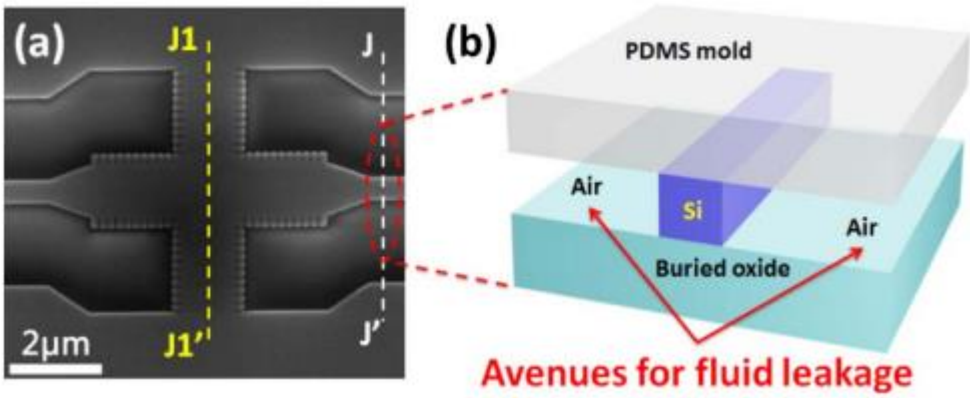

Fig. 3. (a) SEM image of a typical waveguide crossing. Conventional waveguides are characterized by cross-sections J-J0 and waveguide crossings are labeled by J1-J10. (b) Crosssectional view of the PDMS microfluidic channel when integrated with optical waveguides in silicon in a SOI substrate.

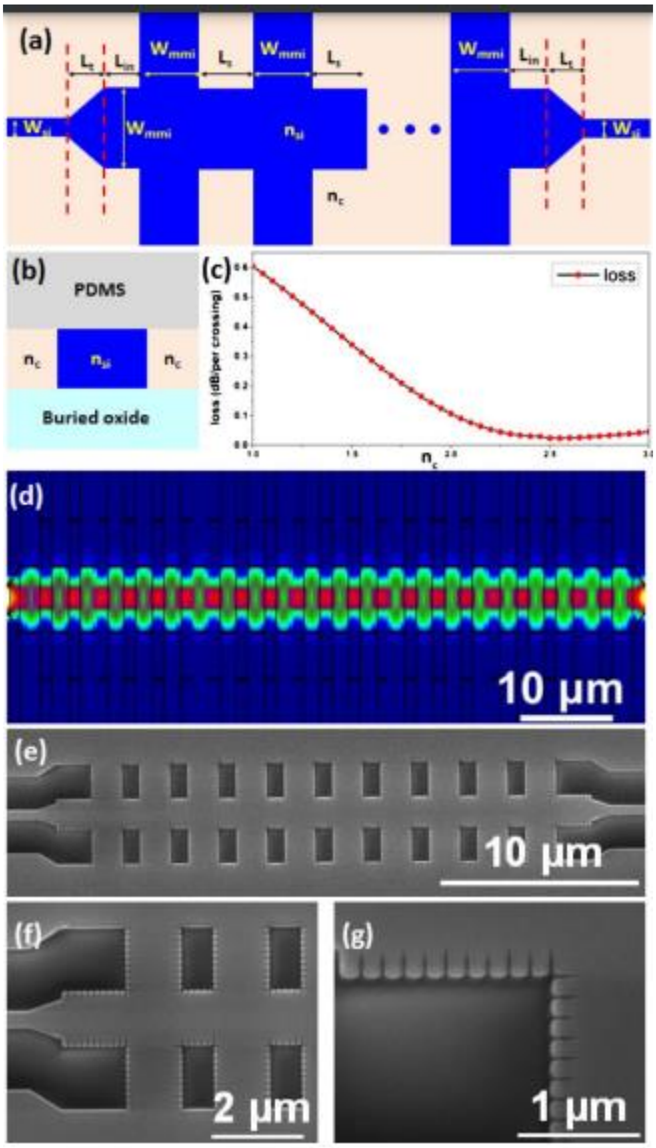

Fig. 4. (a) Top-view schematic of cascaded MMI-based waveguide crossings. (b) Side view schematic of simulated structure. (c) Simulated propagation loss versus lateral cladding index for the structure in (a). (d) FIMMWAVE simulation result of 20 waveguide crossings with optimized parameters. (e)–(g) SEM images of fabricated waveguides crossings.

