ROENTGENDOSIMETRIC CHARACTERISTICS OF DETECTORS ON THE BASE OF $TlGaS_2$ <Yb> SINGLE CRYSTALS

S.N. Mustafaeva, E.M. Kerimova, P.G. Ismailova, M.M. Asadov

Institute of Physics, Azerbaijan National Academy of Sciences
Baku, AZ–1143, G. Javid av. 33

There have been studied the influence of partial substitution of Ga on Yb in $TlGaS_2$ single crystals, on roentgendosimetric characteristics of grown single crystals. Analysis of obtained experimental data showed that roentgenconductivity coefficient (K_σ) in all crystals under investigation is regularly decreased as with the rise of irradiation dose (E) as increasing the value of accelerating voltage (V_a) on X-ray tube. As a result of partial substitution Ga→Yb in $TlGaS_2$ single crystals K_σ is increased, and roentgen-ampere characteristics ($\Delta I_{E,0} \sim E^\alpha$) tend to linearity ($\alpha$=1) in the range of low intensities of soft (low V_a) roentgen radiation. In the range of comparatively high intensities of harder (high V_a) roentgen radiation $\alpha \to 0.5$ as for $TlGaS_2$, as for $TlGaS_2$<Yb>.

$TlGaS_2$ single crystals are representatives of laminated semiconductors. These crystals are wide-band and high resistive. Dc- and ac- conductivities of $TlGaS_2$ single crystals were investigated in [1, 2]. In [3], the results of study of γ-radiation influence on ac-conductivity of $TlGaS_2$ single crystals were described. Of some interest is the study of influence of Ga partial substitution in $TlGaS_2$ for rare earth elements on their physical properties.

The aim of the present paper is the study of influence of partial substitution of Ga on Yb in $TlGaS_2$ single crystals, on roentgenconductivity and roentgendosimetric characteristics of these crystals.

Samples of $TlGaS_2$<0.1 mol.% Yb> composition have been synthesized by melting of initial high-purity (no less 99.99) components in vacuumed quartz ampoules up to 10^{-3} Pa, and their single crystals have been grown by Bridgeman-Stockbarger method. X-ray analysis showed that $TlGa_{0.999}Yb_{0.001}S_2$ is crystallized in monoclinic structure with elementary cell parameters: a = 10.776; b = 10.776; c = 15.646 Å; β = 100.06°; z = 16; roentgen density ρ_x = 5.022 g/cm^3. Samples from $TlGaS_2$ and $TlGaS_2$<Yb> for measurements are obtained by spalling along the C-axis of the natural spall from massive single crystals and have a thickness by 50÷100 μm order. Ohmic contacts of samples are made by In melting. Samples have produced in planar structure so that constant electric field applies along the layers of single crystals, and X-rays were directed along the C-axis of crystals. Distance between the indium contacts was equal to 0.10÷0.15 cm for different samples. Electric conductivity (σ) of obtained samples has been measured at 300 K. Intensity of applied constant electric field is corresponding to ohmic

and quadratic section on volt-ampere characteristics (VAC). For measurements the samples have been placed in screened cell. The ratio of dark resistivities after and prior to Yb-doping amounts to ~ 70.

Roentgenconductivity and roentgendosimetric characteristic measurements are carried out in low load resistance regime at 300 K. The source of roentgen radiation is the installation of X-ray diffraction analysis (URS-55a) with the tube BSV-2 (Cu). Intensity of roentgen radiation (E) is regulated by measurement with current variation in tube at each given value of accelerating potential (V_a) on it. Absolute values of roentgen radiation dose E(R/min) are measured by crystal dosimeter (DRGZ-02).

Roentgenconductivity coefficients K_σ characterizing roentgensensitivity of investigated crystals are determined as the relative change of conductivity under roentgen radiation a per dose:

$$K_\sigma = \frac{\sigma_E - \sigma_0}{\sigma_0 \cdot E} = \frac{\Delta\sigma_{E,0}}{\sigma_0 \cdot E}, \tag{1}$$

where, σ_0 is conductivity in the absence of roentgen radiation (dark conductivity), σ_E is conductivity under the effect of radiation with the dose intensity E(R/min).

There have been determined values of characteristic coefficients of roentgenconductivity as of the initial single crystal $TlGaS_2$ as of $TlGaS_2$<0.1 mol.% Yb> at different values of accelerating voltage (V_a) on the tube and corresponding doses of roentgen radiation.

