Ultra-high sensitive Mercury ion detector using AlGaN/GaN HEMT

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Abstract: Mercury is a naturally occurring element that occurs in water, soil and air. Mercury has toxic effects on the nervous, digestive, immune system, lungs, kidney, skin and eyes. World Health Organisation (WHO) reports that even a small amount of Mercury can lead to serious health problems and is also a threat to the development of children in utero as well as in their early life. As per the WHO norms, the naturally occurring level of Mercury in groundwater and surface water is less than 0.5 µg/litre (0.5 ng/ml) [1]. A small number of groundwater and shallow wells have been surveyed in the USA which shows to have Mercury levels that exceeds the maximum contaminant level of 2 µg/litre (2 ng/ml) set by the US Environmental Protection Agency for drinking water [1]. Therefore, high sensitivity detectors are required to timely detect the nano level of Mercury in drinking water.

In this paper, we report on an ultra-high sensitive GaN HEMT based sensor for the detection of nano level amount (0.27 ng/ml) of Mercury contamination in water. The developed sensor consists of a 22 nm $Al_{0.25}Ga_{0.75}N$ followed by a Fe doped GaN buffer layer. In order to increase the sensitivity of the sensor, the interdigital gates are proposed. The novel Interdigital gate (ID) design has multiple gates in electrode fashion for higher sensitivity. As per our knowledge, the design has not been published for HEMT sensors. The source-drain distances used for sensing are 25 µm and 50 µm. The measured drain currents at a V_{ds} of 3.3 V for both the designs are 0.18 mA/mm and 0.11 mA/mm respectively. The sensor is packaged using low temperature co-fired ceramic (LTCC) technique for the robust operation in a harsh environment. Fig.1 shows packaged device and the detection of nM mercury in DI water. A handheld and portable electronic system has been also developed, which shows a good response to the nM solution of Mercury as shown in fig.2. The drain current is measured in dry conditions and then the sensor is immersed into DI and nM Mercury solutions subsequently. The Mercury is detected by the change in the drain current due to the generation of the surface potential over the gate area. It shows a good change of 6.66% in drain current when it is immersed into 1 nano-molar Mercury solution.

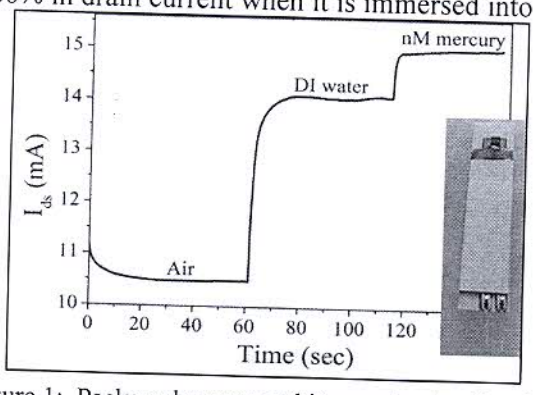

Figure 1: Packaged sensor and its running test for air, DI water and nM mercury solution at V_{ds}=3.3 V

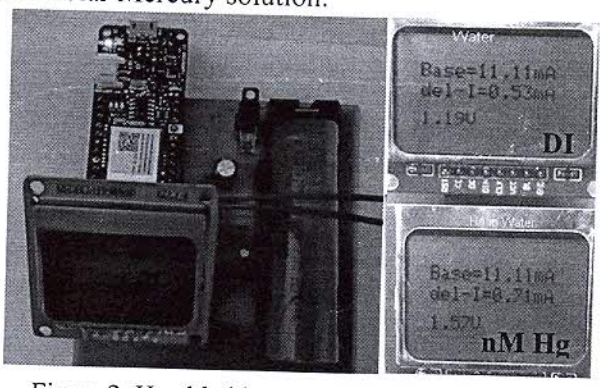

Figure 2: Hand-held system and its response to DI water and 1 nm concentrated Mercury water

References

[1] https://www.who.int/water_sanitation_health/dwq/chemicals/mercuryfinal.pdf