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DETECTION OF SIGNS OF DEGRADATION OF PHOSPHIDE-GALLIUM LEDS BY THE LEVEL OF LOW-FREQUENCY NOISES

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Abstract. The results of measurements of low-frequency noises of light-emitting diodes are considered. It has been established that LEDs with an increased level of noise or with anomalous their growth kinetics in the first hours of testing are potentially unreliable, that is, they show further rapid or catastrophic degradation (failure). The prospects of noise measurements for the selection of LEDs in terms of reliability are shown.

Keywords: LED, noise, degradation

ВИЯВЛЕННЯ ОЗНАК ДЕГРАДАЦІЇ ФОСФІД-ГАЛІЄВИХ СВІТЛОДІОДІВ ЗА РІВНЕМ НИЗЬКОЧАСТОТНИХ ШУМІВ

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Анотація. Розглядаються результати вимірювань низькочастотних шумів світлодіодів. Встановлено, що світлодіоди з підвищеним рівнем шумів або з аномальною кінетикою зростання в перші години випробувань потенційно ненадійні, тобто виявляють надалі швидку чи катастрофічну деградацію (відмова). Показана перспективність шумових вимірів для відбору світлодіодів за показниками надійності.

Ключові слова: світлодіод, шум, деградація

The assessment of the reliability of semiconductor devices that are part of electronic devices is becoming increasingly important due to the complication of these devices and the increasing requirements for their reliability. An important feature of LEDs is that there is a gradual decrease in their luminous flux, while the issue of reducing the flux, that is, LED degradation, is of particular relevance.

The degradation of LEDs is studied by various authors from different angles of view, due to technological and metrological capabilities and challenges. The paper [1] describes the results of accelerated tests of gallium phosphide LEDs in the forced mode. This allows for a relatively short test time to determine the median resource of a batch of LEDs – the time to halve the brightness. At the same time, it was not possible to determine the service life of each LED separately.

The works [2–3] describe testing of LEDs at elevated temperatures and current densities. The decisive role of current density in the degradation process was confirmed and it was recommended to avoid high current loads.

Measurements of the noise characteristics of semiconductor devices also make it possible to draw conclusions about their reliability [4–5]. Of greatest interest are low-frequency noises, which are caused by various defects in the structures of devices. These noises are sometimes called flicker noise or 1/f noise. Experimental studies have shown that often the main cause of 1/f noise is the presence of states near the interface between the semiconductor and protective layers. Fluctuations in the density of surface states cause a change in the space charge in the depletion region and, as a consequence, change the potential barrier [6]. This entails current fluctuations through the p-n junction (noises).

Various volumetric inhomogeneities (impurities, dislocations, microcracks), being trapping centers, also strongly affect the passage of current through the p-n junction. As a result of relatively slow diffusion processes, the impurity concentration in the region of the p-n junction is equalized, the transition is broadened, and impurities diffuse along dislocations, which is accompanied by an increase in low-frequency noises. Thus, an increase in noise is a sign of degradation of the active regions of the semiconductor structure, which can lead to a complete failure.

The purpose of the article is to develop a method for rejecting unreliable light emitting diodes (LEDs), in a short test time, using the example of gallium phosphide LEDs.

In this work, gallium phosphide LED sign indicators of the ALS321A type were studied the dependence of their noise and light characteristics were investigated. The light-emitting segments, identical in properties, were turned on one at a time, since when all segments are turned on simultaneously, their temperatures are different due to their different location on the sign indicator. The maximum allowable current of 25 mA was passed through the segments. The spectral density of the current noise was measured from the voltage drop across the etalon resistor with a selective microvoltmeter V6–2. The brightness of the glow was measured by a silicon photocell in the short circuit mode in relative units. The Noise Power Spectral Density (NPSD) is obtained by multiplying the current noise by the LED voltage and dividing by the bandwidth of the microvoltmeter (0.15 of the set frequency).

The measurement results are shown in Fig.1–3.

Figure 1a shows the NPSD (denoted by Q) of a typical LED sample No. 15, segment A, measured before operation (curve 1), after 1 day (curve 2), 3 days (curve 3) and 8 days (curve 4). Figure 1b shows the dependences of the NPSD on the operating at frequencies of 100 Hz (curve 1), 180 Hz (curve 2), and 540 Hz (curve 3). As can be seen from Fig. 1a, b the noise spectrum corresponds to the form 1/f, and as time goes by, the noise sharply increases in the first 10 days, becoming practically constant in the future up to 50 days (1200 hours) and slightly increasing after this period. Further operation showed a high brightness stability of this LED.

Figure 2a shows the noise characteristics of LED sample No. 31, segment G, measured before operation (curve 1), after 2 days of operation (curve 2), and after 10 days of operation (curve 3).