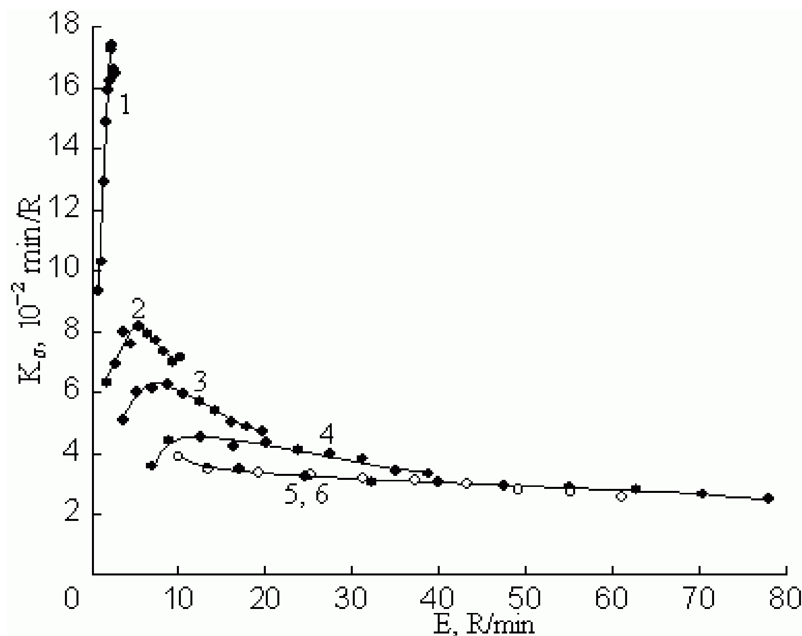

Fig. 1 Dependences of characteristic coefficients of roentgenconductivity on dose intensity for $TlGaS_2$ single crystal (F = 80 V/cm) at various values of accelerating voltages: 1 – 25; 2 – 30; 3 – 35; 4 – 40; 5 – 45; 6 – 50 keV and 300 K.

In Fig. 1 there have been presented dependence of K_σ on dose intensity for $TlGaS_2$ single crystal at 300 K and electric field F = 80 V/cm (ohmic section of VAC). Curves 1-6 correspond to various values of accelerating voltage V_a from 25 to 50 keV (effective hardness).

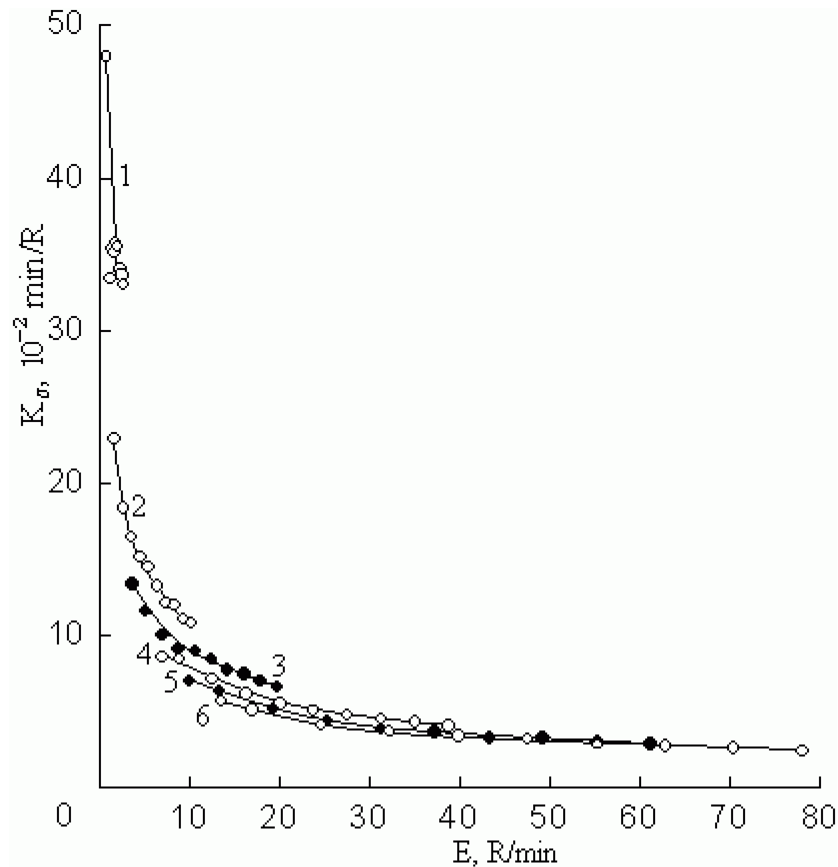

Fig. 2 $K_\sigma(E)$ – dependences for $TlGaS_2$<Yb> single crystal (F=70 V/cm) at various values of V_a: 1 – 25; 2 – 30; 3 – 35; 4 – 40; 5 – 45; 6 – 50 keV (T = 300 K)

Fig. 2 shows same dependence $K_\sigma(E)$ for $TlGaS_2$<Yb> single crystal at F = 70 V/cm. It is seen from these figures that roentgensensitivity of $TlGaS_2$ single crystal changes in interval 0.025÷0.174 min/R, but in $TlGaS_2$<Yb> K_σ = 0.024÷0.480 min/R, i.e. roengenconductivity coefficient of $TlGaS_2$<Yb> crystal is increased comparing with K_σ of $TlGaS_2$ crystal. Analysis of obtained data showed that roengenconductivity coefficient of $TlGaS_2$<Yb> crystals are regularly decreased as with the rise of dose as with the increase of values of accelerating voltage V_a on roentgen tube. At V_a > 30÷35 keV and E > 10÷15 R/min change of K_σ (E,V_a) is slight in studied crystals $TlGaS_2$ and $TlGaS_2$<Yb>. One of the possible reason of observed regularities is that roengenconductivity in investigated crystals, especially at comparatively low accelerating voltages is predominantly due to radiation absorption in thin layer of crystal. In this case with the rise of radiation intensity there have been started to prevail the mechanism of surface quadratic recombination which leads to observed decrease of roengenconductivity. With the rise of accelerating potential effective hardness is increased owing to penetration depth into crystal is increased, as a result of which there have been taken place predominantly absorption-generation of free roentgen carriers in volume and fraction of incident radiation passing through crystal is increased.

