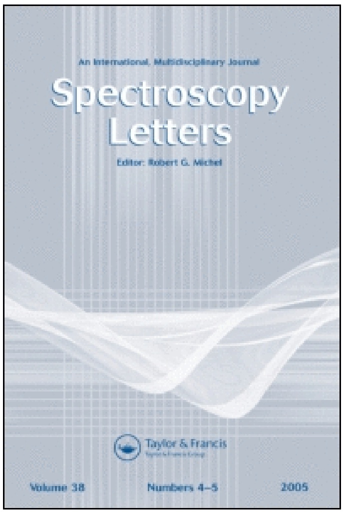

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THE DYNAMIC OPTOGALVANIC SIGNAL IN HOLLOW CATHODE DISCHARGE AS A SPECTRAL AND MONITORING INDICATOR

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THE DYNAMIC OPTOGALVANIC SIGNAL IN HOLLOW CATHODE DISCHARGE AS A SPECTRAL AND MONITORING INDICATOR

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ABSTRACT

Four optogalvanic (OG) measuring specific solutions are developed. They are based on the OG effect, in particular on the sensitivity of the OG signal form to the operating point. This form changes with each variation of gas discharge conditions. A transformation of the Dynamic OG signal in quasi-amplitude one is reported. All of the solutions represent a fast and more sensitive method for atomic line diagnostics. The optogalvanic analogue of the AC EL-spectrum is investigated in a inverted OG scheme.

Key Words: Optogalvanic technique; Hollow cathode gas discharge; Dynamic optogalvanic signal and its transformation in amplitude one; Purity and pressure monitoring; Optogalvanic marker; Optogalvanic diagnostic of AC EL emitter.

INTRODUCTION

The Dynamic Optogalvanic (DOG) signal $\Delta U(t, \lambda)$ manifests itself as a time resolved light induced galvanic relaxation. Usually it consists of one to three peaks of a μs scale and changing in sign. The OG effect and DOG signals are discussed in many articles [1,2], and various processes may be attributed to the DOG signal [3]. Recently an oscillating type of DOG reaction in a Hollow Cathode Discharge (HCD) was described as an anomalous signal [4]. It arises at a lower degree of stability to cause a disturbance of the OG circuit. The light pulse causes a damped oscillation of amplitude and duration increase by a factor of 10^2. An anomalous amplitude signal was also observed [5,6]. The anomalous signal is an instrumental effect, less informative [7], but its sensitivity to the operating point may be used.

In this communication three applications of form and duration of both the normal and anomalous DOG reactions are described. The fourth application is based on average of the DOG signals. In the four cases the measuring scheme is simple and inexpensive. One should note that these applications are based on the higher sensitivity of the OG method, i.e. limit of detection of 10^6 atoms $\cdot$ cm^{-3} or $10^{-3} \div 10^2$ ng/ml [8]. Often the limit of detection of the OG method is essentially lower than the other ones, and the linearity in concentration is $10^4 \div 10^5$ and higher [8].

DOG Signal in Gas Pressure and Purity Monitoring

This procedure was grounded in details found in reference [9]. It is based on the sensitivity of the operating i_0U_0-point to gas pressure and purity. Here the main considerations are described.

The oscillating anomalous signal $h(t) = A \cdot \exp(-qt). \sin \omega t$ was attributed to the negative parts of the iV curve (4). In the vicinity of an inflection i_0U_0- point a brief transition *normal* $\leftrightarrow$ *anomalous* signal occurs at each variation of discharge current Δi or voltage ΔU (Fig. 1), i.e. the type of relaxation changes dramatically in both frequency and relaxation time. The indispensable condition is to irradiate a characteristic transition inserting strong perturbation. In neon gas, for example, these transitions are $1s_i - 2p_j$. Their illumination is the most efficient OG perturbation and the corresponding DOG signals are two- or three-components. Then if the operating i, U-point is close enough to i_0U_0, each deviation ΔI, due to gas pressure or gas composition variation, replaces i, U-point, changing dramatically the type of DOG signal. Thus the change of either gas pressure or composition manifests itself as a variation of the DOG response type. The latter becomes *more normal* or *more anomalous* (oscillating) and it may be observed. It may be also used in gas flow.

