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TEMPERATURE DEPENDENCE OF 1/*f* NOISE IN GALLIUM NITRIDE EPITAXIAL LAYER

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1/f noise investigation was performed on n-GaN epitaxial layer grown on sapphire. The variation of spectral power density of voltage fluctuations density was observed as a function of frequency (100-50 *Hz*) *and it showed the 1/f spectra. This type of behavior was attributed to the presence of traps. The variation in spectral power density of voltage fluctuations with temperature was also observed with in the temperature range* 80 *K and* 300 *K and it was found to be slightly increasing with temperature. It was attributed to the trapping-detrapping process of charge carriers by the defects. Four probe configuration was used for noise measurement and contacts were made with indium. To check the stability and ohmic behavior of contacts, I-V measurements were performed with in the temperature range* 80-325 *K.*

Keywords: *1/f NOISE, SPECTRAL POWER DENSITY, VOLTAGE FLUCTUATIONS, OHMIC CONTACTS, TRAPS, TEMPERATURE.*

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1. INTRODUCTION

The study of the 1/*f* noise is important both from fundamental as well as technological point of view, since it sets the limit to the ultimate resolution achieved with the devices made from the materials [1-3]. If a constant voltage is applied to a semiconductor sample or device, to a resistor or vacuum tube, the current will exhibit fluctuations. The frequency spectrum is in general constant at high frequencies, superimposing with shot-noise components. However, at low frequency f, ($f < 100$ Hz), spectral power density of voltage fluctuations is found to be proportional to $1/f^{\gamma}$ (γ in the range 0.8-1.2) [6]. This kind of noise is frequently called as low-frequency noise, flicker noise or 1/*f* noise. The 1/*f* noise observed in semiconductors arises due to presence of traps having wide distribution of activation energies [2]. Although the low-frequency fluctuation phenomenon are also observed in other non-electronic systems, such as earth rotation frequency, loudness of speech, nerve membrane potential, highway traffic current etc, none of them is as crucial as the noise in electronic systems because the noise directly deteriorates the device and system performances [2]. We report here 1/*f* conduction noise studies performed on MOCVD grown n-GaN epitaxial layer on sapphire. Ohmic contacts were made with indium and in order to check the stability of contacts, I-V measurements were performed from 80 K to 325 K. The variation of spectral noise density with temperature was also investigated.

2. EXPERIMENTAL WORK

To measure 1/*f* noise and I-V, we had employed standard four probe detection method. The sample used in present study was cut from 2 inch epitaxial layer grown on sapphire. The dimension of sample was 1cm by 1cm by 3 μm. Sample was ultrasonically cleaned using TCE, acetone, DI water and finally dipped for 2 min in Hydrochloric acid. Contacts were made manually with indium and in order to ensure the ohmic behaviour and thermal stability of contacts, I-V measurements were done from 80 K to 325 K. For I-V and noise measurement, the sample was mounted in the cryostat and a rotary pump was used to have a vacuum of the order of $2.5 \cdot 10^{-2}$ mbar. The electrical connections from the sample were taken out (from cryostat to measuring circuitry) using the vacuum compatible BNC cables and connectors.

For I-V measurements, Keithley 2612 A source meter was used and voltage (– 5 V to + 5 V) was applied across the sample. A heater of 50 W, 40 V was used for heating from liquid nitrogen temperature to 325 K. Lakeshore 340 temperature controller was used for controlling the temperature and Pt-100 sensor was used for detecting temperature.

1/*f* noise was measured using the four probe method. The setup for the noise is shown below. A dc current was passed through the two probes of the sample using battery operated dc current source (consisting of a 9 V battery and a variable resistance). The voltage developed across the sample was fed to a low noise preamplifier (model SR 552, Stanford, USA). The preamplifier blocks the dc component of voltage and allows only the ac component to pass through it. The amplified ac signal was then fed to a HP spectrum analyser that displayed the spectral power density of voltage fluctuation (S_V) as a function of frequency (f). For determining 1/*f* noise with frequency, we took the noise spectra with and without (consisting of preamplifier + thermal noise) current. Then the latter spectrum was subtracted from the former, and we obtained pure 1/*f* noise spectrum that was due to the conductivity fluctuations inside the sample. The background noise spectrum showed a 1/*f* contribution arising from the preamplifier for frequencies < 5 Hz. Above 5 Hz, background noise remains constant (frequency independent white noise). We could achieve a sensitivity of $2.5 \cdot 10^{-18}$ V ^{2}/Hz at room temperature and 10 Hz.

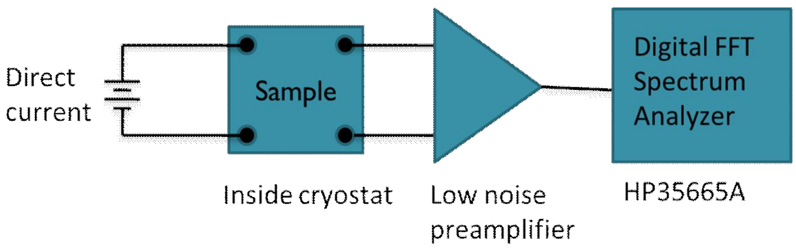

Fig. 1 *– 1/f noise measurement setup*

In order to study the temperature variation, the sample was loaded in the cryostat. The temperature was varied between 80 K and 300 K using Lakeshore 340 temperature controller. Pt - 100 sensor was used for detecting the temperature and cartridge heater was used for the heating purpose. Before taking the noise reading at any value, the temperature was stabilized within 10 mK.