(shown in Fig. 2b). Tis can be accounted for the formation of the percolating carbon nanotube networks which considerably reduce the infuence of potential barriers between ZnO NWs on conductivity, thereby lowering the adsorption sites for oxygen molecules . However, the high rapidity of the networks was not afected. Te calculated UV response for each type of samples is presented in Fig. 2c. Te pristine ZnO NW networks demonstrated a low UV response of about 150. By adding 2.0wt% of CNTs the UV response was considerably increased to 7300 (about 50 times). Tis value is much higher than any reported studies ever for MWCNT/ZnO NWs7 and rGO decorated ZnO nanostructures

Fig. 6a show a SEM image of a nanosensor fabricated using an individual ZnO-CNT NW from samples with 2.0wt% CNT. Te diameter (D) of the NW is about 100nm, while the length is ~6.6 µm. Te NW was contacted to pre-patterned

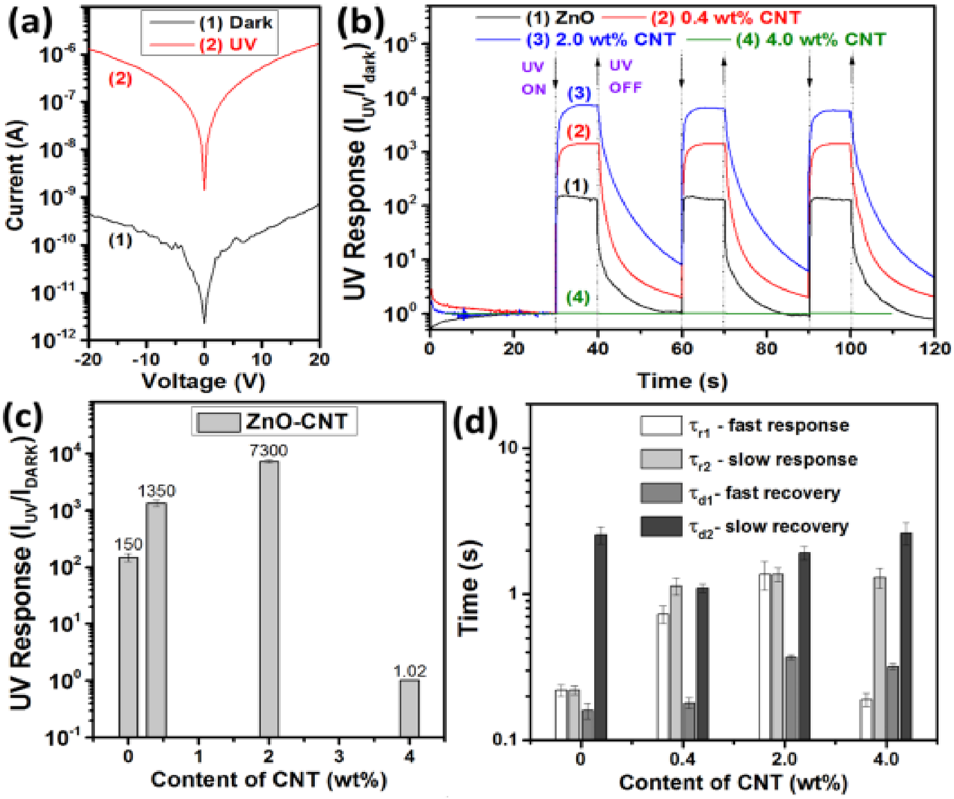

Fig. 5. (a) Current – voltage characteristics of the device based on ZnO-CNT networks with 2.0wt% CNT. (b) Dynamic UV response of ZnO-CNT networks with diferent content of CNT at 10V. (c) UV response versus content of CNT in ZnO-CNT networks. (d) Calculated rise and decay time constants from UV response curves.

