International Academic Institute for Science and Technology

International Academic Journal of Innovative Research
Vol. 7, No. 2, 2020, pp. 21-25.

ISSN 2454-390X

International Academic Journal of Innovative Research

www.iaiest.com

Design and Evaluation of Nanostructured Materials for Humidity Sensing

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Abstract

Understanding the importance of low humidity levels is crucial across many fields, which is why there's a push for better low humidity sensing devices. Unfortunately, developing these devices comes with its own set of tough challenges that can be hard to tackle. Plus, there's a noticeable lack of research on low-sensing devices compared to the wealth of studies focused on sensors that measure relative humidity over a broader range. The current methods for detecting humidity have their limitations, which really slows down the progress in low humidity sensor technology. One major reason for the drop in performance of these sensors is often tied to how water molecules interact with the sensing material. This phenomenon is well recognized in the scientific community. However, in low humidity conditions, the sensitive layer struggles to absorb water molecules effectively. This limitation makes it difficult for the sensor to pick up on even the slightest changes in the electrical signal.

Keywords: Humidity, Sensor, Nanotechnology.

Received: 08 September 2020/Revised: 21 October 2020/Accepted: 26 November 2020/Published: 31 December 2020

Introduction

Humidity plays a vital role in supporting life and enhancing human activities in manufacturing here on Earth (Zhang et al., 2016). For many living organisms and production processes, a specific range of moisture levels is essential for survival and growth. In plants, air humidity is particularly important as it affects transpiration, which in turn influences their growth and development. The optical microscope, also known as a light microscope, enlarges images of small objects by using visible light and a combination of lenses. Numerous scientific disciplines, including microelectronics, nanophysics, biotechnology, pharmaceutical research, geology, and microbiology, heavily rely on this kind of microscopy (Farahani et al., 2014). The PAA membrane that was created in the lab was examined closely for fractures and folds using the microscope seen in Fig. 1.



Fig. 1: Optical Microscope

In an upright microscope, the light that passes through the sample and the condenser are located below the stage, directed upwards. Meanwhile, the objectives are placed above the stage, facing downwards. The specimen is viewed from above, using either a petri dish lid or a coverslip (Tomer & Duhan, 2016). The object sits on a platform and is examined directly through one or two ocular lenses of the microscope.

Materials and Methods

The image is typically captured using a camera. Opaque objects can be lit up by the light that comes through or around the lens. In contrast, transparent objects can be illuminated from below. By using phase-polarity imaging, we can boost the contrast in micrographs, highlighting tiny features that have different refractive indices (Zafar et al., 2016).

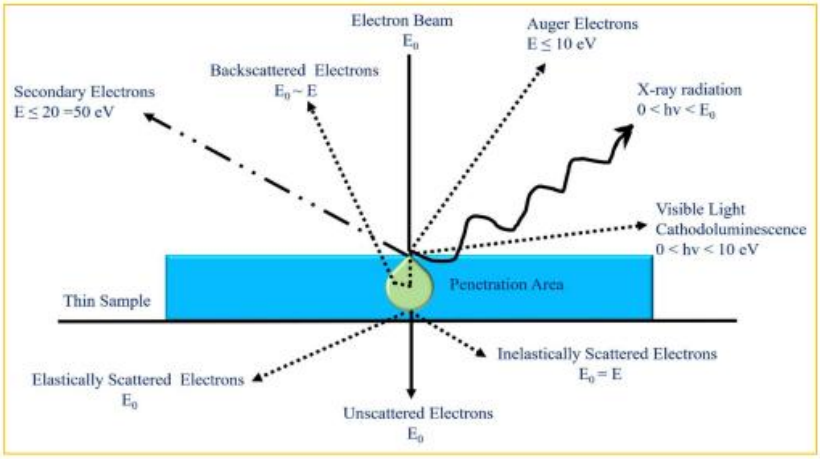


Fig. 2: Diagram of Electron Beam Interaction with Specimen

When it comes to optical microscopes, you'll typically find a range of objective lenses with different magnification levels mounted on a rotating turret. This setup allows you to easily switch between lenses for better focus. However,

the maximum magnification you can achieve is usually around 1000x, mainly because visible light has its limits in terms of resolution. To figure out the total magnification of a compound optical microscope, you simply multiply the eyepiece magnification (like 10x) by the objective lens magnification (for instance, 100x), which gives you that impressive total of 1,000x (Ashok & Rao, 2017).

