Novel Normally-off GaN HEMT Device Structure by Using Nano-rods Technology

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The High Electron Mobility Transistor (HEMT) based on AlGaN/GaN hetero-structure device has low resistance characteristic by taking advantage of two-dimentional electron gas (2DEG) induced by piezoelectric polarization mechanism. However, the conventional HEMT device has a negative threshold voltage and therefore it becomes a normally-on device and thus it is rather inconvenient of use, especially in some safety concerned applications. Although many papers [1][2] adopted various methods to form normally-off GaN devices, it sacrificed device performance in some cases. The purpose of this investigation is to develop a normally-off device with no impact on the drain current by proposing a novel imprint method to form nano-rod or nano-strip gate structures. A nano-rod hard mask was formed by thermally annealed Ni particles at the gate region, followed by partially etching AlGaN and implanting F-ion by SF_6 plasma irradiation. And then the P-type GaN is selectively grown on the AlGaN to help to raise the potential of the 2DEG channel region. This device combines all the benifits of F-ion implantation, p-GaN gate and recessed gate devices to exhibit the normally-off property. Owing to the AlGaN layer under the gate is not fully removed, the piezoelectric polarization can still be high enough so that the drain current can be almost comparable to the conventional HEMT dvice. Figure 1 illustrates the schematic structure in this investigation and the schematic illustration and cross-sectional TEM image of nano-rod structure are shown in Fig. 2. Some key process steps are as shown in Fig. 3. and the plan view of nano-rod or nano-string structures are shown in Fig. 4. The engineering run of the novel device is under investigation and the nano-rod scheme for the gate shows very promising for realizing both normally-off and low on-resistance properties.

References:

[1] C. Chen, et al., IEEE Electron Device Letters, vol. 32, no. 10, p. 373, 2011.

[2] R. Chu, et al., IEEE Electron Device Letters, vol. 32, no. 5, p. 632, 2011.

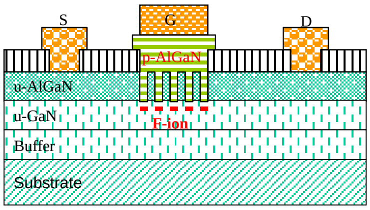
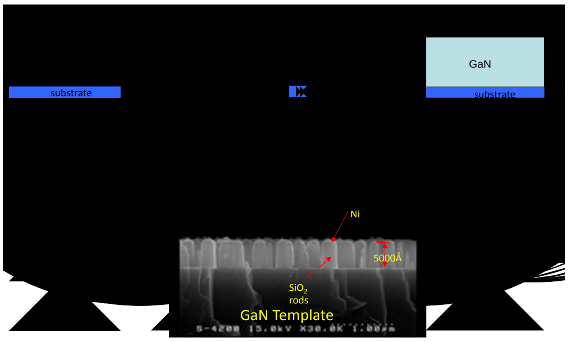


Fig.1 Schematic representation of device cross-sectional structre in this investigation.



(e) TEM picture of cross-sectional nano-rod structure

Fig.2 Schematic representation of Nano-rod formation and cross-sectional TEM image of Nano-rod structure.

