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SCANNING PHOTOSTIMULATED ELECTROMETRY FOR TESTING THE UNIFORMITY OF SPATIAL DISTRIBUTION OF SEMICONDUCTOR WAFERS PARAMETERS

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Abstract. *The paper presents the results of the development of the method and means of photostimulated scanning electrometry for non-destructive contactless testing of the uniformity of spatial distribution of semiconductor wafers ion-doped and diffusion layers' parameters.*

Keywords: *scanning photostimulated electrometry, non-destructive contactless testing, photovoltage, surface resistivity, semiconductor wafer.*

The great importance in the control of the technology of integrated circuits, especially on the basis of submicron layers, is not only the control of finished device structures, but also of the starting materials and layers used in specific technological operations. One of the main parameters characterizing the quality of the near-surface layers of semiconductor wafers is the surface resistivity and the uniformity of its spatial distribution over the wafer area.

In this work, to implement the method of contactless control of the uniformity of the distribution of the parameters of ion-doped and diffusion semiconductor layers, it is proposed to use the parameters of the features of the spectral and spatial distribution of the surface photo-EMF of submicron semiconductor layers when exposed to modulated optical radiation of various wavelengths. The magnitude of the surface photo-EMF is directly related to many physical parameters of a semiconductor material, such as the lifetime (diffusion length) of nonequilibrium charge carriers, specific surface resistance, the presence and concentration of surface states (defects) and their energy spectrum.

The method of non-destructive measurement of the surface resistivity of semiconductor layers is based on the features of the spatial distribution of the surface potential associated with the generation of nonequilibrium charge carriers. Under local illumination of a semiconductor with a shallow junction formed in the process of diffusion or ion doping, a gate photo-EMF (JPV) with a value of V_{JPV1} is generated. With distance from the region of generation of excess charge carriers, their concentration decreases, and at a certain fixed distance from the region of illumination, the surface potential will be V_{JPV2}. The difference between these values is determined by the processes of current spreading and depends on the resistivity of the semiconductor layer [1].

To implement this method, an electrometric probe was developed and manufactured, the sensitive element of which is a system of four concentric sector electrodes (Figure 1) located in the same plane. The necessary modulation of the measuring signal is provided by mechanical vibration of the sensing element (mode of measuring the electric potential of the surface) [2] or by modulating the acting optical radiation (mode of measuring the surface photo-EMF).

Local impact on the surface of the semiconductor wafer by optical radiation is carried out through a hole with a diameter of 0.5 mm in the central electrode, while the semiconductor surface

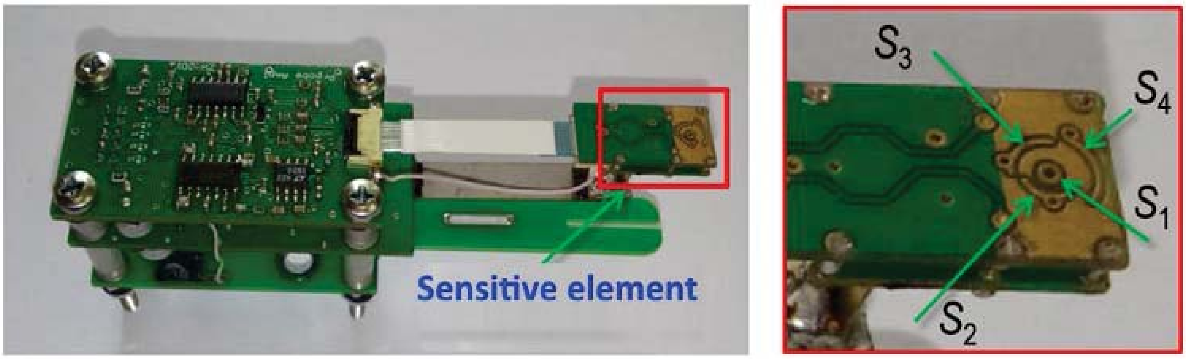


Fig. 1. General view of the zelectrometric probe and the electrode system of the sensitive element: $S_1 = 0.746$ mm2; $S_2 = 0.567$ mm2; $S_3 = 0.785$ mm2; $S_4 = 1.004$ m.

directly under the electrodes remains unlit. The change in the modulated photo-EMF $V_{JPV1} - V_{JPV4}$ under the electrodes $S_1 - S_4$ is determined by the lateral drift of the photogenerated nonequilibrium charge carriers. The total signal recorded by an electrode with area Si is calculated by integrating the surface photo-EMF over the area of the electrode.

To increase the speed and accuracy of control during scanning measurements, a unique method of registering the surface potential, implemented in the mode of incomplete compensation of the measuring signal, was used (Patent EA 026858). This method is based on the use of digital signal processing and is implemented in the design of a digital microprocessor probe (Figure 3) [3].

The method is implemented in the measuring system SCAN-2019, developed and manufactured at BNTU by order of OAO "Integral" (Figures 2 and 3).

