Analysis of the Urbach energy of quasi-two-dimensional semiconductor oxide micro and nanocoatings

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In this work, the photoconductivity of quasi-two-dimensional micro and nano coatings based on semiconductor oxide dispersed particles in the fundamental absorption band and when shifted from it to the long wavelength region was investigated. The Urbach energy is estimated based on the rate of increase in photoconductivity.

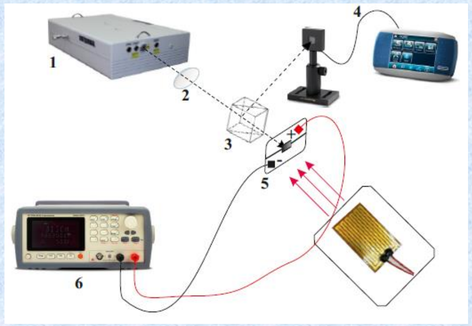

Figure 1 - Scheme of the experimental setup. 1 – laser LOTIS TII 2145-OPO; 2 - quartz lens; 3 - beam splitting cube; 4 - measuring instrument Gentec Maestro Q12MF1; 5 - sample; 6 – teraohmmeter Tetron M13A; Heating was carried out by a resistive heater.

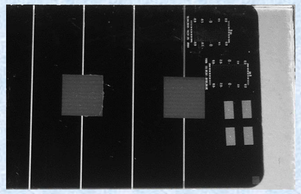

Figure 2 – Matrix counter-electrode system used for WO_3 and SnO_2 particles.

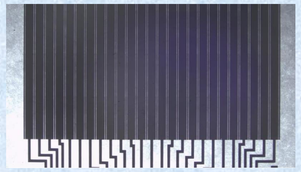

Figure 3 – Matrix counter-electrode system used for TiO_2 particles.

Sample	Particle size	Average layer thickness	Temperature	Voltage	Band gap	The density of the incident energy
TiO_2	<25 nm	125 nm	308 K	12 V	3.2 eV	0.5 mJ/cm^2
WO_3	<25 μm	65 μm	308K	3 V	2.8 eV	1 mJ/cm^2
SnO_2	20 μm	130 μm	300 K	3 V	3.6 eV	2 mJ/cm^2

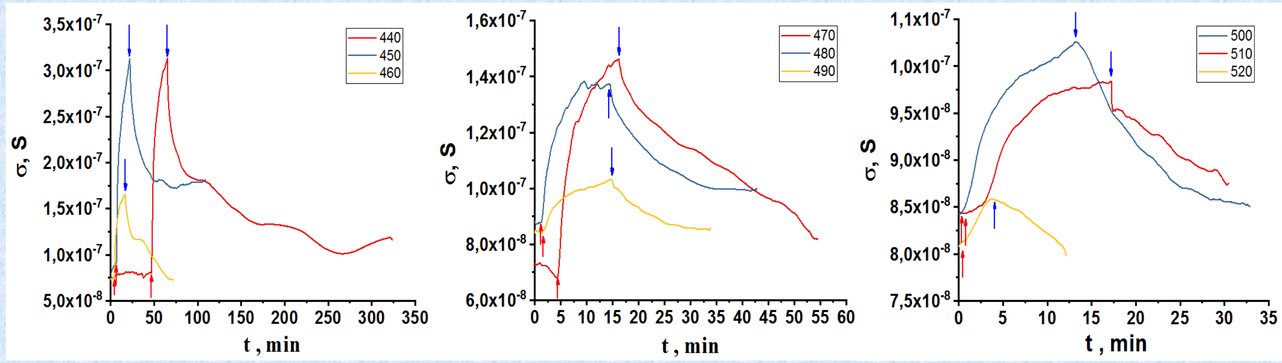

Figure 4 - Time dependences of photoconductivity for tungsten trioxide samples in the wavelength range from 440 to 520 nm. The red arrow marks the beginning of the laser action, the blue arrow symbolizes the end of the laser pumping.

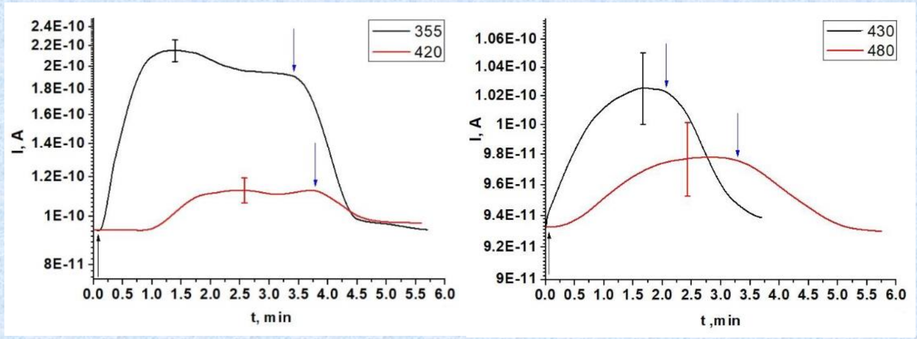

Figure 5 – Time dependences of photocurrent for anatase titanium dioxide samples in the wavelength range from 440 to 520 nm. The black arrow marks the beginning of the laser action, the blue arrow symbolizes the end of the laser pumping.