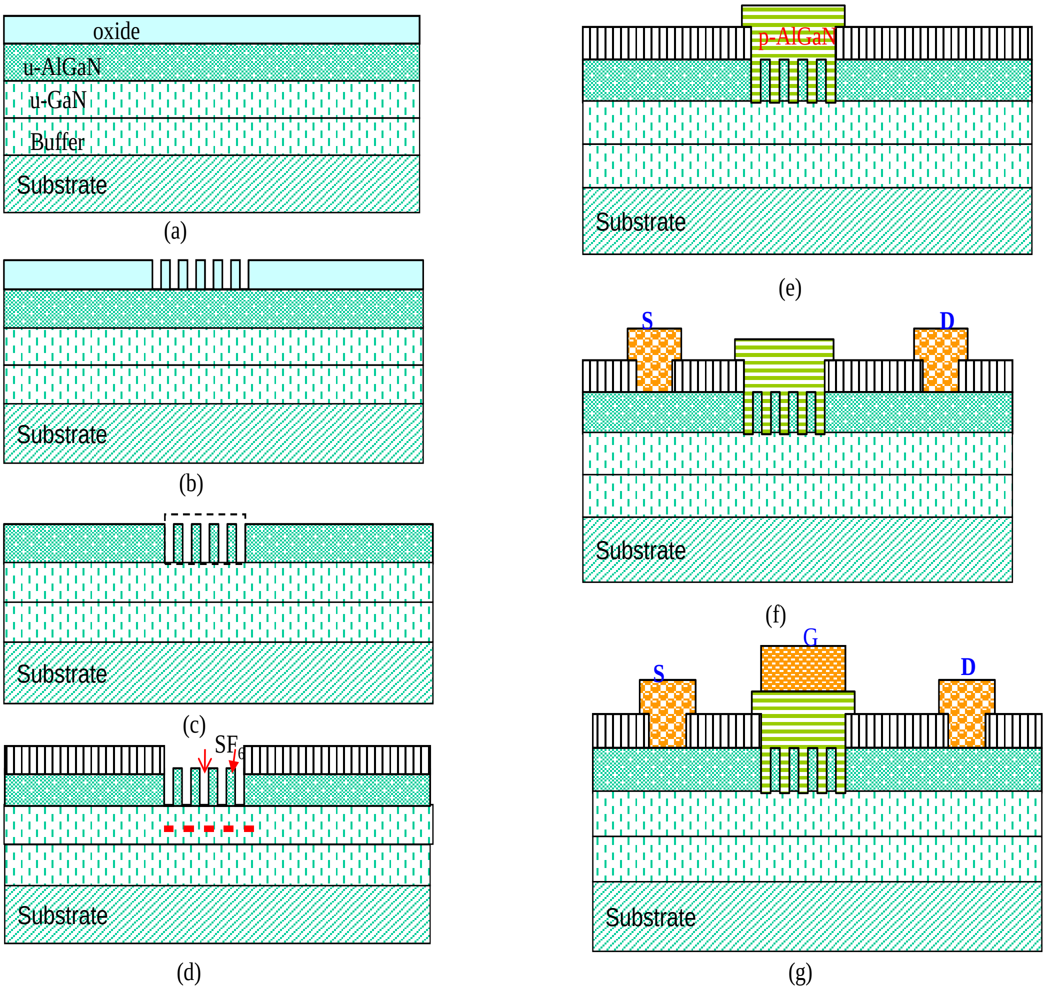


Fig.3 Key process steps for the novel device.

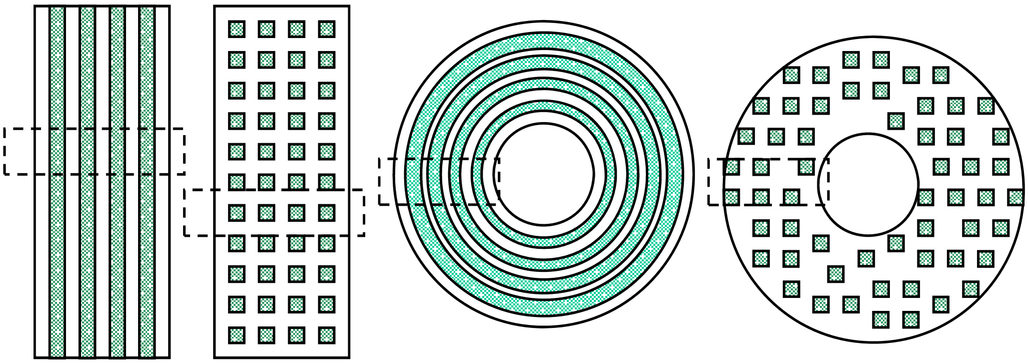


Fig.4 Plan view of various nano-rod and nano-string structures.