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Polydiacetylene-based selective NH_3 gas sensor using Sc_2O_3/GaN structures

G. S. Lee[1], **C. Lee**[1], **H. Choi**[1], **D. J. Ahn**[*, 1], **J. Kim**[*, 1], **B. P. Gila**[2], **C. R. Abernathy**[2], **S. J. Pearton**[2], and **F. Ren**[3]

[1] Department of Chemical & Biological Engineering, Korea University, Anam-dong 5–1, Sungbuk-gu, Seoul, Korea
[2] Department Materials Science Engineering, University of Florida, Gainesville, FL 32611, USA
[3] Department of Chemical Engineering, University of Florida, Gainesville, FL 32611, USA

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PDA(Polydiacetylene)-supramolecules were successfully immobilized on the surface of Sc_2O_3/GaN/Sapphire structures for use as selective NH_3 gas sensors. The Sc_2O_3 was epitaxially grown on GaN/Sapphire templates by molecular beam epitaxy (MBE) to replace the non-uniform native Ga_2O_3. The GaN-based PDA gas sensors showed excellent selectivity for ammonia detection after the end-functional group was modified to respond to this specific gas species.

There is significant interest in the development of the next generation gas-sensors, bio-sensors, and information processing devices using the integration of both organic materials and inorganic materials for low cost, large area, and multi-functionality. Promising candidates in this regard are GaN-based diodes and field effect transistors functionalized with specific organic overlayers [1–11]. GaN substrates and the sapphire on which epitaxial GaN is commonly grown are transparent in visible spectral region, which makes the optical characterization from the back side of substrate convenient. The use of GaN-based materials in the area of bio- or chemosensors has been limited due to the absence of high quality oxides. The native SiO_2 of Si provides the oxygen-terminated surface essential for attaching functional blocks such as amine, biotin, and avidin. Without a reproducible high quality oxide on the surface, it is difficult to functionalize the surface of semiconductors. The native gallium oxide of GaN is generally unstable and non-uniform. Various oxides have been tried for surface passivation and gate dielectrics for GaN, including gadolium oxide, SiO_2, gallium oxide, scandium oxide, and magnesium calcium oxide by Molecular Beam Epitaxy, thermal oxidation, wet oxidation, and Plasma-Enhanced Chemical Vapor Deposition (PECVD) techniques [12–17]. Sc_2O_3 films deposited by rf plasma-enhanced MBE have been shown to provide low interface state densities (in the 10^{11} eV^{-1} cm^{-2} range) on n- and p-GaN and also are effective in reducing the effect of surface states on current collapse in AlGaN/GaN high electron mobility transistors (HEMTs). The Sc_2O_3 has a crystal structure similar to bixbyite with a 9.2% lattice mismatch to GaN, a high dielectric constant (14) and reasonable bandgap (6.0 eV) [13, 14, 17].

For functionalization of the Sc_2O_3/GaN surface, we focused on conjugated, self-assembled supramolecules because of their good stimulus propagation to neighboring molecules and unique electrical and optical characteristics. Among many different conjugated polymers (polypyrrole, polythophene, phenyleneethylene, polydiacetylene), polydiacetylene supramolecules dispersed in aqueous media have

[*] Corresponding authors: e-mail: ahn@korea.ac.kr, hyunhyun7@korea.ac.kr