Modern Electronic Materials (2015) 1, 93–96

Available online at www.sciencedirect.com

SciVerse ScienceDirect

www.elsevier.com/locate/moem

Modern Electronic Materials

Method of separate determination of high-ohmic sample resistance and contact resistance

Vadim A. Golubiatnikov[a], **Fedor I. Grigor'ev**[a], **Aleksandr P. Lysenko**[a], **Natal'ya I. Strogankova**[a], **Mukhamed B. Shadov**[a], **Aleksandr G. Belov**[b], **Vladimir E. Kanevsky**[b]

[a]*National Research University Higher School of Economics, 12/4, Malaya Pionerskaya Str., Moscow 115054, Russia*
[b]*Joint Stock Company "Giredmet", 5-1, B. Tolmachevsky Lane, Moscow 119017, Russia*

KEYWORDS
Separate determination;
Sample volume resistance;
Contact resistance;
High-ohmic semiconductor;
Two-polar sample;
Near-contact region illumination

Abstract
A method of separate determination of two-pole sample volume resistance and contact resistance is suggested. The method is applicable to high-ohmic semiconductor samples: semi-insulating gallium arsenide, detector cadmium-zinc telluride (CZT), etc. The method is based on near-contact region illumination by monochromatic radiation of variable intensity from light emitting diodes with quantum energies exceeding the band gap of the material. It is necessary to obtain sample photo-current dependence upon light emitting diode current and to find the linear portion of this dependence. Extrapolation of this linear portion to the *Y*-axis gives the cut-off current. As the bias voltage is known, it is easy to calculate sample volume resistance. Then, using dark current value, one can determine the total contact resistance. The method was tested for *n*-type semi-insulating GaAs. The contact resistance value was shown to be approximately equal to the sample volume resistance. Thus, the influence of contacts must be taken into account when electrophysical data are analyzed.

Introduction

For electrophysical measurements, the electrical resistance of the sample is a fundamental one, in particular, for measurements of high-ohmic semiconductor materials (semi-insulating gallium arsenide, detector cadmium-zinc telluride (CZT), etc.). Typically, the contact resistance of the sample is so high that retrieving the useful signal becomes impossible. For example, during galvano-magnetic Van der Pau measurements in $Cd_{1-y}Zn_yTe$ detector material (CZT) with electrical resistivity $\rho \geq 10^7\,\Omega$, the following phenomenon is observed: due to change in current polarity, the output signal either does not change sign at all, or the

E-mail address: vad.golub@mail.ru (V.A. Golubiatnikov).
Peer review under responsibility of the National University of Science and Technology MISiS.

http://dx.doi.org/10.1016/j.moem.2016.03.004

signal sign changes but the absolute signal value significantly (by several times) differs from the previous one. And in this case one cannot separate the useful signal and hence determine the electrophysical parameters of the sample.

The above mentioned phenomenon is largely caused by contact phenomena and, primarily, high transient resistances of the contacts (or the near-contact regions) [1-3]. Eliminating the influence of the contacts (or at least significantly reducing it), one can expect to be able to calculate these parameters.

The fabrication of ohmic contacts for *p*-type high-ohmic CZT material is an extremely complex technical problem. The existing contact fabrication methods require special technologies that are often labor-consuming and expensive [2-14], and the desired result is not always guaranteed. For conventional methods, the resistivity is calculated from the experimental resistance R of the two-polar sample using the standard formula $\rho=(RS)/L$, where S is the sample cross-section and L is its length. As there are solid grounds to assume that contact resistance can be comparable or even much higher than the sample resistance, the resistivity calculation error can be inadmissibly high.

Below we suggest a simple method of separate measurement of sample and contact resistance without special equipment by illuminating the near-contact regions of the sample with monochromatic light of controlled intensity at quantum energies higher than the sample band gap. The method is primarily applicable to semi-insulating gallium arsenide and detector cadmium-zinc telluride but can be extended to other high resistivity semiconductors.

Separate resistance measurement method

Figure 1 shows (a) the conventional two-polar sample resistance measurement setup and (b) the setup of the suggested method.

