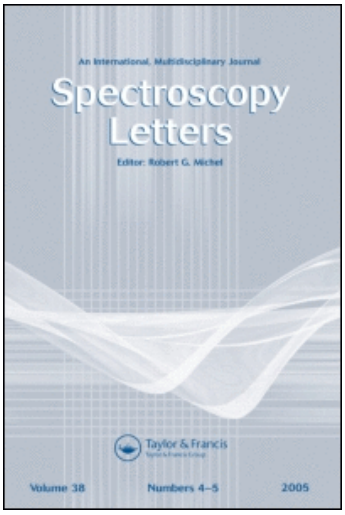

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Automatized System for Measuring the Surface Density of Current Carriers and Electrical Permittivity of Conducting Materials

O. Ivanov[a]; D. Svircov[a]; Ts. Michailova[b]; P. Nikolov[c]; V. Pustovoit[d]
[a] Institute of Solid State Physics Bulgarian Academy of Sciences, Sofia, Bulgaria [b] RDIA "Scientific Instrumentation" Bulgarian Academy of Sciences, Sofia, Bulgaria [c] Department of Physics, Pedagogical Institute, Silistra Bulgaria [d] Institute of radioengineering and electronics Russian Academy of Sciences, Moscow GPS. 3, Russia

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AUTOMATIZED SYSTEM FOR MEASURING THE SURFACE DENSITY OF CURRENT CARRIERS AND ELECTRICAL PERMITTIVITY OF CONDUCTING MATERIALS

Key words: electron topography, conducting surface, measuring system

O. Ivanov, D. Svircov

Institute of Solid State Physics
Bulgarian Academy of Sciences, 72 Tzarigradsko Chausee, Sofia 1784, Bulgaria

Ts. Michailova

RDIA "Scientific Instrumentation"
Bulgarian Academy of Sciences, 72 Tzarigradsko Chausee, Sofia 1784, Bulgaria

P. Nikolov

Pedagogical Institute, Department of Physics, Silistra
Bulgaria

V. Pustovoit

Institute of radioengineering and electronics, Russian Academy of Sciences, Mokhovava str. 11, Moscow, GPS.3, 103907 Russia

ABSTRACT:

An automatised system for analyzing the electron topography of a conducting surface (semiconductors, metals, ferrites or conductor ceramics) is represented. The function of the system is based on the recently observed surface photo-charge effect. The investigation is express and contactless. The system allows visualisations of different formations on the surface such as defects, ion-implanted areas, etc. on a computer screen. The structure of the system is described. The results from investigations with GaP and Cu are reported.

INTRODUCTION:

For a number of purposes it is necessary to analize the electron topography of a conducting surface (we imply semiconductor, metal, ferrite or conductor ceramic). In our work aiming the creation of due measuring system initially we exploited the transverse acoustoelectric effect (TAV) to scan semiconductor surface [1,2]. We had in mind that the acoustoelectron interactions in general and especially TAV offer great capabilities in the investigation of semiconductors [3]. However our latter investigations on TAV resulted in the observation of another effect, as we reckon - closely related with TAV, the so-called surface photo-charge effect [4,5].

It is known that near the surface of the conductor the charges are distributed non-uniformly and there exists the so-called double layer whose electrostatic field repels the free charge away from the surface. The irradiation incident on the conductor surface acts on the medium with a force proportional to the gradient of the permittivity (in the simplest case). The essence of the photo-charge effect is that under the action of this force

the electrons near the conductor surface rearrange causign corresponding spatial changes of the double layer potential, witch develops itself as a potential difference when the sample is illuminated.

The experimental investigations of the surface photo-charge effect in copper, zinc, cadmium, copper alloys, etc. confirmed the existence of this new effect and good qualitative agreement between the experimental results and the classical theory was observed. We have shown in our previous paper [5] that the change in the electrostatic potential near the conductor surface depends on the surface condition and is proportional to the irradiation intensity when the latter is high [5].

This effect offers some advantages with respect to our aims: it may be utilised for the examination of all kinds of conducting surfaces, significantly simplifies the experimental set-up, so we swung toward its application.

In the present work the automatised system for measuring the density profile of the current carriers over conducting surfaces developed on the base of the surface photo-charge effect is reported. The system allows express contactless visualisation of mechanical nonuniformities, defects, ion-implanted areas etc. on a computer screen.

