Research Statement

Dr. Mohammed Gamil Mohammed Abdelghany

Mechanical Engineering Department, Faculty of Engineering at Shoubra, Benha University.

I am an assistant professor in mechanical engineering department at Benha University with an interest in contributing to sensing applications by nanomaterials using MEMS technology.

This research statement is organized as follows: The first section discusses my work in the area of using carbon-based nanomaterials (Graphene, CNTs) for strain sensing, with a focus on my dissertation papers. The second section discusses my current work in the area of sensing applications and nanocomposites. The third sections include plans for future research in the respective areas.

Carbon-Based Nanomaterials (Graphene, CNTs) for Strain Sensing

My Ph.D is divided into experimental part and simulation part. In each part the strain sensing of graphene and CNT is examined and analyzed.

In the experimental part, a flexible graphene-based strain gauge formed on PET substrate is fabricated using a new technique suitable for large-scale and low-cost mass production. The graphene film is synthesized by drop-casting a graphene oxide (GO) solution on a flexible PET substrate, followed by simultaneous reduction and pattern to the dried GO film with a carbon dioxide laser beam. The measured GF (~ 77) of the fabricated strain gauge is higher than that of the metallic foil strain gauge (2.1) and stable with temperature change if it is compared with silicon. In addition, another graphene-based strain gauge on Si/SiO_2 substrate using a new low-cost patterning technique was also fabricated. The graphene film was prepared by chemical vapor deposition (CVD) on a copper foil and transferred to Si/SiO_2 substrate using a successful transfer method and patterned by a high-power CO_2 laser beam. A higher GF was achieved by this sensor (~ 255 for single layer and ~ 104 for multilayer) than the flexible one due to the fewer number and the high quality of the prepared graphene layers. On the other hand, the GF of SWCNT bundles was measured by using a MEMS device. Strain was applied by thermal actuator to the suspended SWCNTs bundles and the resistance change was measured simultaneously. GF up to 13.7 was measured.

In the simulation part, the strain response to geometry of a monolayer graphene was investigated by first-principles calculation with the 2-dimensional periodic boundary model. The optimized C-C bond length was 1.422 Å and the calculated poison's ratio was determined as $\upsilon = 0.28$ for the $[1\bar{1}00]$ strain and $\upsilon = 0.14$ for the $[11\bar{2}0]$ strain. By referring to these results, first-principles calculation of the 1-dimensional periodic boundary models for graphene nanoribbon and SWCNT has been carried out to predict gauge factors of them with the armchair and zigzag orientations, respectively. The gauge factors were evaluated by the strain response to conductivity calculated by the band carrier densities and the band effective masses derived from the first-principles band structures for both strain-free and strain models. The highest calculated GF for graphene ribbon was -55.21 for zigzag model 13-rings while the highest calculated GF for SWCNT was -22.8 for Armchair model (7,7).

Eight international papers were published from this research work in different international journals and conferences. Two international papers were published in the Japanese Journal **Sensors and Materials, one** paper was published in **Sensor Review**, Two papers were published in **Key Engineering Materials**, one paper was published in **Modeling and Numerical Simulation of Material Science**, one paper in the **First International Conference on Innovative Engineering Systems (ICIES)** organized by E-JUST and published by IEEE Xplore and the final paper was published in the **International Conference on Engineering and Technology (ICET)** organized by GUC and published by IEEE Xplore.

Sensing Applications and Nanocomposites (My current work)

My current work is focusing on sensing applications of nanomaterials such as temperature and pressure sensors. In this research work, we presented the fabrication of an efficient and reliable graphene nanoplatelets (GNPs) based temperature sensor. A high-quality dispersion of GNPs was dropped by casting method on platinum electrodes deposited on a polyethylene terephthalate substrate (PET). The GNPs were characterized by SEM, Raman spectroscopy and XRD spectra to ensure its purity and quality. The temperature sensing behavior of the fabricated sensor was examined by subjecting it to different temperatures, range from room temperature (RT) to 150 °C. Excellent resistance linearity with temperature change was achieved. Temperature coefficient of resistance (TCR) of the fabricated sensor was calculated as $1.4 \times 10-3$ /°C. The sensor also showed excellent repeatability and stability for the measured temperature range. Good response and recovery times were evaluated at all the measured temperatures. With measuring the sensor response, the ambient temperature can be determined.

My current research work is extended for making nanocomposite materials for improving the performance of the cooling unit in the automobile engine. In this research work, ultra-high concentration dispersion of graphene nano-platelets (GNPs) was incorporated into Aluminum alloy AA5052-H32 using friction stir processing (FSP) to form metal matrix composite (MMC). For this purpose, grooves made in the AA5052-H32 were packed with the graphene nano-platelets and then FSP was applied in two steps; first using pinless tool at constant processing parameters of 1200 rpm and 100 traverse speed, second using conventional tool with pin and shoulder at the same processing parameters of (1200 rpm and 100 mm/min traverse speed). Scanning electron microscopy (SEM), Raman spectroscopy and X-ray diffraction (XRD) analyses were used to examine the GNPs dispersion. The thermo-mechanical properties of the fabricated MMC were studied. Thermal conductivity, micro-hardness, tensile strength and fracture surface were examined before and after FSP. The measured thermal conductivity was improved by about 75% compared to the base metal due to the MMC with GNPs. Meanwhile, the hardness was increased from 67 Hv to 94 Hv and the ultimate tensile strength decreased from 238 MPa to 196 MPa.

Future Research Work

In the future work I intended to extend my work in sensing applications using MEMs technology. I intend to get the advantages of the MEMs lab existed at E-JUST to make high accuracy sensors based on nanomaterials. I made a trail for developing a macro-scale temperature sensor based on graphene nanoplatelets. This trial was sent for publication and still under review. So, I want to extent my work in this regard but in the micro-scale with some modifications and improvement. After that, I intend to work on pressure sensors. Furthermore, I will be more welcome to cooperate with the academic staff in any research work related to the MEMs technology.