The setup of the suggested method is as shown in Figure 1b. The sample is the same as in the previous setup, but all its surface except small near-contact regions is covered with a non-transparent coating. Contact resistance is reduced by illuminating the near-contact regions [15]. Illumination is effected using monochromatic LEDs with quantum energies exceeding the semiconductor band gap. One can accept that the LED intensity is proportional to the bias.

An electrical diagram of a two-polar sample is shown in Figure 2. The contacts are assumed to be ohmic, and the resistances of the left and the right contacts are taken equal for simplicity.

We stabilize the power unit output voltage (it should not change during the measurements). Then the dark sample current can be calculated as follows

$$I_s = \frac{U}{2R_c - R_s} \tag{1}$$

Illuminating the near-contact regions of the sample with the LEDs, we induce additional photocurrent I_{ph} in the circuit due to the generation of additional carriers. Then the total current measured by the in-line amperemeter will be the sum of the currents: $I=I_s+I_{ph}$. Taking into account Eq. (1) and the fact that I_{ph} is proportional to the LED

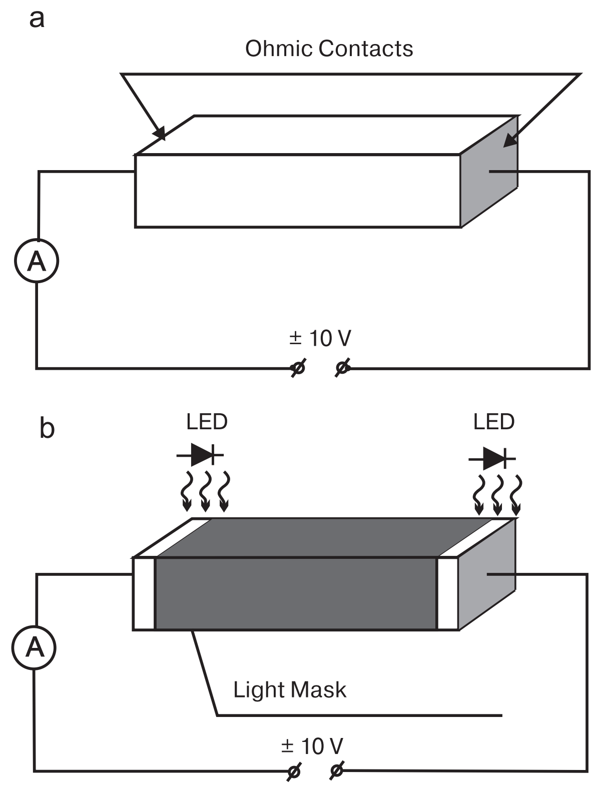

Figure 1 (a) Conventional two-polar sample resistance measurement setup and (b) the separate resistance measurement setup.

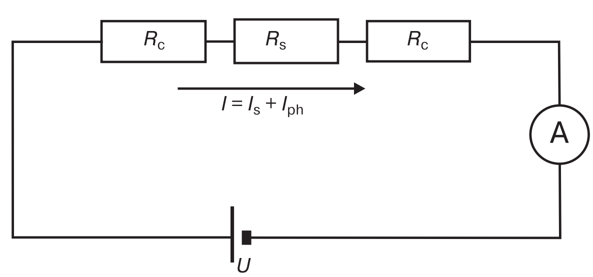

Figure 2 Electrical diagram of two-polar sample in the circuit: R_c is the contact resistance, R_s is the sample resistance, U is the voltage, I_s is the dark sample current and I_f is the photocurrent.

current ($I_{ph}=kI_{LED}$ where k is the coefficient and I_{LED} is the LED current) we obtain

$$I = kI_{LED} + \frac{U}{2R_c - R_s} \tag{2}$$

We then assume that by illuminating the near-contact regions of the samples, reduced the contact resistance to the extent that the condition $2R_c \ll R_s$ is true; then the $I=f(I_{LED})$ function will tend to be linear (Figure 3, curve 2) [15].

The intersection of that line with the Y-axis gives that cut-off current $I_{co}=U/R_s$ (see Eq. (2)) and the slope angel tangent will be the coefficient k. Knowing U and I_{co} one can easily calculate R_s and then the contact resistance

$$2R_c = (U/I_{co}) - R_s \tag{3}$$