Electrical measurements laboratory

The laboratory performs measurements of the $C(V_G)$, $I(V_G)$ and $G(V_G)$ characteristics of semiconductor structures with ultimate sensitivity and resolution of 0.1 fA / 0.5 μV. This is primarily done using the Agilent B1500A semiconductor device analyzer and Cascade Summit 12k semi-automatic probe station (Fig. 2a). Based on these characteristics, measured at different temperatures T and signal frequency f, following parameters are evaluated: semiconductor substrate doping level or profile, flat-band voltage V_{FB} and threshold voltage V_T, energy distributions of the density of interface traps D_{it} and border traps N_b, and distributions of other trap parameters (time constant τ and capture cross-section σ).

a) b)

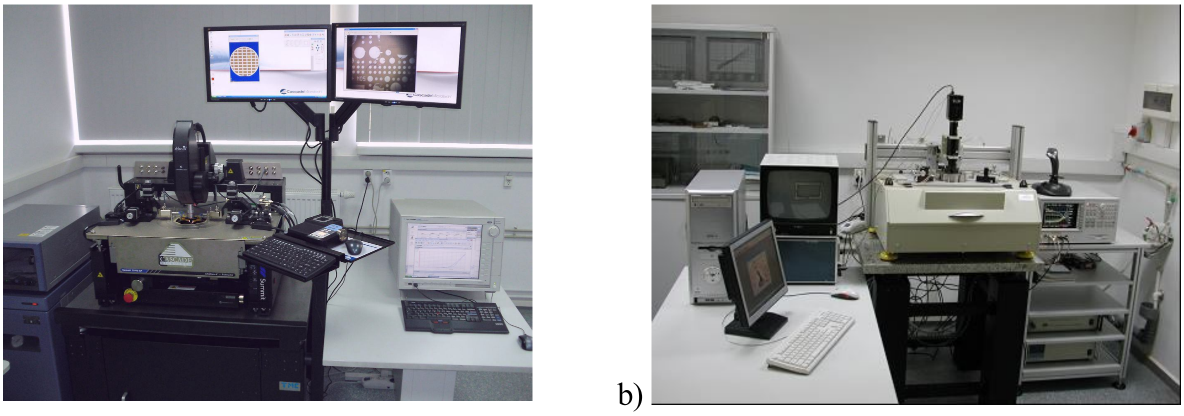


Fig. 2 **a)** Electrical parameter measurement system equipped with the Agilent B1500 measurement and analysis unit and temperature controller ESPEC ETC200L. **b)** Admitance spectroscopy measurement setup equipped with the Agilent 4294A.

Admittance spectroscopy investigations can also be performed using Agilent 4294A precision impedance meter and specialized computer fitting software (Fig. 2b). This method allows to determine equivalent circuits of nanostructures and to evaluate charge carrier trap distributions in materials and interfaces. Also, the MPAS (multiparameter admittance spectroscopy) technique of visualization of measurement results is provided. The MPAS method consists in graphical analysis of a measured MOS capacitor conductance dispersion (G_m/ω) as a function of surface potential ϕ_S (resulting from gate bias voltage V_G) and of the inverse of the measuring signal angular frequency ω^{-1}. With the MPAS method it is possible to evaluate the trap capture cross-section σ_n directly from the conductance dispersion map. An example of an MPAS "map" is shown in Fig. 3. All the above mentioned measurements can be made at different temperatures in the range of T = -60 ÷ 200°C.

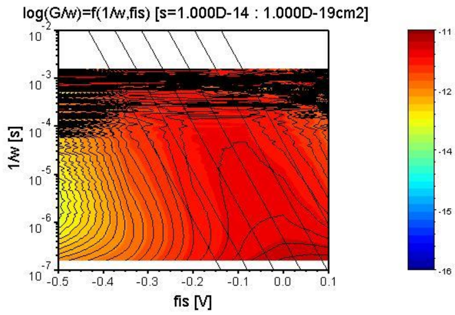


Fig. 3 An example of a MPAS analysis – a conductance dispersion map (G_m/ω) measured on SiC-4H/SiO_2/Al sample. The equi-sigma lines allow for evaluation of capture cross-section σ from the slope of the G_m/ω.

Photoelectric measurements laboratory

The laboratory performs complex characterization of semiconductors and their interfaces with insulators in MOS devices using standard and in-house developed photoelectric methods. The package of measurement methods enables identification of characteristic energy levels and potentials of semiconductor structure energy band model, energy distributions of interface trap parameters, as well as the distributions of local values of certain parameters over the characteristic areas of the device. On the basis of internal photoemission phenomena in the MOS system at low electric fields a very accurate measurement method of the ECPD was developed and successfully implemented for modern nanoelectronic structures characterisation.

All measurement setups dedicated for photoelectric measurements have been entirely designed by our team and installed in this laboratory. The first system: WSBF (Fig. 4a) is an advanced system which allows accurate measurements of a number of photoelectric characteristics of nanoelectronic structures, e.g.:

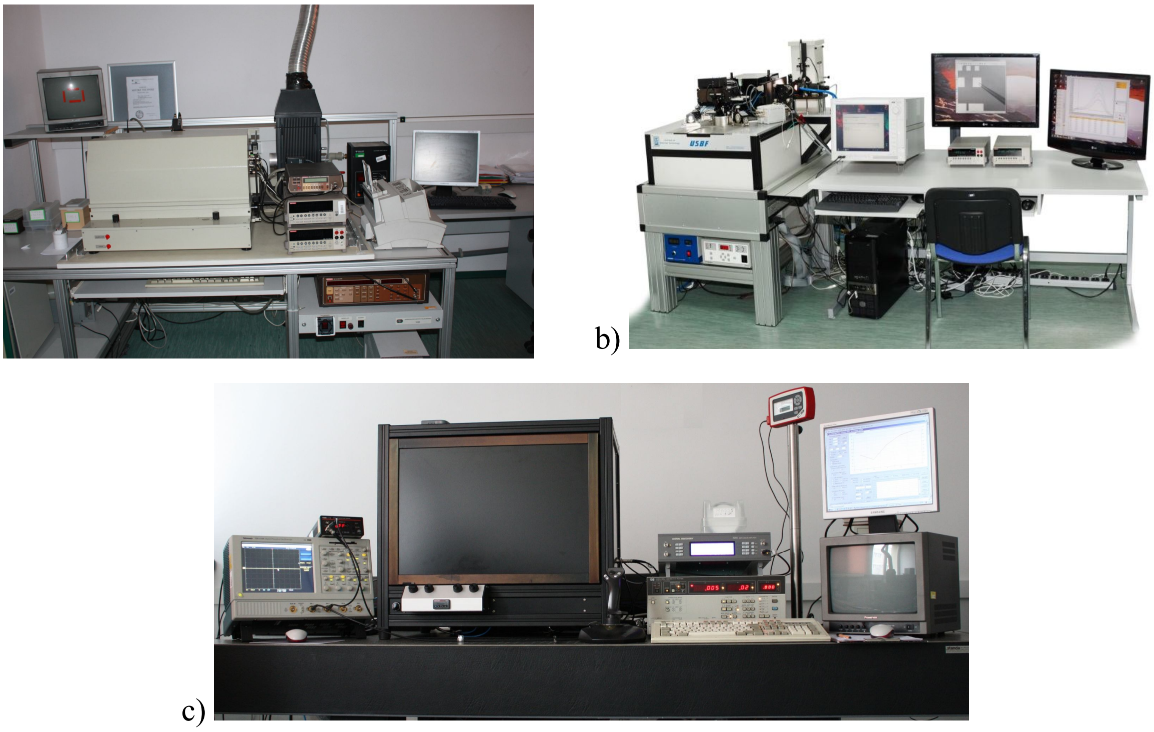
- current I and photocurrent I_F in function of wavelength λ of light and gate voltage V_G;
- capacitance C vs. λ and V_G;
- above mentioned characteristics vs. the power P of the light beam.

The WSBF system has won the title "Champion of Technology-Warsaw 2001" granted by the Polish Federation of Technical Associations.

The second system, USBF (Fig. 4b) has the extended range of light wavelengths λ = 160 ÷ 900 nm, better definition of the light spot, the possibility of scanning the measured structure with the light spot, higher resolution of current measurements (10^{-16} A), control of spectrum and light power distributions over the light spot and semiautomatic execution of measurements.

USBF system has received recognition in the Polish nationwide competition “Champion of Technology – 2012/2013” organized by the Polish Federation of Technical Associations.

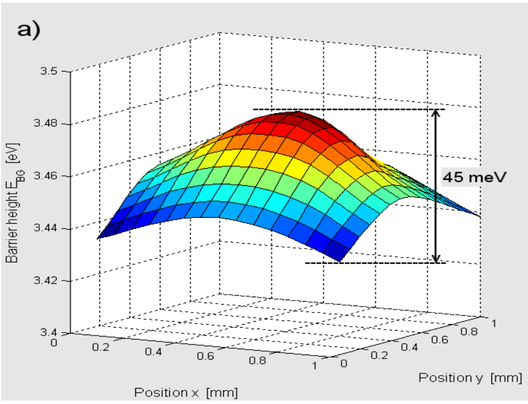
The next measurement setup, called LPT system (Fig. 4c) has been developed and especially adapted for photoelectric measurements of flat-band voltage (V_{FB}) in semiconductor structures made from new materials of unknown electrical properties.



a) b) c)

Fig. 4 Measurement systems dedicated for photoelectric investigations: **a)** the WSBF system, **b)** the USBF system and **c)** the LPT system.

Measurements of illuminated $I_F(V_G)$, $I_F(\lambda)$, $C^*(V_G)$, $C(\lambda)$, $u(V_G)$ characteristics at different light power P and light beam diameters enable to evaluate: effective contact potential difference ϕ_{MS} and its surface distribution under the gate $\phi_{MS}(x,y)$, semiconductor flat-band voltage V_{FB} and its surface distribution under the gate $V_{FB}(x,y)$, flat-band voltage in dielectric V_{G0} and its surface distribution under the gate $V_{G0}(x,y)$, barrier heights at metal-dielectric interface E_{BG} and semiconductor-dielectric interface E_{BS} and their surface distribution under the gate $E_{BG}(x,y)$ and $E_{BS}(x,y)$ (Fig. 5a), dielectric band gap energy E_G and energy band model of the investigated semiconductor structure (Fig. 5b).

a) 

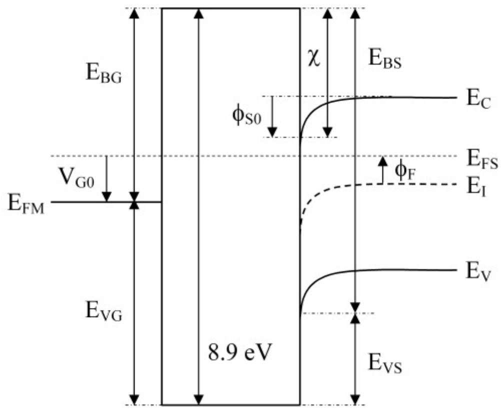
b) 

Fig. 5 **a)** Two-dimensional distribution of the gate-dielectric, E_{BG}, barrier height measured using modified photoelectric Fowler method. **b)** Band diagrams of the Al-SiO_2-SiC(3C) structure constructed for the flat-band state in the dielectric V_{G0} (not to scale).