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DLTS SPECTROMETER MODIFICATION TO RETRIEVE TIME DEPENDENCIES OF CAPACITY RELAXATION

A principal hardware changes to existing automated relaxation spectrometers of deep levels in semiconductors for complete relaxation curves measurements are offered. The results are demonstrated the diode series D231A.
Keywords: DLTS, spectrometer, capacity relaxation, deep levels.

Introduction. The DLTS method [5], which is proposed in 1974 by Lang, allows observing the processes of emission of carriers from the deep energy levels during the thermal scan and gets the key parameters of deep centers such as the thermal capture cross section, activation energy and concentration of defects.

Due to the method's simplicity and high measurement speed and accuracy, the method has gained great popularity, which led to the development of automated systems for the of semiconductor materials studying. One such system was established in the 90s at the Kiev National University named after Taras Shevchenko at the Radiophysics Faculty. In contrast to the classical method, in which capacity difference in two time points are measured, that system used the correlation function, which measures the difference between averaged values of capacity during two time intervals [1]. As a result, it allowed improving the signal-to-noise ratio in the spectrum and increasing sensitivity to low concentrations of deep levels.

In the above approaches, only two points or two parts of the relaxation curve are processed, but in other parts there is also information that can be used to study the parameters of semiconductor materials. Also technical limitations of method do not allow using emission windows larger than 50ms.

Considering the modern technology requirements to more complete and accurate information that could not be obtained by previous methods of spectroscopy and existing of modern mathematical methods for results processing based on Laplace transformation (Laplace-DLTS) [3]) and artificial neural networks [2,4], the transition to complete relaxation curve measuring approach was made. It also provided an opportunity to use the emission windows rate more than 50 ms.

As a result, the question regarding possibility of modifying existing DLTS system to directly obtain the capacity relaxation curves was raised.

Analysis and researches. Information processing block of typical systems for the spectrum retrieving has the form shown in fig.1 and consists of a high-frequency amplifier, which reinforces signal from semiconductor sample in wide frequency range, and an analog multiplier to select capacity component from signal.

A signal at the entrance of the two-channel boxcar is proportional to the sum of the barrier and relaxation capacities. It has been proposed to measure the described signal by an ADC.

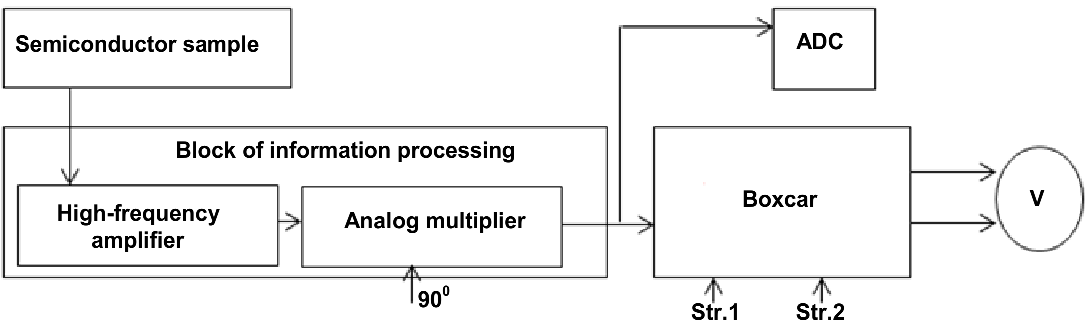

Fig. 1. The partial block diagram of system

Implemented changes allow making temperature scanning of D231A diode. So a family of relaxation curves at different temperatures was retrieved (fig.2).

To check the reliability of the measurements results, the spectrometer's correlation function was programmatically applied to the received data for the spectrum construction (fig.3), and the classical DLTS spectrum for the same diode was measured (fig.4). As you could notice there is the peaks congruence on temperature.

The obtained relaxation curves (fig. 2) represent the sum of a barrier capacity and relaxation capacity caused by the direct emission of carriers from deep centers. So finally we have a signal Cc (T) + Cr (t,T). However, to measure the concentration of deep levels, the measurement of constant capacity component should be performed to retrieve ratio ΔC (T) / Cc (T).

The spectrometer allows using the windows of emission up to 50 ms, that due to the correlation function leads to the maximum bias pulse duration up to 170 ms. It is not enough to finish relaxation from deep levels at certain temperatures, as one can see from presented family of curves (fig.2).

