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Investigation of the current stability of AlGaN/GaN high electron mobility transistors in various liquid/solid interface on the gate area

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AlGaN/GaN high electron mobility transistors (HEMTs) have demonstrated great potential for high power, high frequency and sensor applications at room temperature and elevated temperature. For these applications, the stability of devices is a very important factor. We verify the stability of devices with different sensing surface by using a simple method. The results showed not only the stability of sensing surface, but also the temperature dependence of devices.

Figure 1 (a) and (b) show the schematic of AlGaN/GaN HEMTs and the top-view of the devices, respectively. The HEMTs was constructed by a 3 μm-thick undoped GaN buffer layer, a 150 Å-thick undoped $Al_{0.25}Ga_{0.75}N$, a 10 Å-thick undoped GaN cap layer, and a 100Å-thick gold layer on the gate region. Photoresist was used to encapsulate the source/drain regions, only gate regions were opened to allow liquid solutions to across the surface. Figure 2 (a) shows the current of HEMTs with different sensing surface at different temperature in deionized water solution (pH=6). The black line, red line, and blue line are the results of HEMTs with gate metal, HEMTs without gate metal covered by photoresist, and HEMTs without gate metal and photoresist, respectively. For a fixed drain bias, the current of black line and red line have linear relationship with temperature by -4 μA/℃ and -4.92 μA/℃, respectively. Figure 2 (b) shows the current of HEMTs without gate metal at different air temperature and in different solutions with different temperature. For a fixed drain bias, the current of air and vacuum oil have linear relationship with temperature by -4 μA/℃ and -3.44 μA/℃, respectively.

In Figure 3 shows the stability of HEMTs with and without gate metal, respectively. The deionized water solution (pH=6) temperature of HEMTs with gate metal and without gate metal are 21.19 ℃ and 22.35 ℃, respectively. The vacuum oil temperature of HEMTs without gate metal is 22.11 ℃. The current variation of HEMTs with gate metal in deionized water solution (pH=6) and of HEMTs without gate metal in vacuum oil are less than 0.5 μA. However; the current variation of HEMTs without gate metal in deionized water solution (pH=6) is very large.

In summary, the current of HEMTs without gate metal in polar solution is unstable. But, it is stable in air and vacuum oil. The possible reason is ions in polar solutions probably attracted to the charged surface of AlGaN when a drain bias is applied, so the current of HEMTs without gate metal in polar solutions are unstable. The current fluctuation of deionized water solution (pH=3), phosphate buffer solution (pH=7.54), and 150 mM sodium chloride solution are larger than deionized water solution (pH=6). The possible reason is the deionized water solution (pH=3), phosphate buffer solution, and sodium chloride solutions consisting of more ions than deionized water solution (pH=6). More ions attracted to the charged surface lead to the larger current fluctuation. However, ions in air and vacuum oil can't be ionized and be attracted to the charged surface of AlGaN when a drain bias is applied, so the current of HEMTs without gate metal in air and vacuum oil are stable and only be affected by temperature. Furthermore, the current of HEMTs with gate metal and HEMTs without gate metal covered by photoresist in deionized water solution (pH=6) are stable. The possible reason is the metal and photoresist covering the surface of AlGaN. So, the ions can't be attracted to the charged surface of AlGaN when a drain bias is applied, the current of HEMTs with gate metal and HEMTs without gate metal covered by photoresist are stable and only be affected by temperature. We will further confirm the reasons in the future.

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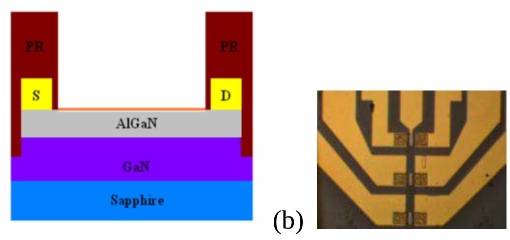
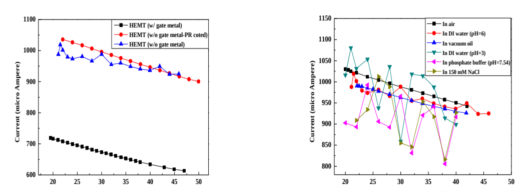


(a) (b)

Figure 1. (a) Schematic of the AlGaN/GaN HEMTs. (b) The top-view of the AlGaN/GaN HEMTs.



(a) (b)

Figure 2. (a) The current of HEMTs with different sensing surface at different temperature in deionized water solution (pH=6). (b) The current of HEMTs without gate metal at different air temperature and in different solutions with different temperature.

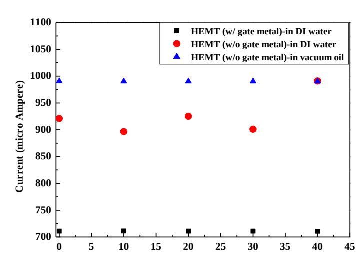


Figure 3. The stability of HEMTs with gate metal and without gate metal, respectively .