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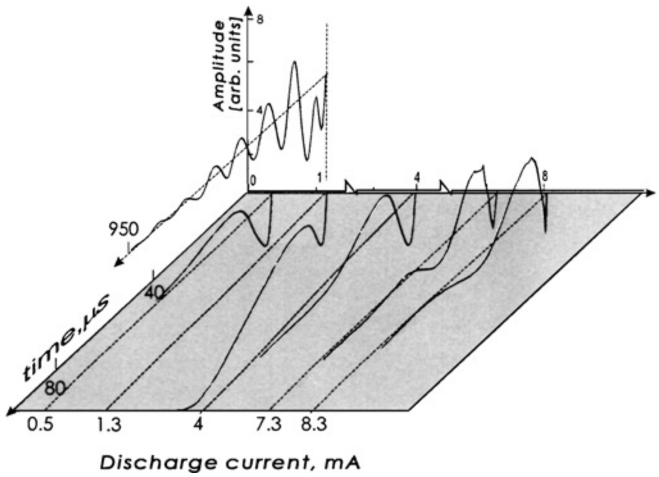

Figure 1. Transition *normal* ↔ *anomalous* DOG signal in Ne/Cu ("Narva") HCD lamp induced by DYE laser pulse (594.5 nm, 10 ns) at discharge current changing with enough small step. The time scale $(0 \div 80)$ μs is non sufficient large for the oscillation by $(0 \div 980)$ μs at $i = 1.3$ mA.

DOG Signal as a Characteristics Pectral Marker

The OG signal has been used as a spectral marker for many years 10. In this paper a new calibrating property of the DOG signal is reported. Its form depends upon the closeness of the transition to the potential of ionization as well as on the type of absorbing atom, i.e. sputtered or carrier. For example, the optical transitions for the upper level is closer than 1 eV to the ionisation limit giving a single OG peak of increased conductivity. The DOG signals from sputtered atoms, as well as from ions, reach maximum in the cathode dark space. On the other side the same signals never transform themselves to oscillations. This variety allows additional wavelength OG indications to be used in the absence of other spectral equipment. Figure 2 illustrates this possibility under *NdI* 581.39 nm and *NaI* 588.99 nm spectral line identification. A DAY laser (*Rhodamine* 6G) has to be tuned at these frequencies for identification of *NdI* and *NaI* isotopes. The laser pumped by a YAG laser induces a multitude of single- and bipolar DOG signals in the vicinity of the searched lines excited in an identification HCD tube with neon buffer gas.

The spectral region of interest may be localized by means of the three consecutive bipolar DOG signals belonging to three of $(1s_i - 2p_j)$ optical transitions, i.e. of *NeI* 597.55 nm, 594.50 nm, and 588.19 nm spectral lines. The first signal is the weakest, the middle is the strongest one. Then the single DOG peak within

