Nanostructured Flexible Gas Sensors for Breath Monitoring System

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Introduction/Significance. Clothing is a microenvironment surrounding the human body that has the most proximity than anything else, which can be a good tool for monitoring and interfacing with the human body (Dunne, 2012). Monitoring breath gives important information about body condition simultaneously for wearers, guardians, and medical specialists to protect from hazardous situations and emergencies (Galassetti et. al., 2005). Gas sensors embedded on this proximal microenvironment, clothing, will allow them to be easily portable without wearers making efforts to bring and care for the sensors (Cho et. al., 2011). To be worn daily and for long-term monitoring, the crucial problem that needs to be researched is finding the best way to integrate hard electronic parts into soft fabric materials to reduce the material differences and minimize the battery parts, which can be made into soft materials (Dunne, 2012). These will enhance comfort, durability, wearability, avoid attracting others' attention, and be cost efficient (Koo, 2011). This research will experiment the possibilities of developing a flexible fabric-based gas sensor that can harvest energy at the same time by using Zinc oxide (ZnO), which has not been explored among extent research. This research will give ideas for apparel designers and engineers when developing a flexible fabric-based gas sensor and health care clothing.

Literature Review/Theoretical Framework. ZnO has a wide band gap (3.37eV) and large exciton binding energy (60 meV) (Xu & Wang, 2008). ZnO received much attention for the promising material for solar cells, photodetectors, and sensors (Ates & Unalan, 2011). The idea for research developed from the sustainable model for smart clothing design (Koo, 2011), defined the key design factors that are required for sustainable smart clothing, and the developed gas sensor focused on energy harvesting and flexible applications of various end-usages. Various methods have been conducted to integrate ZnO into substrates such as radio frequency (RF) sputtering, which runs energetic waves to coat thin film, and sol-gel method, which is a wet-chemical technique. In this research, Ahn et al.'s, (2010) research demonstrated the possibility of Kapton polyimide film as gas sensing on making a gas sensor, and guided the deposit methods of ZnO on flexible materials.

Methods. To test the feasibility of gas sensors on fabric, polyester (100% PET) and cotton (100% CT), which are two of the most widely used fabrics for clothing, are used as a substrate. Following the methods of Ahn et al. (2010), r.f. sputter and chemical solution methods were applied to deposit ZnO on the substrate. Electrodes were stitched with conductive silver plated threads in an interdigitated pattern to make the sensor as small as possible to prevent electrical

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shortage. First, the fabrics were cleaned by ultrasonication and then were cleaned with isopropanol, ethanol, and deionized (DI) water. Second, ZnO thin films were used as a seed layer and deposited to electrodes by r.f. sputter. ZnO nanorods were grown by chemical solution assisted by thermolysis. In DI water, Zinc nitrate hexahydrate ($Zn(NO_3)_2 \bullet 6H_2O$) and hexamethylenetetramine (HMT) were mixed with the same mole of 0.01. Third, the solution was stirred for 24 hours, placed into a hot water bath for 4 hours at 85℃, and then cleaned with DI water. Fourth, the fabricated gas sensor was placed in the isolated chamber and surrounded with synthetic air with ethanol gas which is one of the key gasses in breath, controlled by mass-flow controller. Temperature was controlled (75-95℃) and UV was exposed to the sensor to enhance the reaction between the sensor and the gas. The resistance change of the sensor was recorded by a Keithley 2400 sourcemeter before and after inducing the gas. The ZnO deposition condition on the fabrics was examined using a scanning microscope (SEM) and X-ray diffraction (XRD).

Results/Conclusions. The use of conductive threads as electrodes on the gas sensor remained stable and prevented electronic shortage, even after the cleaning process when producing a gas sensor using ZnO. In addition, the ZnO thin film and nanorods were well grown, and the ZnO seed layer was uniformly deposited over the flexible fabric substrates for both polyester and cotton. This research will provide significant contributions for the development of flexible gas sensors applied on fabrics. In future research, various fabric types should be used as substrates and prototyped as a patch and a clothing type.

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