Au/Cr contacts by Pt complex, resulting in the formation of double Schottky contacts (see Fig. 6b). A SEM image with higher magnifcation of an integrated individual ZnO-CNT NW is presented in Supplementary Fig. S6a, showing the presence of CNTs on the surface of ZnO NW. Te I-V characteristics at diferent temperatures of the nanosensor are presented in Fig. 6b, showing a semiconducting behaviour. Te device was tested to diferent gases and VOCs at diferent operating temperatures. Fig. 5c shows the dynamic response at room temperature to 10 ppm of NH3, 100 ppm of ethanol vapours and 10 000 ppm of H2 gas. Te nanosensor showed excellent repeatability and complete recovery to the initial electrical baseline. Te calculated gas response of our nanosensor is presented in Fig. 6d, showing the excellent selectivity to NH3, as in the case of ZnO-CNT networks.

CONCLUSIONS

The main purpose of this study for the SWAD is to design and analyze the casing of the transmitter and receiver with a similar function and mechanism to more improvement for suitable to use at the emergency lane. Developing a device casing is necessary to solve the detector system problem, contributing to the progress and the development of Signal Warning Detector (SWAD). The other purpose of this system is expected to reduce the accidents or danger from happening in the emergency lane on the highway. Static analysis was carried out with the finite element method by using the Simulation plug of SolidWorks. The results will show the stress, strain, and displacement of the casing structure as structure deformation.

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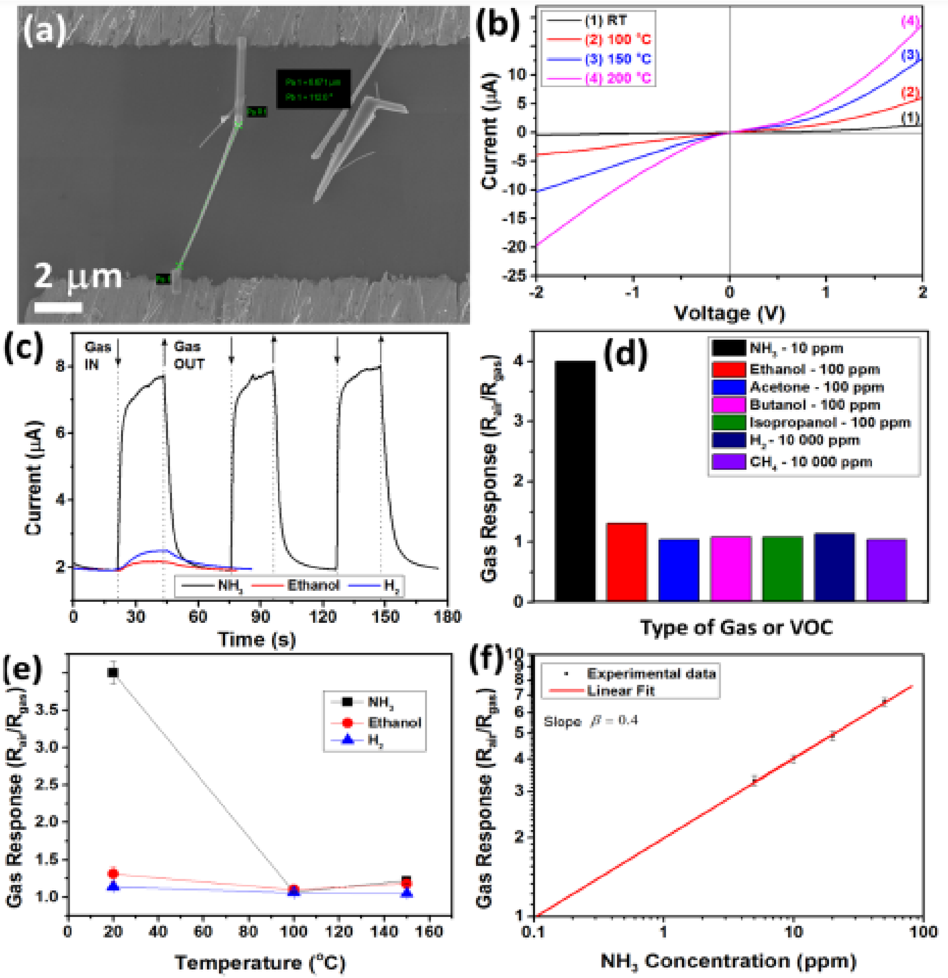