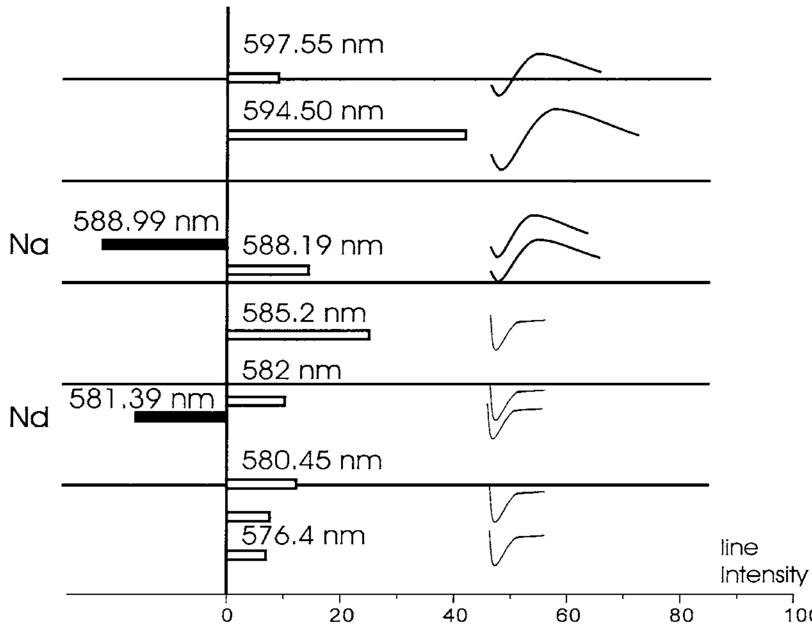

Figure 2. The searched *Nd* and *Na* lines, a part of *NeI* optical spectrum (open bars) and their OG signals as markers in the DYE laser spectrum.

the strong *Ne* bipolar signals (but closer to *NeI* 588.19 nm) should belong to *NaI* 588.99 nm. Further, the single peak closest to *NeI* 582 nm is the searched *NdI* 581.39 nm one.

Transformation DOG Spectrum → Amplitude OG Spectrum

By adding a simple integrating scheme, the above mentioned DOG signals $\Delta U(t,\lambda)$ received another application, based upon its peak transformation to a stationary $\Delta U(\lambda)$ spectrum and increasing some $\Delta U(\lambda_i)$ peaks by using the oscillating DOG response.

A filter-integrating *RC* circuit (Fig. 3) averages either of the $\Delta U(t,\lambda)$ polarities, usually the dominating one. Hence a scanning DYE laser forms an OG spectrum where for every λ: $\Delta U(\lambda) = \int_\tau \Delta U(\lambda, t)dt$, τ is the average constant adjusted by the resistor R_2. The latter together with the capacitor C_a determine the smoothness of every peak $\Delta U(\lambda)$. Figure 3 shows a part of the OG spectrum obtained by integration of the DOG signals, where $R_1 = 0.5$ kΩ, $R_2 =$ 4 kΩ, $C_a = 0.33$ μF. Obviously, in this case the amplitude $\Delta U(\lambda)$ depends also

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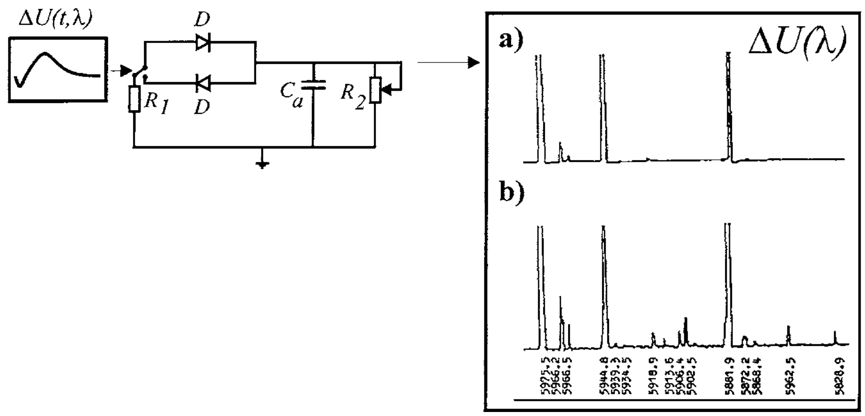

Figure 3. Peak OG spectrum in *Ne*/*Cu* HCD ("Narva") at discharge current 3 mA (a) and discharge current 12 mA (b) within 583 ÷ 589 nm.

upon the integrated polarity. Moreover Figure 3 also illustrates the OG sensitivity of various optical transitions to the discharge current (spectra a and b). In particular only the metastable $1s_5$ level gives an OG signal at a 3 mA discharge current.