Fig.2. General view of the SCAN-2019 installation: 1 - measuring system SCAN-2019; 2 - personal computer

The main technical characteristics of SCAN-2019:

1. The main controlled parameter is the electrical resistivity of submicron layers on semiconductor wafers in the range of values from 10 to 100,000 Ohm/(Ohm/sq);

2. Additional controlled parameters - surface potential (relative work function of an electron) and photo-EMF (lifetime of minority carriers);

3. Diameter of the controlled plates: - up to 200 mm;

4. Range of control of the electric potential of the silicon dielectric structure surface: ± (2… 2500) mV;

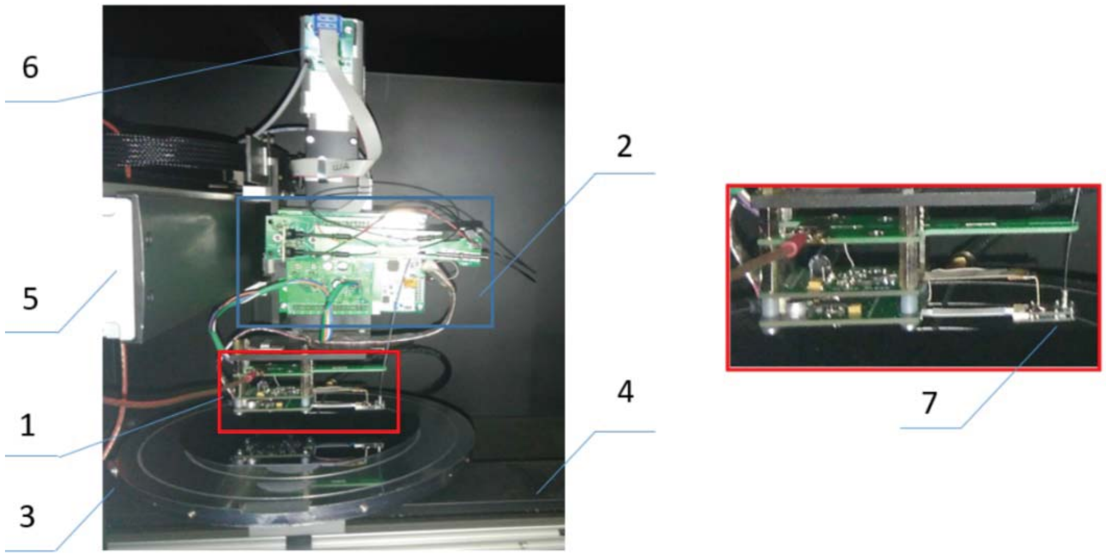


Fig.3. Measuring transducer (digital microprocessor electrometric probe): 1 - measuring head; 2 - microprocessor unit with control drivers; 3 - subject table; 4, 5 - drives for two-dimensional scanning (coordinates [x, y]); 6 - drive for supplying the reference electrode (coordinate [z]); 7 - reference electrode (system of measuring probes).

5. Dynamic error in measuring the electric potential of the silicon dielectric structure surface: less than 1.0 mV;

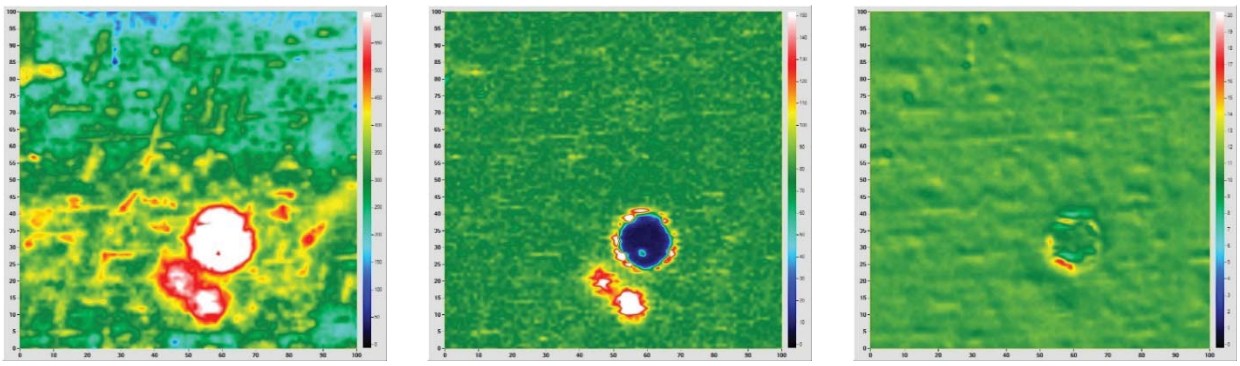
6. Additional influencing factor: optical illumination of the surface of the instrument structure by radiation of various wavelengths;

7. Spatial resolution: less than 0.5mm;

8. Maximum number of mapping points: from 100 to 100,000;

9. Control of the spatial movement of the reference electrode over the surface of the measurement object is performed with a relative error not exceeding 0.01 mm along the coordinates [x, y, z].

SCAN-2019 provides determination of the spatial distribution of such parameters as the surface electric potential (Figure 4, a), surface photo-EMF (Figure 4, b) and electrical resistivity (Figure 4, c) of submicron layers of a semiconductor wafer.



A *b* *c*

Figure: 4. Characterization of defects in the epitaxial layer of a silicon wafer: a - in the mode of a scanning Kelvin probe (work function of an electron); b - in the mode of scanning photo-EMF (lifetime of minority carriers); c - in the mode of photo-EMF of barrier structures (surface electrical resistance).

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