EXPERIMENTS AND RESULTS:

A block diagram of the setup is shown in Fig. 1. Two step motors (2) are fitted to the driving screws of the optical X-Y stage (1). The working area of the stage is 10 x 10 cm. A mechanical fixture (3) supporting the sample under test is mounted on the optical stage. The sample is scanned by a light beam which is pulse-modulated by the mechanical chopper (6) and focused by the optical system (7). In our investigations up to now we

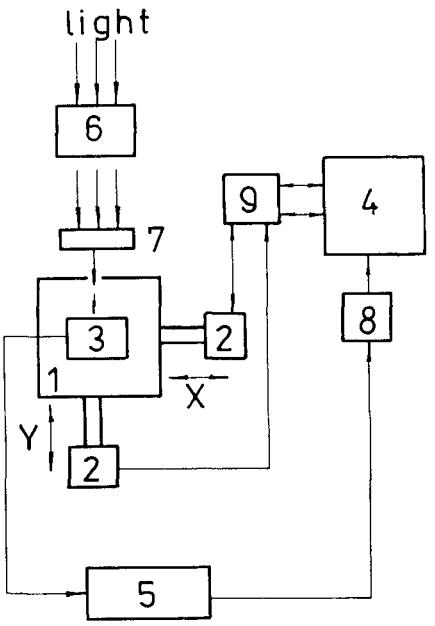

FIG. 1 Block diagram of the measuring system

have mainly used a He-Ne laser as a light source with λ=630 nm. The diameter of the focal spot was 40 μm. The scanning is produced by the movement of the optical stage alongside the X and Y axes. A selective voltmeter (5) synchronised to the chopper frequency measures the voltage difference arising in result of the illumination of the sample.

From the voltmeter a direct-current output proportional to the measured signal is applied to the analog-digital convertor (8), where it is digitised and applied to the computer input (4). Computer drives the step motor (2) via the control block (9). With the optical stage and the step motors we used a minimal step of 10 μm was achieved over maximal scanned area of 30 x 30 mm. These parameters can be easily improved

without principal alternations in the system by using more precise optical stage and finer step motors.

In Fig. 2 a sketch of the fixture (3) from Fig. 1 is shown. The sample under investigation (1) is pressed to the glass plate (2) by a simple mechanical assembly exerting a force F on the sample. For the sake of simplicity this assembly is not shown in Fig. 2. The examined sample is placed in a screening box (4), which has a window to allow the light beam in. There is a transparent conducting film of SnO_2 (3) deposited on the glass plate which is grounded to the screening box, thus improving the sample screen. Essentially, the glass plate and the corresponding conducting film are not necessary and can be omitted. In practice the measured voltage is taken between the sample and the screening box. It is quite sufficient the signal lead to be simply in touch with the sample. No special contact is required. In fact it is even not necessary this lead to touch the sample/ The signal may be taken from an electrode placed near the scanned sample. but not directly connected to it [5]. With illuminating power under 1 W the measured signal for metals, ceramics and ferrites is some microvolts. The structure producing the signal has a high-impedance output therefore the measuring instrument must be of high input impedance. It is advisable R_{in} to be about 10^8 ohm. For semiconductors the signal is appreciably greater and can achieve some millivolts even with poor illumination. It can mount to millivolts for some metals when the input impedance is high enough and the illuminating power is nearly 1 W.

The system can be operated in the following modes: entire scanning; scanning along a straight line; digital voltmeter mode; processing of measured data. All the measured data and the computer graphics are saved on floppy-disks and can be printed out. In the digital voltmeter mode

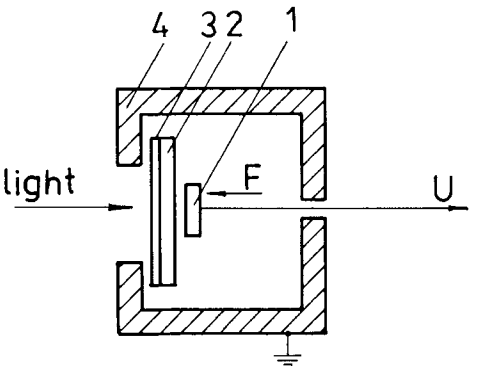

FIG. 2 Sketch of the sample fixture

the optical stage is driven to a given point and measurements are made on the sample by choice automatically or manually. In the mode "scanning along a line" the measurements are carried out along a chosen straight line in the X or Y direction and presented graphically on the computer screen. The mode "entire scan" permits scanning over the whole sample with arbitrary steps along X and Y. In the beginning of the measuring the optical stage always goes to the zero position and the operator adjust the initial point of the scan. The adjustment include setting the parameters of the scan and checking if the highest signal over the whole scanned area is within the instrument range. The remained processing procedure is automatised: The optical stage is moved to a point and fixed for a set time to avoid the relaxation effects, after the measurement the signal is checked for stability within given error limits and stored into the computer memory; then the next point is reached. If any doubt arises about the measured value at a point the stage can be adjusted to repeat the questionable measurement. The data array obtained is presented as a 3-D plot,