An advantage of this scheme is the possibility of monitoring the gas discharge current value, the most suitable for the appearance of the weakest lines. This may be achieved by choosing a proper gas discharge value to enlarge the suitable quantity of sputtered atoms, leading to the appearance of the atomic line of interest. If necessary the scheme allows one to make alterations in the geometry of the cathode construction with a goal of increasing the quantity of the atom of interest. In [11] this is proven by changing the planar cathode bottom by conical bottom one.

This scheme gives one more specific advantage in the case of weak signals. At selected discharge current, giving the oscillating DOG signal, the transformed signal is of higher amplitude due to the larger integrated area.

On a New Diagnostic Advantage of the OG Method

AC EL are known as a new types of Alternating Current Elements created by the combination of two technologies, i.e. the binder and vacuum types [12]. They are intended for visual information, providing ecological advantages, and for energy efficiency. AC EL are applied in devices and equipment displaying colour information. That is why the behaviour of their brightness is an important problem. The optogalvanic method turns out to be more informative [13] relative to the important AC EL characteristics: optimal maximum light emission at low

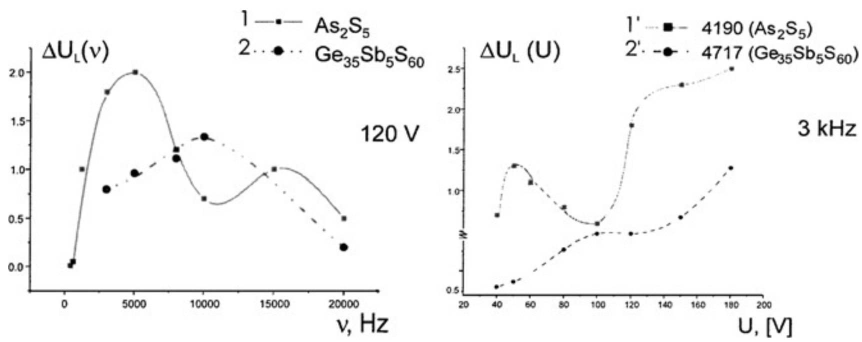

Figure 4. OG analogues ΔU of the sample with red light emission vs. a) frequency ν and b) the power supply voltage U for As_2S_5 (curves 1, 1′) and $Ge_{35}Sb_5S_{60}$ (curves 2, 2′) protective films.

power parameters (i.e., low current, low voltage power, optimal frequency), for elements with various protective chalcogenide films.

In this application an inverted OG scheme is used, i.e. AC EL irradiates a hollow cathode discharge, which transforms the AC EL emission to an integral OG signal. In spite of the weak AC EL emission the OG indication turns out to be a sensitive tool.

Figure 4 illustrates the influence of the power parameters (viz. frequency, voltage) on two protective films—As_2S_5 and $Ge_{35}Sb_5S_{60}$. Here the AC EL emission through the films is the object studied. The OG curves confirm optical data at low parameter values [12,14] but a deviation from the saturation also takes place. Both methods give higher integral signal from the As_2S_5 sample film, but OG detection shows an extreme value. In this way the OG method separates the area of 5500 Hz ÷ 15000 Hz (for frequency dependence), where the emission trough As film has an inverted reaction, i.e. it becomes lower than that trough for the Ge film. Obviously the OG method confirms the optical data; simultaneously it precisely indicates the operating regions where the general dependence is valid.

Thus the OG technique avoids some disadvantages of conventional photometry. The frequency selectivity of the absorbing centres (i.e., one or more certain optical transitions of the gas discharge plasma) is the main reason for this improved sensitivity.

CONCLUSION

These measuring solutions enlarge the field of the OG effect, giving four applications: non-destructive gas control, spectral marker, amplitude OG spectrum from transformed DOG signals and OG detection of AC EL emitter spectrum.

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