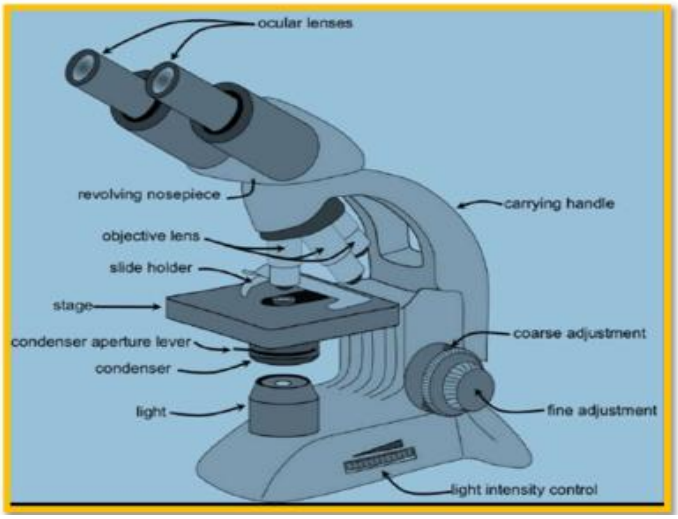


Fig. 3: Schematic of an Upright Optical Microscope

Results and Discussions

For a comprehensive study of the sensing data, it is essential to look at the surface morphology of each component in the PAA-GO bilayers as well as two reference samples, GOR and PAAR, as sensing is all about surface interactions (Tripathy et al., 2014). We used FESEM (FEI, NOVA NANOSEM 450) to describe the surface morphologies of the individual components prior to forming the PAA-GO bilayer system. The results are shown in Figure 4 at two distinct resolution scales.

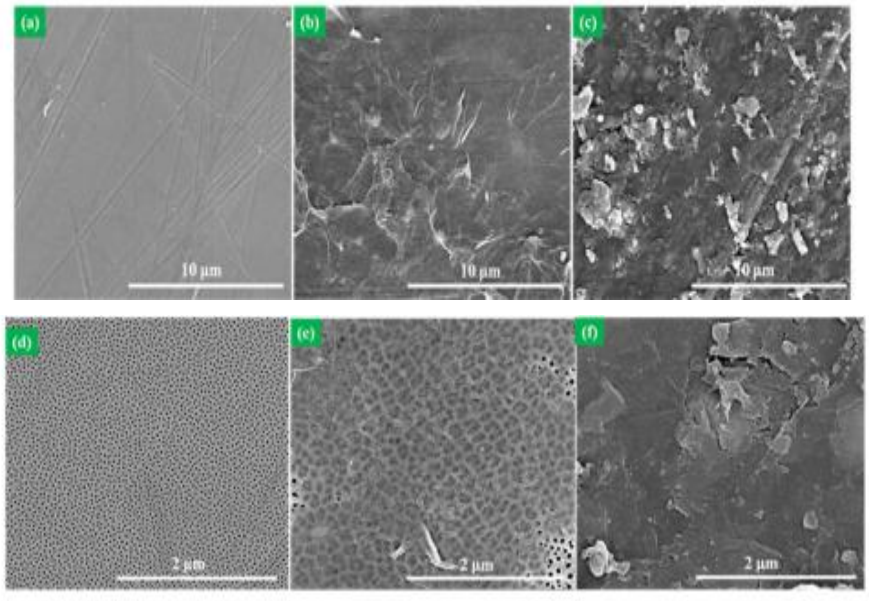


Fig. 4: Sensor Characterization

A novel bilayer system consisting of porous anodic alumina and graphene oxide (GO) has been developed for a new capacitive humidity sensor (Fratoddi et al., 2016; Noah, 2020). The GO dispersion solution's graphene oxide flakes

content has been meticulously controlled. The PAA-GO1 sensor was put to the PAA surface by drop-casting and has a flake density of 1.0 mg/ml.

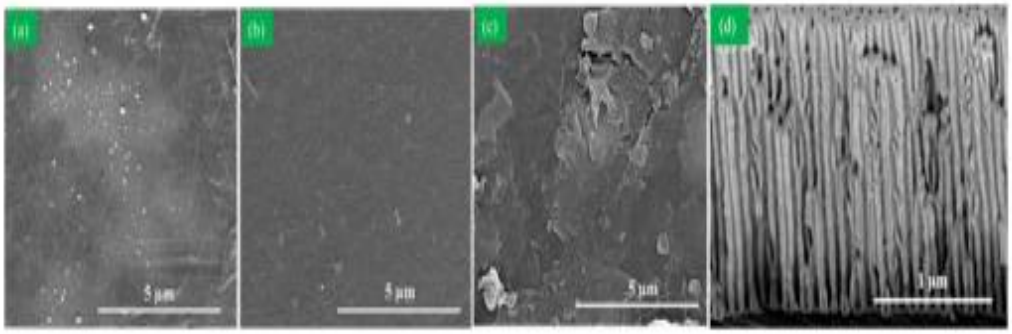


Fig. 5: Displays the Results Obtained from Field Emission Scanning Electron Microscopy

This sensor demonstrated a remarkable sensitivity of 1178.76 pF/% RH, which is four times higher than that of the reference sensor, PAAR, while achieving a limit of detection (LOD) of only 0.9% RH. Additionally, the PAA-GO1 sensor was twice as quick as the reference sensor, with a response time of 0.8 seconds (Noah, 2020).