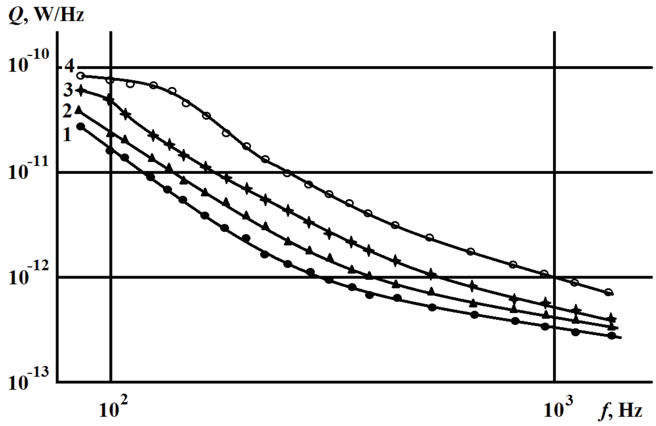

Fig. 1a. NPSD LED sample No. 15, segment A, with operation: 1–0 day, 2–1 day, 3–3 days, 4–8 days.

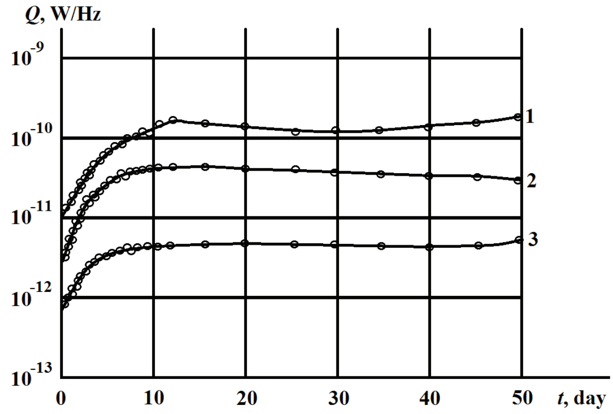

Fig. 1b. Dependences of NPSD LED sample No. 15, segment A, on the operating time at frequencies: 1–100 Hz, 2–180 Hz, 3–540 Hz.

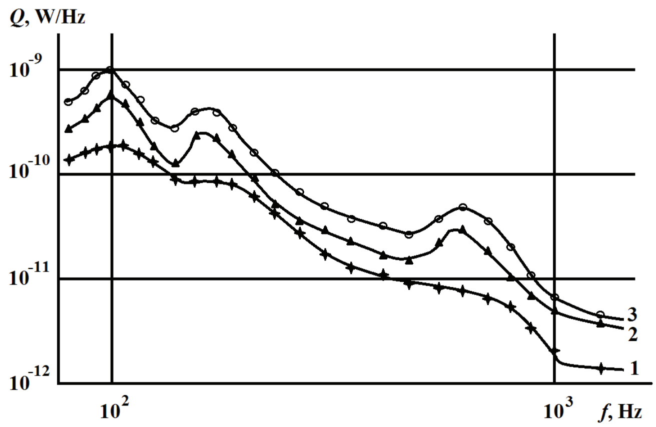

Fig. 2a. NPSD LED sample No. 31, segment G, with operation: 1–0 day, 2–2 days, 3–10 days.

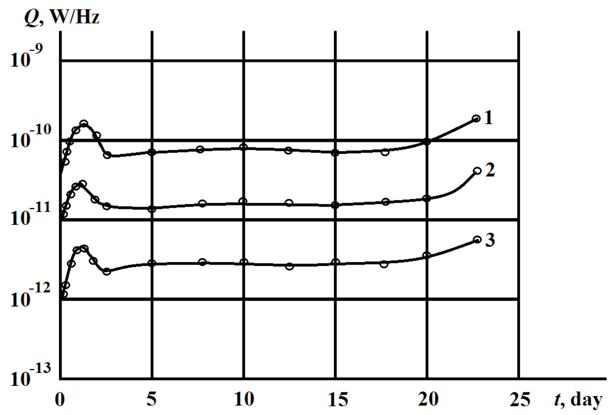

Fig. 2b. Dependences of NPSD LED sample No. 31, segment G, on the operating time at frequencies: 1–200 Hz, 2–500 Hz, 3–1000 Hz.

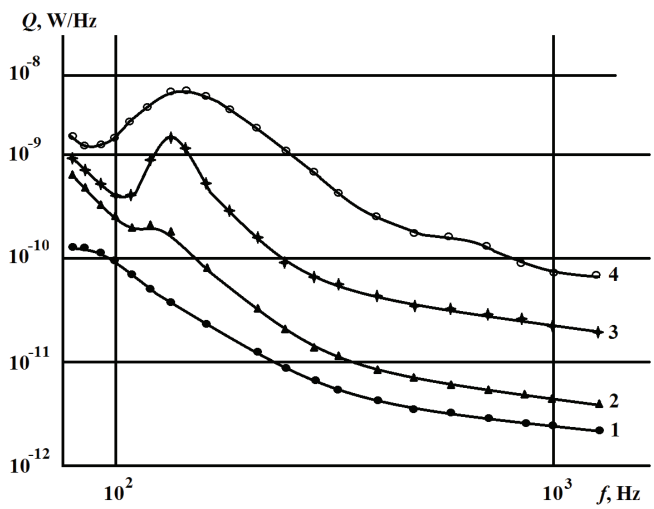

Fig. 3a. NPSD LED sample No. 9, segment C, with operation: 1–0 day, 2–3 day, 3–5 days, 4–8 days.