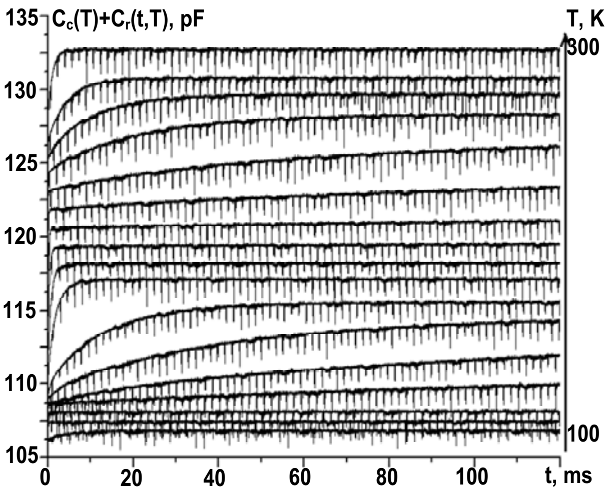

Fig. 2. The family of relaxation curves

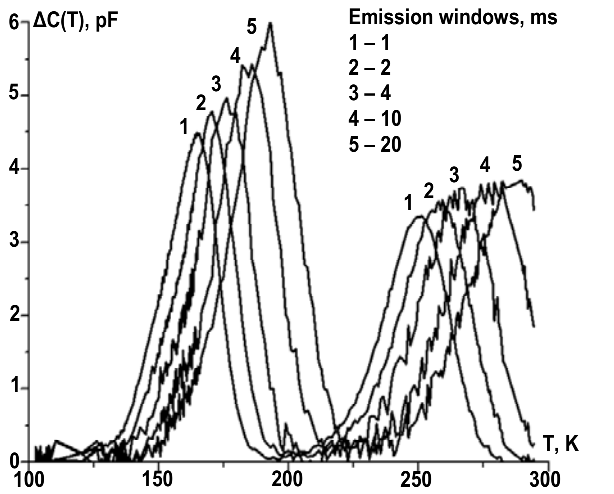

Fig. 3. DLTS diode spectrum based on the programmatically processing of the family of relaxation curves

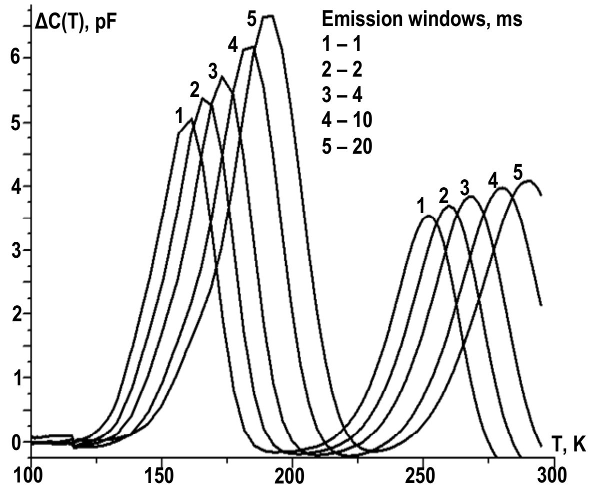

Fig. 4. DLTS diode spectrum

Therefore, modification (dash-dotted line in fig. 5) to the filling and reverse bias (FB) pulse shaper block was proposed. It was decided to remove connections to FB from the low-frequency generator (AG), which is used to control the power supply and the generation of filling and reverse bias pulses. Instead, a permanent voltage impulse was supplied to key 1 to keep it in open state in order to supply a semiconductor with constant reverse bias.

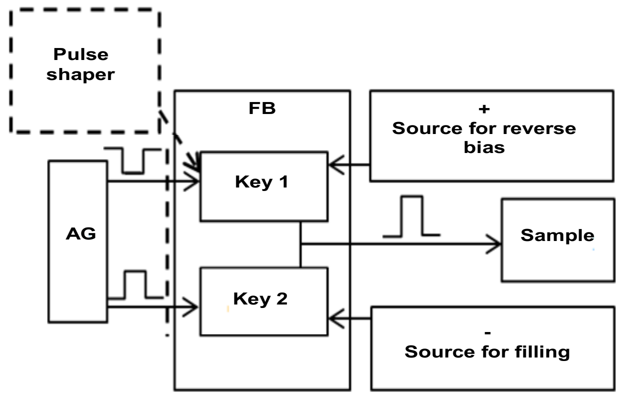

Fig. 5. The block diagram of the filling and reverse bias pulse shaper (FB)

As a result, measurements of the signal constant component and its dependencies on temperature were held (fig.6). The output allowed obtaining ΔC (T) / C_c (T) data required for processing by modern mathematical methods.

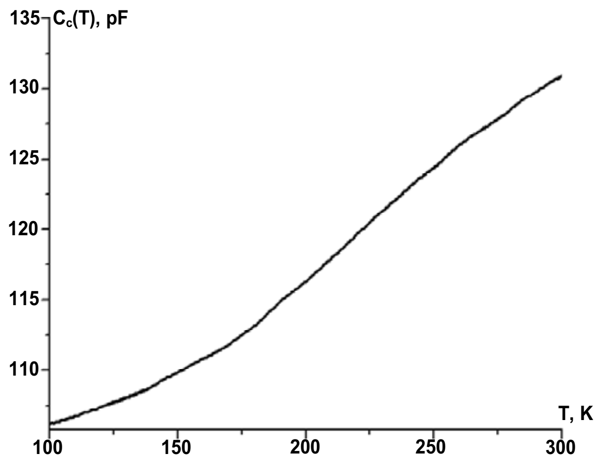

Fig. 6. Dependence of constant capacitance on temperature

Conclusions. Thus, the proposed modifications allow making quick and easy changes into existing automated relaxation spectrometers to meet the modern technological requirements and obtain data required for processing by advanced mathematical methods.