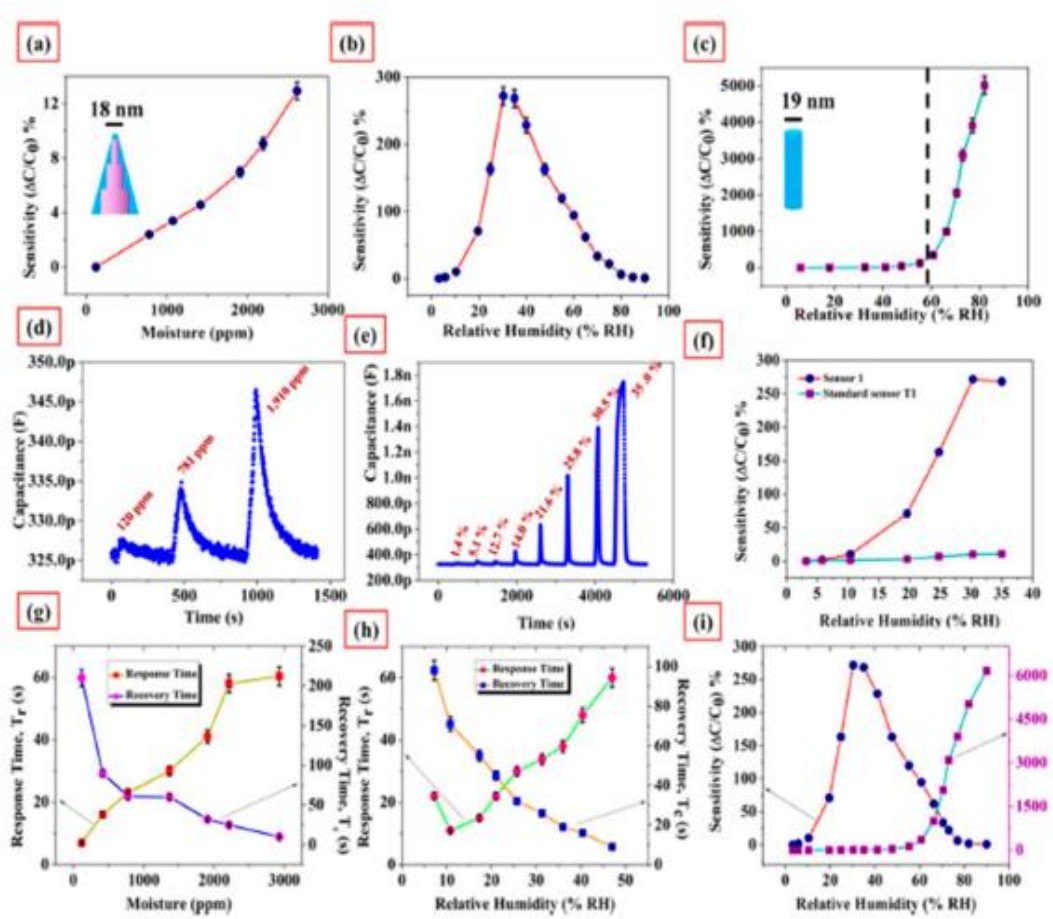


Fig. 6: Humidity Sensing Plots of Sensor

Because of its great sensitivity, the sensor can be used in applications that require accurate relative humidity level measurement, even when a lower humidity detection threshold is of paramount significance. Due to the multiple-step anodization technique used in its manufacturing, the unique nanostructure displays uncommon characteristics.

Conclusion

Both biological survival and human participation in Earth's industrial processes depend heavily on humidity. A certain range of moisture levels is necessary for many objects to survive and flourish under various living and generating settings. The process of transpiration in plants is greatly influenced by air humidity, which also affects the growth and development of plants. Humidity levels that are too high or too low can both negatively impact people's comfort. Furthermore, a variety of difficulties in the fields of industrial and agricultural output can result from low humidity levels. In a number of sectors, such as healthcare, industry, agriculture, food and fuel storage, weather forecasting, environmental preservation, and national infrastructure, humidity monitoring and control have become increasingly important. The need for current data on how moisture content affects dependability, affordability, safety, satisfaction, and human health is high.

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