



---

Soviet-era science, translated into English

# PHYSICS

Academician of the Academy of Sciences of the Uzbek SSR E. I.  
ADIROVICH, V. M. RUBINOV, Yu. M. YUABOV

1964

SovietRxiv

---

View the original and related papers at <https://sovietrxiv.org/items/ru-196401.59442>

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

**Abstract**

**Full Text**

## PHYSICS

Academician of the Academy of Sciences of the Uzbek SSR E. I. ADIROVICH,  
V. M. RUBINOV, Yu. M. YUABOV

### INVESTIGATION OF ANOMALOUSLY LARGE PHOTOVOLTAGES IN THIN SILICON FILMS

1. In paper <sup>(1)</sup> the preparation of thin silicon films possessing anomalously high photovoltages (a.p.v.) was reported. The present article gives the results of their investigation. The dependences of  $V_{a.p.v.}$  on the light intensity  $I$ , on the wavelength  $\lambda$ , and on the temperature  $T$  have been studied. The a.p.v. effect in polarized light has been investigated, and the dependence of  $V_{a.p.v.}$  on the orientation of the plane of polarization has been established. An electret effect has been found in silicon a.p.v. films at room temperature.

**Table 1**

Film No.	$\rho$ , ohm · cm	Substrate	$R$ , ohm	Polarity	$V_{a.p.v.}$ , V ( $I = 10^5$ lux)
3	1500	Quartz	$1.5 \cdot 10^{14}$	A	40
9	1500	Quartz	$1 \cdot 10^{14}$	A	25
13	1500	Quartz	$1.2 \cdot 10^{11}$	B	5
16	1500	Quartz	$6 \cdot 10^{11}$	A	36
19	1500	Quartz	$2.5 \cdot 10^{12}$	B	100
22	1500	Glass	$5 \cdot 10^{11}$	B	2.4
28a	0.1	Glass	$1.2 \cdot 10^{12}$	B	3
33	0.1	Quartz	$7 \cdot 10^{11}$	B	2.2
101	0.1	Quartz	$5 \cdot 10^{12}$	B	2
102	0.1	Quartz	$2 \cdot 10^{12}$	A	16.3
105	0.1	Quartz	$4 \cdot 10^{11}$	B	7.4

All the films investigated in this work were prepared by the method described in paper <sup>(1)</sup>. In addition to fairly pure silicon ( $\rho \sim 1500$  ohm · cm), low-resistance silicon ( $\rho \sim 0.1$  ohm · cm) was also used as the starting material. As is seen from Table 1, the dark resistance of the films  $R$  is very large, independently of the resistivity of the starting material. Apparently, the main contribution to  $R$  is made by intercrystalline regions. In Table 1, in those cases where the “plus”

Figure 1 and Figure 2: graphs of  $V$  versus light intensity and temperature dependence of  $V$ .

Figure 1: Figure 1 and Figure 2: graphs of  $V$  versus light intensity and temperature dependence of  $V$ .

potential arises at the thicker end of the film, its polarity is denoted by A, and in the opposite case by B. The film thickness is of the order of 1 to 5  $\mu$ . A thickness gradient is observed visually.

2. Studies of the dependence of the photovoltage of silicon a.p.v. films on light intensity were carried out by attenuating the light flux with a set of neutral light filters of the NS type of different optical density. The light source was a 750-watt incandescent lamp with a concentrated filament. A quartz condenser with an SZS-17 heat filter was used. The maximum illumination was  $10^5$  lx.

The dependence of the photovoltage on the light intensity proved to be linear. The lux-volt characteristics of three of the films investigated are shown in Fig. 1. We note that in one of these films (No. 9) the a.p.v. effect has A-type polarity, and in the others B-type. There is no unambiguous relation between the magnitude of  $V_{a.p.v.}$  and the dark resistance of the film; however, analysis of the entire set of experimental data shows that, as a rule,  $V_{a.p.v.}$  is larger in higher-resistance films.

Some of the lux-volt characteristics do not pass through zero, as is seen from the curves  $V_{a.p.v.}(I)$  near the origin, shown in Fig. 1 on an enlarged scale. A constant (or very slowly changing) residual voltage  $V_{el}$  of the order of 0.1–0.5 V is observed in approximately one-third of the total number of films obtained. Monitoring of these films, kept in the dark for more than a month, did not reveal any noticeable change in  $V_{el}$ . Experiments on heating the films in vacuum to  $\sim 100^\circ$  likewise did not lead to the disappearance of this residual voltage.

3. Temperature measurements were carried out as follows. The film deposited on the substrate was placed on a copper table located in a glass vessel evacuated to  $10^{-1}$  torr. Heat transfer was effected through a molybdenum rod brought out to the exterior. Cooling of the films was achieved by immersing the rod in liquid nitrogen to various depths. To raise the temperature of the films, an electric heater was mounted on the rod. The temperature was measured with a thermocouple located on the same side of the substrate as the film and shielded from light.

The experimental setup described above makes it possible to provide a sufficiently high leakage resistance, which is especially important at low temperatures, when the resistances of the films are large.