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Запропоновано принципові апаратні зміни до існуючих автоматизованих релаксаційних спектрометрів глибоких рівнів у напівпровідниках для отримання повних релаксаційних кривих. Отримані результати продемонстровано на діоді серії Д231А.
Ключові слова: РСГР, спектрометр, релаксація ємності, глибокі рівні.

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МОДИФИКАЦИЯ РСГУ СПЕКТРОМЕТРА ДЛЯ ПОЛУЧЕНИЯ ВРЕМЕННЫХ ЗАВИСИМОСТЕЙ РЕЛАКСАЦИИ

Предложены принципиальные аппаратные изменения к существующим автоматизированным релаксационным спектрометрам глубоких уровней в полупроводниках для получения полных релаксационных кривых. Полученные результаты продемонстрированно на диоде серии Д231А.
Ключевые слова: РСГУ, спектрометр, релаксация емкости, глубокие уровни.

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LASER ABSORPTION SPECTROSCOPY OF ELECTRIC ARC DISCHARGE PLASMA WITH COPPER IMPURITIES

Technique of laser absorption spectroscopy was applied for diagnostics of electric arc plasma between composite Cu-Mo electrodes. Spatial brightness distributions of laser emission were registered by CCD-matrix in realized experimental scheme. The graphical user interface for experimental data treatment was developed. Expected experimental errors are estimated. Obtained spatial distributions of copper atomic energy level $^5D_{5/2}$ population were used for calculation of plasma composition in assumption of local thermodynamic equilibrium.
Keywords: optical emission spectroscopy, plasma of electric arc discharge.

Introduction. Diagnostic of plasma is important part of numerous scientific investigations and industrial applications. The optical emission spectroscopy is the most widely used method for arc plasma diagnostic [7]. It is well known, that laser based techniques can significantly expand capabilities of plasma diagnostics.

Different approaches of laser based techniques were applied for arc plasma diagnostics. In work [6] distribution of tungsten impurities in atmospheric arc was obtained by techniques of laser-induced fluorescence. Thomson scattering of laser emission were used in work [8] for obtaining of electron density, gaseous and electron temperature distributions. Two dimensional distribution of electron density was obtained by Shack-Hartman method in work [5]. This method provides determination of refractive indexes, which depends on electron density in plasma.

Methods based on absorption of laser emission by plasma components also can be applied for arc plasma diagnostics. Particularly, method of linear laser absorption spectroscopy (LAS) provides simultaneous registration of plasma properties in different spatial points [1, 9].

Applications of copper based composite materials in the electrical engineering industry stimulate the interest in studying of the arc discharge plasma between such electrodes. It is reasonable to investigate such plasma by LAS with using of copper vapor laser.

The main aim of this work is determination of spatial distribution of copper atoms in the plasma of electric arc discharge between Cu-Mo electrodes by LAS. Analysis of obtained results is carried by specially developed graphical user interface. Obtained results are discussed as well as occurred errors.

Experimental setup. The arc was ignited between non-cooled electrodes in argon flow 6.4 slpm. The discharge gap was 8 mm and arc current was 3.5 A. Cu-Mo composite electrodes fabricated by electron beam evaporation and following condensation in vacuum were used. These electrodes have layered structure, content of molybdenum changes from layer to layer in range 1%–20%; average content of molybdenum was 12%.

Copper vapor laser "Kriostat 1" was used as source of probing emission on wavelength 510.5 nm, which is absorbed by copper atoms in arc plasma volume. Grade of laser emission absorption depends on population of copper atomic energy level $^2D_{5/2}$. As diameter of laser beam exceeds dimensions of arc plasma, so absorption distribution for different spatial points can be simultaneously registered by CCD-matrix (Fig.1).

Registered brightness distributions of reference laser beam and absorbed emission were used for determination of plasma properties. Reference image of spatial distribution of brightness in laser beam without arc is shown in Fig.2, *a*. The image obtained in presence of the arc is shown in Fig.2, *b*. These images were registered at the same operation conditions. CCD-matrix dynamic range selection was realized by changing of exposure time.

Graphical user interface for treatment of brightness spatial distribution (images) was specially developed. It allows:

- visualization of obtained brightness distributions;
- interactive selection of studied cross-section;
- determination of absorption characteristics for selected cross-section;
- determination of local values of absorption coefficient by Abel transformation.