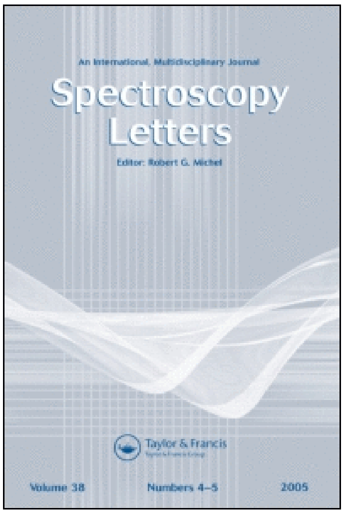

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Experimental Investigations of Surface Photo-Charge Effect in Different Materials

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EXPERIMENTAL INVESTIGATIONS OF SURFACE PHOTO - CHARGE EFFECT IN DIFFERENT MATERIALS

KEY WORDS: SURFACE PHOTO - CHARGE EFFECT, SUPERCONDUCTING CERAMICS, FERRITES, METALS

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Abstract:

This paper deals with some new experimental investigations, connected with so - called surface photo - charge effect.

An experimental set - up for irradiating samples with white light is designed and it is used for investigating different types of materials: metals, superconducting, ceramics, conducting ferrites, semiconductor crystals. All of them exhibit the effect with a different response amplitude. The dependence of the signal amplitude on the incident light intensity for the different materials is plotted graphically.

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An experimental investigations on the influence on the modulation frequency, polarization (in the case of a monochromatic source) and propagation direction of the incident light with respect to the sample surface is carried out.

Introduction:

Pustovoit et al. was the first to report on the so - called photo - charge effect - that takes place in conductors (semiconductors and metals) under the action of an electromagnetic irradiation falling on their surface [1,2]. The essence of the effect lies in the redistribution of the surface charges in the conductor and change of the corresponding double - layer potential.

The electromagnetic irradiation penetrates the skin layer and acts on the medium with a force F(r) that is proportional to the gradient of the permittivity [1,2,3]. At a certain value of the near - surface electron concentration, the force F(r) will surpass Coulomb force in the double layer and this result in a redistribution of the electrons over the surface of the conductor.

The theoretical model of the effect and the first experimental observations are described in Ref. [1,2,5]. The effect was registered in some metals and semiconductors by measuring the response in two different experimental set - ups, altering the wavelength of the electromagnetic irradiation. It turned out that the response is strongly dependent on the optical irradiation intensity, on the properties of the surface and on the area of the illuminated spot of the conductor. The sample was irradiated with monochromatic, as well as white light.

The aim of this paper is to describe further experimental investigations on this effect. They were devoted not only to metals and semiconductors, but to ceramics and ferrites (surface photo- charge effect was observed in dielectrics too [6]). The dependence of the response magnitude on the intensity of the electromagnetic irradiation, incident on the sample, was studied.

Attempts were made to clarify whether the signal depends on the light polarization and on the angle between the normal to the surface and the direction of light propagation.

Experiments and results

The first experiments were aimed the extraction of a good signal different kinds of substances - metals, ceramics and ferrites. All samples were tested under equal conditions. Fig. 1 shows how the plates were mounted [1]. The sample was placed in a metal box, grounded and screened against external disturbances. The signal was measured through a wire, electrically coupled with the illuminated sample. The investigations were carried out with the experimental set-up in Fig.2. The light-source is a halogen incandescent lamp L with a maximum power of 250 W. The light was focused by a condenser system K onto the mechanical modulator M. The modulated light falls on the sample P through lens L1. The signal is amplified by an amplifier P1 with high input impedance (around 100 MΩ) and 20 dB gain and is fed to the measuring device P2 (phase-sensitive nanovoltmeter). In all measurements the light is modulated by 126 Hz and illuminates the entire surface of the plates which is about 1 cm^2.

The investigations were carried out on metals - Cu, Al, Cd, Ni, Pb, Wo, Ta, Mo, Mg, Au, Zn, Cr, and alloys - brass. For all of them a strong signal was obtained and the greatest amplitude (of the order of several millivolts at intensity of light ray I=310 mW) was measured in copper, lead and brass. Measurements were also conducted on five different types of ceramics and the amplitude measured was on the order of several microvolts at I=310mW. The ceramic samples had a composition $YBa_2Cu_3O_{7-6}$, and their surface was polished at a depht of 1 μm with a diamond paste. Some of them are superconductors at nitrogen temperatures. A good response was obtained in piezoelectric ceramics SrBa.TiO with a superconducting layer $YBa_2Cu_3O_{7-6}$ with a thickness of