Fig. 6. (a) SEM image of the nanosensor based on individual ZnO-CNT NW with D=100 nm, (b) Current – Voltage characteristics of the nanosensor at diferent operating temperatures. (c) Dynamic response of the nanosensor at room temperature, (d) Gas response to VOCs at room temperature. (e) Gas response versus operating temperature. (f) Gas response of nanosensor at room temperature.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

REFERENCES

1. Peden M. World Health Organization dedicates World Health Day to road safety. Injury Prevention. 2004;10(2):67-67.
2. Meng Q, Weng J. Evaluation of rear-end crash risk at work zone using work zone traffic data. Accident Analysis & Prevention. 2011;43(4):1291-1300.
3. Masrol SR, Ibrahim MHI, Adnan S, Amir Shah MSS, Main NM, Esa MF, et al. Effect of Beating Process to Soda Anthraquinone Pulp of Oil Palm Male Flower Spikes Fibre. Applied Mechanics and Materials. 2015;773-774:158-162.
4. Ferreira-Diaz C, Torres-Zapata A, Nanovic C. Worker Injury Prevention Strategies. Purdue University; 2011.
5. Mustaffa N, Khalid A, Sies MF, Zakaria H, Manshoor B. Preheated Biodiesel Derived from Vegetable Oil on Performance and Emissions of Diesel Engines: A Review . Applied Mechanics and Materials. 2013;465-466:285-290.
6. Khairu K, Ibrahim M, Hassan S, Hehsan H, Kasmin A, Fazial E. Study on Layer Fabrication for 3D Structure of Photoreactive Polymer Using DLP Projector. Applied Mechanics and Materials. 2013;465-466:911-915.
7. Roslan MN, Yahya MY, Ahmad Z, Rashid AHA. Axial impact crushing behaviour of thin-walled braided composite tubes: experimental comparison on basalt fibre and glass fibre reinforcement. Journal of Physics: Conference Series. 2019;1150:012048.