observable optionally from the four directions ±X and ±Y under preset angle in the range from 0 to 80 degrees.

There are additional facilities such as a scaling the plots, verification of the conformity between the signal and the voltmeter range etc. If there is a necessity of multiple scanning of the sample, which might has been removed and placed again, two points, A1 and A2, can be marked on its surface, and with suitable command from the computer during the initial reset can be adjusted exactly under the laser beam, after which the computer automatically line up the whole scan identically. A single section can be chosen and derived from the 3-D plots as well or particular parts can be enlarged and examined in detail through "lens".

In Fig. 3 the results from the investigation of a sample of GaP with sulphur impurities with a specific resistivity 10^{-1} Ω.cm. The plate under test is a round wafer with diameter d=43 cm, cut perpendicularly to the grown axis of the crystal. A region in the central part of the wafer with dimensions 20x30 mm is examined with 1 mm step (wavelength 633 nm, focal spot 50 μm, modulation frequency 170 Hz, intensity 1.6 mW). It is known that an accumulation of impurities exists in the central part of the plate, which is recognised on the 3-D plot in Fig. 3.

In Fig. 4 results are presented from the scanning of a copper plate with dimensions 10 x 10 x 0.8 mm, which surface is half manually scratched by a sharp knife and the remaining half is the real surface of oxidazed copper. In the right-hand side of the figure the results from the scratched part are shown with lower amplitude as can be seen. The smooth and the scratched area are clearly distinguished. The scan is produced using argon laser, the beam including several generated lines, the strongest being 514

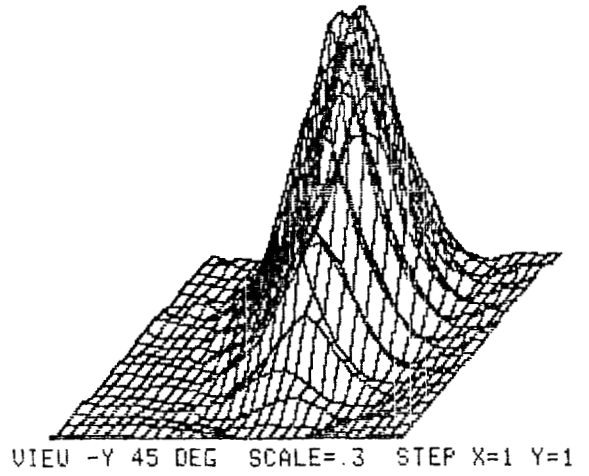

FIG. 3 Response in a GaP wafer with sulphur impurities under laser illumination

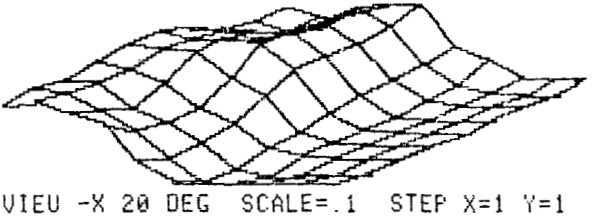

FIG. 4 Response in a scratched copper plate

nm and 488 nm (illuminating intensity 90 mW modulation frequency 105 Hz, step along X and Y 1 mm).

CONCLUSION:

The described system based on the photo-charge effect posses high flexibility since it can be applied for investigations of all kinds of conducting surfaces. The method is fast and contactless. It was found out

that besides the amplitude the signal phase changes as well as a function of the surface condition. We are going to exploit this to derive additional information by measuring simultaneously the phase and the amplitude of the signal. We also intend to extend the automatization of the system appending a computer control of the illuminating beam wavelength. Since the penetration of the light in depth varies with the wavelength this will be equivalent to a depth scan. Last our investigations have demonstrated that surface photo-charge effect is observed in any solids [6]. Our results will allow the application of our device to be applied for identification of any solid surface.

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