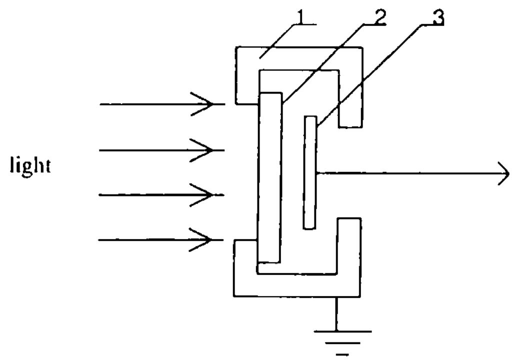

Fig.1. Diagram of sample connection: 1 - metal box, 2 - glass with a transparent conducting SnO_2 layer, 3 - investigated sample.

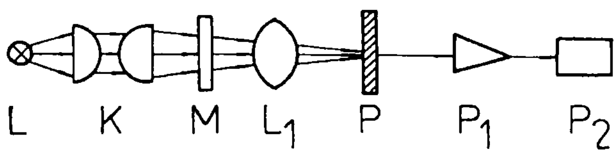

Fig.2. Experimental set-up; L - lamp, K - optical condenser system, M - optical and mechanical modulator, L1 - focusing lens, P - sample, P1 - amplifier, P2 - measuring device.

d<1 μm and temperature of the superconducting transition Tc ≈ 80K. The effect was observed in conducting ferrites, too.

In all experiments both surfaces of the samples were irradiated and different values of the voltage were measured.

A good response was obtained in a $Zn_{0.145}Hg_{0.865}Te$ crystal - a semiconductor material of N-type for infra-red photosensors with a concentration $n \approx 2.10^{16}$ cm^{-2}.

The dependence of the response magnitude on the irradiation intensity for different samples was recorded. In all cases the frequency of light modulation was 127 Hz. White light was used. In Fig.3 these relationship are plotted for gold, brass and tungsten. Fig. 4 and Fig.5 illustrate the same relationships for high-temperature superconducting ceramics and conducting ferrites. The experiments were carried out on the set - up shown in Fig.2. The plotted intensity I is of the light that is really incident on the sample. Ref. [1.2.5] discuss result from such measurements for metals.

We also checked the dependence of the signal on the frequency of modulation of the electromagnetic irradiation for Cu (Fig.6). It is evident that in the range of investigation from 9 to 140 Hz the strongest dependence of the signal on the frequency was observed at low frequencies up to 40 Hz. The voltage increases up to 40 Hz, then becomes saturated and at high frequencies is independent of the frequency of light modulation.

In the course of experiments, the following phenomenon was observation. In some samples the response magnitude depends on the duration of the measurement. At the beginning of the irradiation the signal is strong. Then it diminishes slowly to a constant value. This was observed in brass, Pb, Ta, Cu.

In order to avoid innaccuracy in the measurements of the response amplitude, the sample was covered with an opaque screen that was removed just before irradiation.

While investigating the time dependence of the effect, we made the following experiment with a ceramic sample. Its surface was irradiated five consecutive times by rapidly removing the opaque screen, so that the sample remained in darkness about 20 s. Thr measurements were made from both sides.

After the first irradiation the amplitude of the response was maximum and decreased with each subsequent illumination. It was necessary to find the minimum dark interval Δt for the sample to

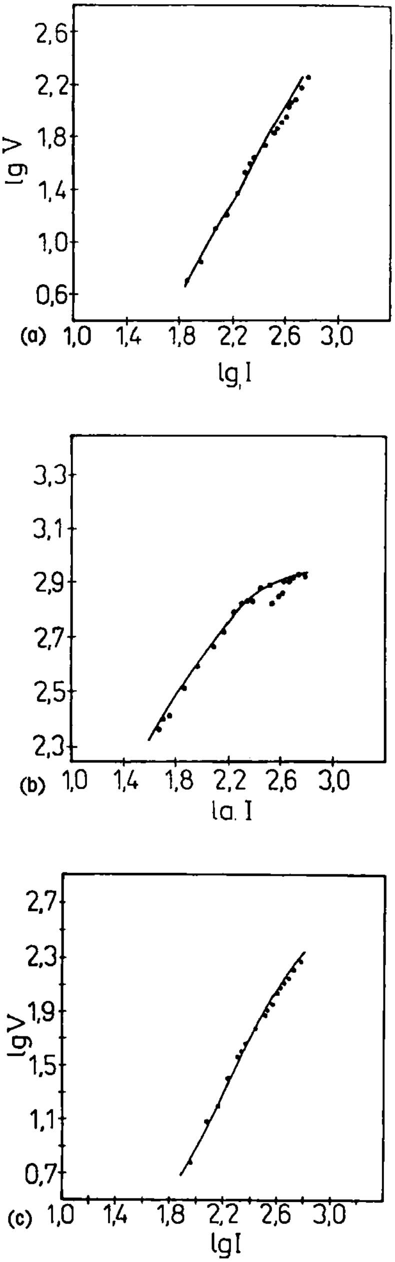

Fig.3. Output signal dependence on the optical irradiation intensity for metals: a - gold; b - brass; c - tungsten.