8. Sies MF, Mustaffa N, Zakaria H, bin Salleh H, Manshoor B, Khalid A. Development of the Premixing Injector in Burner System. Applied Mechanics and Materials. 2013;465-466:302-307.
9. Arditi D, Ayrancioglu M, Jingsheng Shi J. Worker safety issues in night-time highway construction. Engineering, Construction and Architectural Management. 2005;12(5):487-501.
10. Li Z. Highway work zone safety audits for safety improvements. Engineering, Construction and Architectural Management. 2010;17(5):512-526.
11. Rosyadah K, Budiandriani B, Hasrat T. The Role of Fintech: Financial Inclusion in MSMEs (Case Study in Makassar City). JURNAL MANAJEMEN BISNIS. 2021;8(2):268-275.
12. Dabiao Z, Yueyi K, Hongyun L. Design of Automobile Collision Avoidance Warning System Based on LabVIEW. 2007 8th International Conference on Electronic Measurement and Instruments; 2007/08: IEEE; 2007.
13. Shiqing D, Yandong S, Jibin D. The Research for Mechanism of Vehicle Rear-End Collision Avoidance System. 2010 International Conference on Intelligent Computation Technology and Automation; 2010/05: IEEE; 2010.
14. Degeler V, French R, Jones K. Combined Danger Signal and Anomaly-Based Threat Detection in Cyber-Physical Systems. Internet of Things IoT Infrastructures: Springer International Publishing; 2016. p. 27-39.
15. Thong-un N, Hirata S, Orino Y, Kurosawa MK. A linearization-based method of simultaneous position and velocity measurement using ultrasonic waves. Sensors and Actuators A: Physical. 2015;233:480-499.
16. Premeaux E, Evans B. Arduino Projects to Save the World. Apress; 2011.
17. Srijith B. Arduino based Distance Measurement Sensor using Ultrasonic Sensor. International Journal for Research in Applied Science and Engineering Technology. 2021;9(VI):1789-1799.
18. Louis L. Working Principle of Arduino and Using it as a Tool for Study and Research. International Journal of Control, Automation, Communication and Systems. 2016;1(2):21-29.
19. Stiawan R, Kusumadjati A, Aminah NS, Djamal M, Viridi S. An Ultrasonic Sensor System for Vehicle Detection Application. Journal of Physics: Conference Series. 2019;1204:012017.
20. Romadhon AS, Widyaningrum VT. Automatic Food Packaging System using Programmable Logic Controller. Proceedings of the International Conference on Health Informatics, Medical, Biological Engineering, and Pharmaceutical: SCITEPRESS - Science and Technology Publications; 2020.
21. Hassan S, Yusof MS, Embong Z, Kamarudin QE, Haq RHA, Ibrahim M, et al. A study of frequency and pulses for stepper motor controller system by using programmable logic controller. Journal of Physics: Conference Series. 2019;1150:012040.
22. Hassan S, Rahim EA, Mohid Z, Warap NM. Dynamic Analysis of Micro-Milling Machine. Applied Mechanics and Materials. 2013;465-466:699-703.
23. Bedenik BS, Besant CB. Introduction. Analysis of Engineering Structures: Elsevier; 1999. p. 1-14.
24. Pham DC. 3D Progressive Failure Modeling of Drop-Weight Impact on Composite Laminates. Center for Open Science; 2018.
25. Salahuddin MBM, Atikah AF, Rosnah S, Zuhair MNM. Conceptual design and finite element analysis of a high inclusion dough shaping machine using 3D-computer aided design (CAD) (SolidWorks). Materialwissenschaft und Werkstofftechnik. 2019;50(3):267-273.
26. Suherman, Wahono B, Praptijanto A, Santoso WB, Nur A. Modeling and static analysis of a connecting rod in range extender engine. 2016 International Conference on Sustainable Energy Engineering and Application (ICSEEA); 2016/10: IEEE; 2016.
27. Peng S-z, Gao X-l, Yang S-h, Yang J, Zhang H-x. Water requirement pattern for tobacco and its response to water deficit in Guizhou Province. Water Science and Engineering. 2015;8(2):96-101.
28. Chaithanya, B. V, Subba, S., Patange, R., M, S. D., Panbarasu, K., & Joyti, B. (2017). Study on Material Selection for Particular Design. International Research Journal of Engineering and Technology, 708–710.
29. Pyles,R.A.Aging Aircraft USAF Workload and Material Consumption Life Cycle Patterns. Rand, USA, 2003
30. Roh SC, Kim J, Kim CK. Characteristics of nylon 6,6/nylon 6,6 grafted multi-walled carbon nanotube composites fabricated by reactive extrusion. Carbon. 2013;60:317-325.
31. Johnson RW, Evans JL, Jacobsen P, Thompson JRR, Christopher M. The Changing Automotive Environment: High-Temperature Electronics. IEEE Transactions on Electronics Packaging Manufacturing. 2004;27(3):164-176.
32. Segatelli MG, Yoshida IVP, Gonçalves MdC. Natural silica fiber as reinforcing filler of nylon 6. Composites Part B: Engineering. 2010;41(1):98-105.
33. Bhardwaj, V., Gaur, M. K., Chaturvedi, V., & Agrawal, S. (2018). Optimization of Machining Parameters for Nylon 6 Composite in CNC Lathe Using PCA-Based TOPSIS. 4(1), 36–47.
34. Matt Weber & Gaurav Verma (2015). SolidWorks Simulation 2015 Black Book (Vol. 25, Issue 1). CADCAMCAE Works.
35. Hassan S, Yusof MS, Embong Z, Ding S, Maksud MI. Surface study of graphene ink for fine solid lines printed on BOPP Substrate in micro-flexographic printing using XPS analysis technique. IOP Conference Series: Materials Science and Engineering. 2018;298:012012.