**Fig. 1.** Dependence of  $V_{aph}$  on the light intensity  $I$  and the electric effect in Si films ( $T = 293^\circ\text{K}$ )

**Fig. 2.** Temperature dependence of  $V_{\text{aph}}$

In contrast to the results reported by Kalman et al. <sup>(2)</sup>, our measurements showed a significant (by 1-2 orders of magnitude) increase in the resistance  $R$  of the films as the temperature was lowered from room temperature to  $-60^\circ$ . The values of  $R$  for films placed directly in liquid nitrogen, regardless of their resistance at room temperature, evidently reach  $\sim 10^{15} \Omega$ . Since the leakage resistance between electrodes placed in liquid nitrogen is  $\sim 10^{15} \Omega$ , higher values of  $R$  for films in liquid nitrogen naturally cannot be measured.

**Table 2**

		Film No.				
		13	16	101	102	105
$T = 20^\circ$	$V, V$	2	14	0.8	6.5	3
$T = 20^\circ$	$V', V$	1.5	7	5	7.5	3
$T = -196^\circ$	$V, V$	200	640	18	370	300
$T = -196^\circ$	$V', V$	150	500	8	200	250

**Table 3**

	Film No.	5	16	19	22	33	105	107
Polarity of the photovoltage		A	A	B	B	B	B	B
$\varphi_{\text{max}}, \text{deg}$		0	0	90	90	90	0	90

The curves of the temperature dependence of  $V_{\text{aph}}$  are shown in Fig. 2. Separately,  $V_{\text{aph}}$  was measured at  $-196^\circ$  by illuminating films directly immersed in liquid nitrogen. The corresponding values of  $V_{\text{aph}}$  are given in Table 2; here  $V$  and  $V'$  are the values of the photovoltage when the film is illuminated, respectively, from above and through the substrate. All temperature dependences were determined at an illumination of 40,000 lx because of the need to ensure reliable cooling of the films. Despite the comparatively low illumination level, photovoltages up to 600 V were obtained on films 0.5-1 cm long.

4. The spectral sensitivity of the a.p.v.-effect in Si films was determined in the same way as in <sup>(1)</sup>. However, this time we measured not the short-circuit current, but directly  $V_{\text{apv}}$ . The measurements were made by the compensation method. The reduction of the quantity  $V_{\text{apv}}(\lambda)$  to unit incident energy was carried out by calculating the spectral density of the radiation emitted by the exit slit of the monochromator, taking into account the emission spectrum of tungsten and the dispersion of the monochromator.

Fig. 3. Spectral sensitivity  $V_{apv}$

Figure 2: Fig. 3. Spectral sensitivity  $V_{apv}$

Fig. 4. Polar diagram of the dependence of  $V_{apv}$  on the angle  $\varphi$  between the plane of polarization of the light and the line connecting the film electrodes (film No. 19)

Figure 3: Fig. 4. Polar diagram of the dependence of  $V_{apv}$  on the angle  $\varphi$  between the plane of polarization of the light and the line connecting the film electrodes (film No. 19)

**Fig. 3.** Spectral sensitivity  $V_{apv}$

**Fig. 4.** Polar diagram of the dependence of  $V_{apv}$  on the angle  $\varphi$  between the plane of polarization of the light and the line connecting the film electrodes (film No. 19)

The curves  $V_{apv}(\lambda)$  for three films are shown in Fig. 3. The spectra of the a.p.v.-effect for different films differ substantially: along with a monotonically decreasing spectral-sensitivity curve (film No. 16), a complex spectral behavior of  $V_{apv}(\lambda)$  with two inversion points (film No. 19) was found. The spectral sensitivity of film No. 3 may be regarded as an intermediate case. The curve  $V_{apv}(\lambda)$  for this film may be represented as the superposition of the curve for film No. 16 and a bell-shaped curve  $\tilde{V}(\lambda)$  with a maximum  $|\tilde{V}|$  at  $\lambda \simeq 480$  m $\mu$ , falling practically to zero at  $\lambda \simeq 400$  m $\mu$  and  $\lambda \simeq 600$  m $\mu$ . In addition to an analogous region of selective (and sign-inverting in voltage) spectral sensitivity at  $\lambda \simeq 400 \div 600$  m $\mu$ , film No. 19 also exhibits increased positive selective sensitivity in the longer-wavelength region of the spectrum; this, apparently, is also connected with the high value of  $V_{apv}$  produced in this film when it is illuminated with white light from an incandescent lamp (see Table 1).

- Experiments in polarized light showed that, for all the films studied,  $V_{apv}$  depends on the orientation of the plane of polarization of the light relative to the line connecting the film electrodes. A typical polar diagram of the dependence of  $V_{apv}$  on the angle  $\varphi$  between the plane of oscillation of the electric vector in the incident light and the line connecting the electrodes in the film is given in Fig. 4. For all films the maximum is located either at  $\varphi_{max} = 0^\circ$  or at  $\varphi_{max} = 90^\circ$ . For sample No. 19 (Fig. 4) the maximum  $V_{apv}$  corresponds to  $\varphi_{max} = 90^\circ$ . As is seen from Table 3, there is no unambiguous correspondence between  $\varphi_{max}$  and the polarity type A or B. However, the experiment shows that  $\varphi_{max} = 0^\circ$  more often corresponds to polarity of type A, while  $\varphi_{max} = 90^\circ$  corresponds to polarity of type B.

Physico-Technical Institute  
Academy of Sciences of the Uzbek SSR

Received

27 II 1964

## CITED LITERATURE

<sup>1</sup> E. I. Adirovich, Yu. M. Yuabov, *DAN*, **155**, No. 6 (1964). <sup>2</sup> H. Kallman, B. Kramer et al., *J. Electrochem. Soc.*, **108**, 3, 247 (1961).

*Note: Figure translations are in progress. See original paper for figures.*

*Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.*