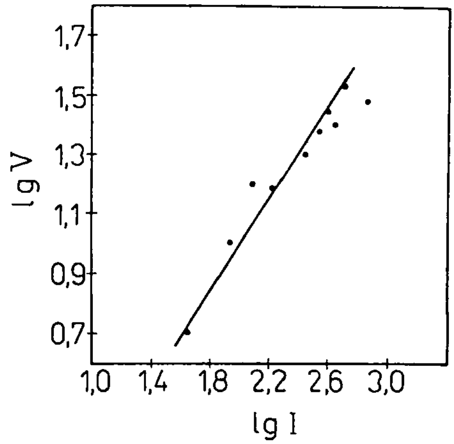

Fig.4. Output signal dependence on the optical irradiation intensity for high - temperature superconducting ceramics at room temperature.

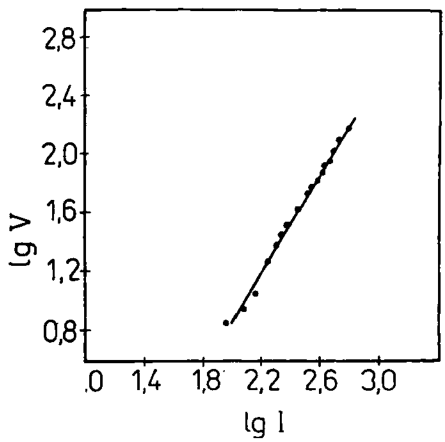

Fig.5. Output signal dependence on the optical irradiation intensity for ferrites.

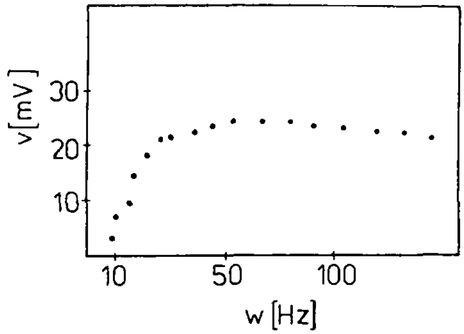

Fig.6. Output signal dependence on the frequency of modulation of the light beam.

restore its initial properties, i.e. to produce one and same signal. For the ceramic sample, repeatability of the output signal is achieved after Δt = 1.5 min. This fact gives us grounds to believe that the irradiation is stored for a given time and affects the properties of the sample.

The last experiments were carried out using the set-up in Fig.7 and were devoted to the dependence of the response on the incident irradiation polarization and on the position of the sample with respect to the direction of the laser light. By means of rotator R the polarization of the linearly polarised laser beam with λ = 633 nm was varied 0^{o} to 90^{o} measuring the angle to the normal to the surface. For all angles the output signal was the same, i.e. it is independent of the polarization.

After that, the rotator R and analyser A were removed from the set - up in Fig.7 and the sample was rotated in two planes. Here again, no relationship between the output voltage and the angle was observed.

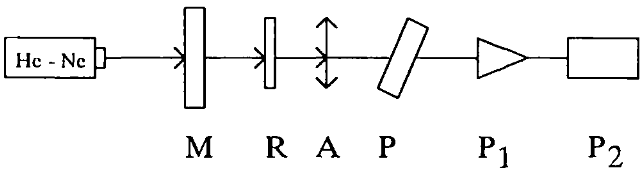

Fig.7.Experimental arrangement for investigating the-dependence of the output signal on the light polarization and sample orientation: M- modulator; R - polarization rotator; A - analyzer; P - sample, P1 - amplifier, P2 - measuring device.

Conclusion:

In the article the dependencies of the observed signal from the intensity of light for the different material are given, which will serve the future work on surface photo - charge effect once again it is proved that the effect is attested in any kind of samples. The accomplished research on the influence of the frequency of modulation, polarization and direction of the falling ray clarify the conditions under which the experiments should be made. At this stage it is difficult to raice a discussion on the physical processes leading to the observed results since we are still lacking a clear theory to explain all the particularities.

In the course of the experiments it is established that in some materials the magnitude of the measured signal depends strongly on the duration of irradiation, and on the pause while it is in darkness.

The experimental results, reported in this paper, are a step forward to the overall investigation of the surface photo - charge effect.

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