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ORIGINAL ARTICLES

Aluminum Gallium Nitride (GaN)/GaN High Electron Mobility Transistor-Based Sensors for Glucose Detection in Exhaled Breath Condensate

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Abstract

Background:

Immobilized aluminum gallium nitride (AlGaN)/GaN high electron mobility transistors (HEMTs) have shown great potential in the areas of pH, chloride ion, and glucose detection in exhaled breath condensate (EBC). HEMT sensors can be integrated into a wireless data transmission system that allows for remote monitoring. This technology offers the possibility of using AlGaN/GaN HEMTs for extended investigations of airway pathology of detecting glucose in EBC without the need for clinical visits.

Methods:

HEMT structures, consisting of a 3-μm-thick undoped GaN buffer, 30-Å-thick $Al_{0.3}Ga_{0.7}N$ spacer, and 220-Å-thick silicon-doped $Al_{0.3}Ga_{0.7}N$ cap layer, were used for fabricating the HEMT sensors. The gate area of the pH, chloride ion, and glucose detection was immobilized with scandium oxide (Sc_2O_3), silver chloride (AgCl) thin film, and zinc oxide (ZnO) nanorods, respectively.

Results:

The Sc_2O_3-gated sensor could detect the pH of solutions ranging from 3 to 10 with a resolution of ~0.1 pH. A chloride ion detection limit of 10^{-8} *M* was achievedt with a HEMT sensor immobilized with the AgCl thin film. The drain–source current of the ZnO nanorod-gated AlGaN/GaN HEMT sensor immobilized with glucose oxidase showed a rapid response of less than 5 seconds when the sensor was exposed to the target glucose in a buffer with a pH value of 7.4. The sensor could detect a wide range of concentrations from 0.5 n*M* to 125 μ*M*.

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Abbreviations: (Ag) silver, (AgCl) silver chloride, (AlGaN) aluminum gallium nitride, (Ar) argon, (Au) gold, (DI) deionized, (EBC) exhaled breath condensate, (GO_X) glucose oxidase enzyme, (HCl) hydrogen chloride, (HEMTs) high electron mobility transistors, (ICP) inductively coupled plasma, (MBE) molecule beam epitaxy, (PBS) phosphate-buffered saline, (Pt) platinum, (RF) radio frequency, (Sc_2O_3) scandium oxide, (SiNx) silicon nitride, (Ti) titanium, (ZnO) zinc oxide

Keywords: AlGaN/GaN, chloride ion, glucose, HEMT, noninvasive detection, pH, sensor

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Abstract cont.

Conclusion:

There is great promise for using HEMT-based sensors to enhance the detection sensitivity for glucose detection in EBC. Depending on the immobilized material, HEMT-based sensors can be used for sensingt different materials. These electronic detection approaches with rapid response and good repeatability show potential for the investigation of airway pathology. The devices can also be integrated into a wireless data transmission system for remote monitoring applications. This sensor technology could use the exhaled breath condensate to measure the glucose concentration for diabetic applications.

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