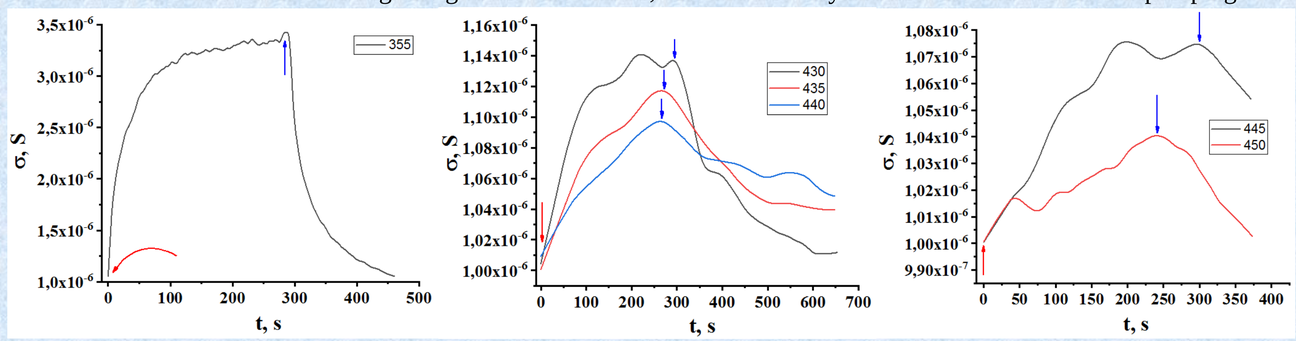

Figure 6 - Time dependences of photoconductivity for tin dioxide samples in the wavelength range from 355 to 450 nm. The red arrow marks the beginning of the laser action, the blue arrow symbolizes the end of the laser pumping.

$$\alpha(E_{pt}) = \alpha_0 exp\left(g\frac{E_{pt}-E_g}{kT}\right)$$

$$g = g_0\left(\frac{2kT}{E_{pn}}\right)tanh\left(\frac{E_{pn}}{2kT}\right)$$

$$E_U = \frac{kT}{g}$$

$$\alpha(E_{pt}) \propto E_{pt}\cdot d\langle\sigma\rangle/dt \propto \exp\left[(E_{pt}-E_g)/E_U\right]$$

E_{pt}, E_g-photon energy and bandgap energy. α_0 is the absorption coefficient at the edge of the fundamental absorption band; g is the steepness parameter that determines the phonon-exciton interaction. E_{pn}- phonon energy.

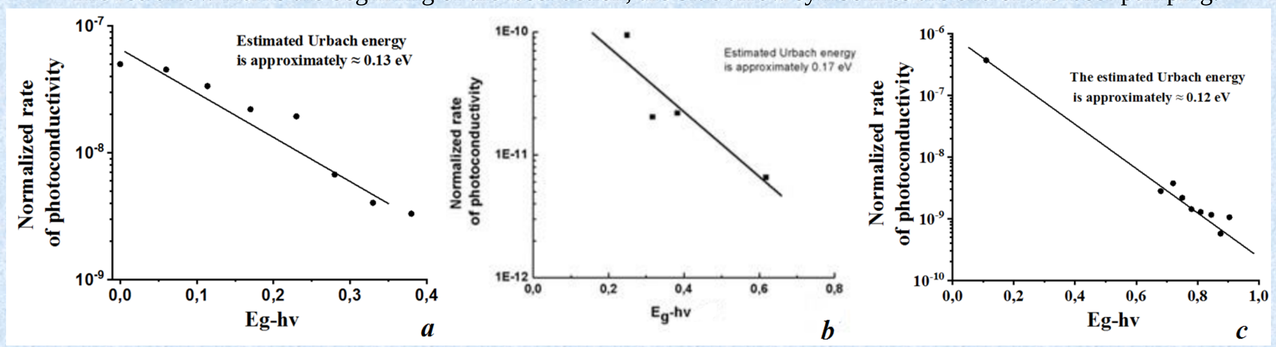

Figure 7 – Estimates of the Urbach energy for the samples under study. (a) – WO_3 ; (b) – TiO_2 ; (c) – SnO_2 ;

Conclusions

In this work, the values of the Urbach energy are reconstructed, which agree with the typical values for semiconductor particles obtained in other works. Despite the differences in the electronic properties of materials, there is a correlation between the Urbach energy values and the specific surface area of the particles, which is expressed in a directly proportional relationship between them. The main mechanism of charge transfer in such systems is electron tunneling through barrier potentials at the boundary of neighboring particles.