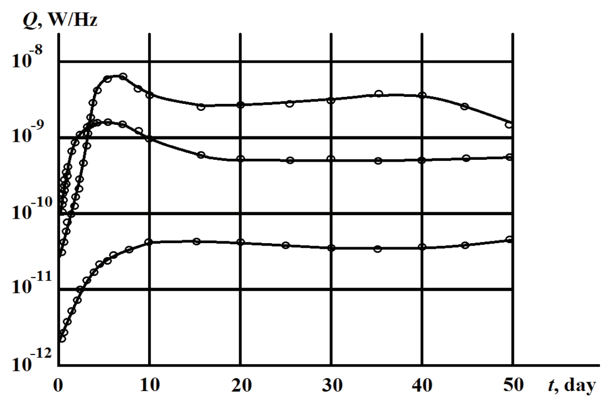

Fig. 3b. Dependences of NPSD LED sample 9, segment C, on the operating time at frequencies: 1–80 Hz, 2–160 Hz, 3–1000 Hz.

Figure 2b shows the dependences of the noise spectral density on the operating time at frequencies of 200 Hz (curve 1), 500 Hz (curve 2), and 1000 Hz (curve 3). As can be seen from Fig. 2a, b, the noise spectrum of the original LED differs from 1/f by the presence of three blurred maxima in the frequency range of 100–1000 Hz, and by the fact that the after operating in the first 1–2 days, the noise increases sharply in the future. After 530 hours of operation, this LED segment experienced catastrophic degradation (failure). It should be noted that the initial noise level at a frequency of 100 Hz was an order of magnitude higher than that of LED No. 15, segment A.

Figure 3a shows the NPSD LED No. 9, segment C, measured before operation (curve 1), after operation for 3 days (curve 2), 5 days (curve 3), and 8 days (curve 4). Figure 3b shows the dependences of the NPSD on the operating time at frequencies of 80 Hz (curve 1), 160 Hz (curve 2), and 1000 Hz (curve 3). As can be seen from Fig. 3a, b, the noise spectrum of the original LED is characterized by an increased level, and with operation, it becomes anomalous in the form of a predominance of noise in the region of 160 Hz and, in general, it have a very high noise level in the entire frequency range. This LED rapidly begins to decrease in brightness, the emission spectrum shifts to the long-wavelength region, i.e. significant degradation is observed.

In conclusion, it should be said that measuring the noise characteristics of LEDs in the low-frequency region, when identifying devices with an increased initial noise level, allows them to be rejected as potentially unreliable. The identification of devices with a non-monotonous initial 1/f noise spectrum and with an anomalous growth of noise in the first day at the maximum allowable current makes it possible to reject specimens that are prone to catastrophic degradation (failure) within several tens of days of operation.

The considered measures make it possible to significantly improve the reliability indicators of the studied LED batch either immediately or in 2–3 days of testing at the stand.

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Summary

The results of measurements of low-frequency noises of light-emitting diodes are considered. It has been established that LEDs with an increased level of noise or with anomalous their growth kinetics in the first hours of testing are potentially unreliable, that is, they show further rapid or catastrophic degradation (failure). Measurement of the noise characteristics of LEDs in the low-frequency region, when identifying devices with an increased initial noise level, allows them to be rejected as potentially unreliable. The identification of devices with a non-monotonous initial 1/f noise spectrum and with an anomalous growth of noise in the first day at the maximum allowable current makes it possible to reject specimens that are prone to catastrophic degradation (failure) within several tens of days of operation.

The prospects of noise measurements for the selection of LEDs in terms of reliability are shown.

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Реферат

Розглядаються результати вимірювань низькочастотних шумів світлодіодів. Встановлено, що світлодіоди з підвищеним рівнем шумів або з аномальною кінетикою зростання в перші години випробувань потенційно ненадійні, тобто виявляють надалі швидку чи катастрофічну деградацію (відмова). Вимірювання шумових характеристик СВД в області низьких частот при виявленні приладів з підвищеним вихідним рівнем шумів дозволяє відбраковувати їх як потенційно ненадійні. Виявлення ж приладів з не монотонним вихідним спектром 1/f шуму і з аномальним ходом зростання шумів у першу добу при максимально допустимому струмі дозволяє відбраковувати екземпляри, схильні до катастрофічної деградації (відмови) протягом декількох десятків діб експлуатації.

Показана перспективність шумових вимірів для відбору світлодіодів за показниками надійності.

Ключові слова: світлодіод, шум, деградація