3. RESULTS AND DISCUSSION

Contacts play an important role in $1/f$ noise studies [5, 7] so it is very important to check the stability of contacts with in the temperature range in which $1/f$ noise investigation has to be done. So in order to check the stability of contacts, I-V measurements were done at various temperatures in the temperature range 80 K – 325 K. The straight line at each temperature ensures that contacts were ohmic. I-V at different temperatures for n-GaN epitaxial layer grown on sapphire with indium contacts is shown in Fig. 2.

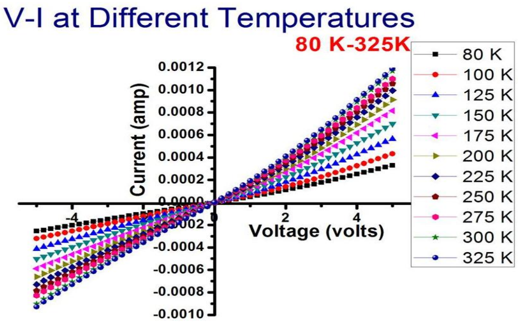

***Fig. 2** – V-I at different temperatures*

The variation in spectral power density of voltage fluctuations (S_{v}) with frequency (f) was observed at various temperatures in the frequency range 100 mHz to 50 Hz. The variation in spectral power density of voltage fluctuation with frequency at 80 K and 300 K is shown in Fig. 3. Theoretical $1/f$ line was also plotted. The deviation of the experimental results from the theoretical $1/f$ line can be explained by Hooge Model [1], which states that spectral power density of voltage fluctuations (S_{v}) varies as $1/f^{\gamma}$ and γ varies between 0.8-1.2.

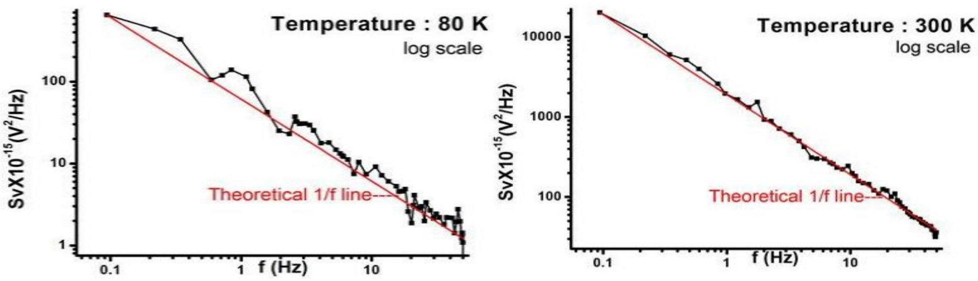

***Fig. 3** – Spectral voltage noise density as a function of frequency at 80 K and 300 K*

$1/f$ noise is more at lower frequency side and it is due to presence of large number of traps having wide distribution of relaxation time and it is found that in semiconductors spectral power density becomes frequency dependent [3]. If τ is the relaxation time for a trap, then spectral power density is given as

$$S(f) \sim 2\tau / (1 + (2\pi f\tau)^2) \quad (1)$$

At the lower frequency ($f << 1/\tau$,) S (f) = constant and at high frequency ($f >> 1/\tau$), S (f) ~ $1/fI$. In the presence of distribution of relaxation time, by averaging the spectrum at different relaxation time, we get 1/*f* spectrum [2].

At $f = 10$ Hz, the variation of spectral power density of voltage fluctuations (S_V) with temperature was observed and it is shown in Fig. 4. S_V was found to be slightly increasing with in temperature range 80-300 K. As temperature increases, more defects will become mobile and participate in the trapping-detrapping of charge carriers [4]. So fluctuation in the conductivity is more due to this trapping and detrapping process, spectral power density of voltage fluctuations increases.

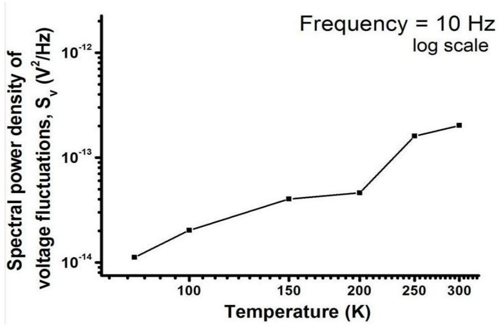

Fig. 4 – *Spectral voltage noise density as a function of temperature at f* = 10 *Hz*

4. CONCLUSION

We have observed the 1/*f* variation of spectral noise voltage density with frequency at the lower frequency side (100-50 Hz). The origin of this type of noise in semiconductors is attributed to the presence of traps. The temperature variation of the noise is also investigated ant it is attributed to the trapping-detrapping process. Contacts plays an important role in 1/*f* noise studies so I-V was done at each temperature of the noise measurement and at each temperature, contacts were found to be ohmic.

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