Dependence of K_σ on dose intensity was measured also at high electric fields (from quadratic section of VAC). $K_\sigma(E)$-dependence for $TlGaS_2$<Yb> single crystal at $F=1.5\cdot10^3$ V/cm has been shown in Fig. 3.

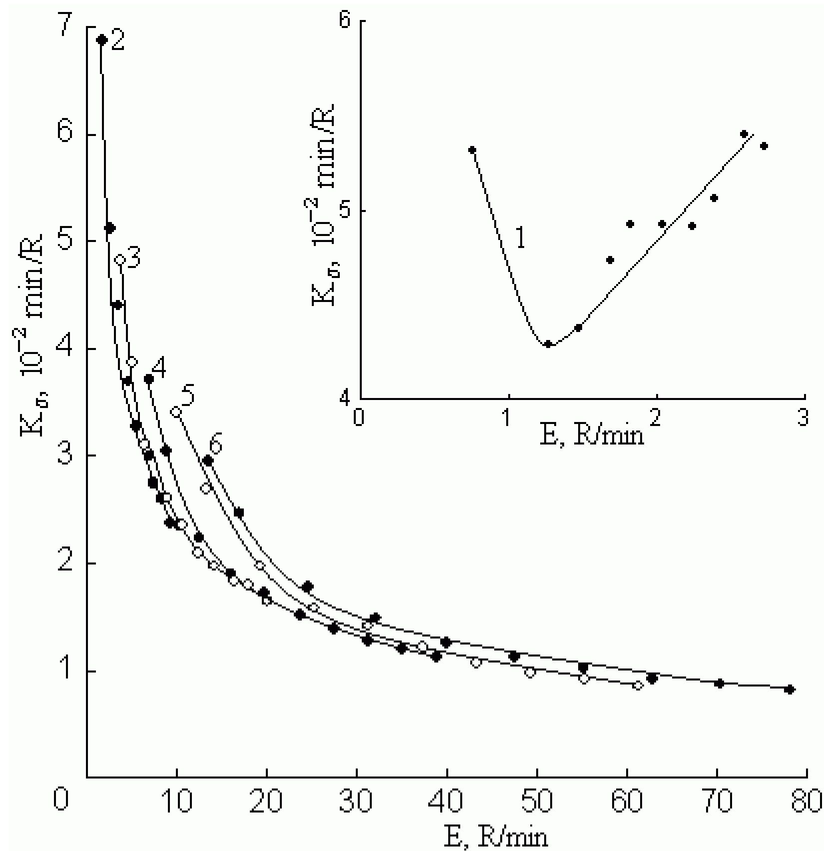

Fig. 3 Dependences of K_σ vs E for $TlGaS_2$<Yb> at $F=1.5\cdot10^3$ V/cm and V_a = 25; 30; 35; 40; 45; 50 keV for curves 1–6.

Table 1 shows the experimental results of $K_\sigma(E)$-study obtained for $TlGaS_2$ single crystal at F = 300 V/cm. It is seen from Fig. 3 and Table 1 that the values of K_σ at voltages from quadratic region of VAC are less comparing with K_σ measured at ohmic voltages as for $TlGaS_2$ as for $TlGaS_2$<Yb> single crystals. This experimental result is evidence of fact that at high electric fields concentration of injected from contact charge carriers is more than concentration of roentgen carriers. In other words in formula (1) dark conductivity σ_0 increased due to injection and as result, K_σ decreased.

We also study roentgen-ampere characteristics of $TlGaS_2$ and $TlGaS_2$<Yb> single crystals (Fig. 4 and 5), from which it follows that dependence of stationary roentgencurrent on roentgen radiation dose has a ratio character:

$$\Delta I_{E,0} = I_E - I_0 \sim E^\alpha \tag{2}$$

Table 1

Roentgenconductivity coefficients of $TlGaS_2$ single crystal at supply voltage (working voltage) equal to 40V (F = 300 V/cm) and T = 300 K.

V_a, keV	E, R/min	K_σ, min/R	V_a, keV	E, R/min	K_σ, min/R
25	0.75	0.067	40	7.00	0.036
	1.26	0.064		8.89	0.033

	1.47	0.068		12.60	0.030
	1.68	0.066		16.38	0.029
	1.82	0.082		20.09	0.029
	2.03	0.089		23.80	0.033
	2.24	0.085		27.58	0.031
	2.38	0.088		31.29	0.031
	2.59	0.093		35.07	0.030
	2.73	0.099		38.78	0.029
30	1.75	0.080	45	10.00	0.025
	2.73	0.073		13.37	0.025
	3.64	0.060		19.32	0.024
	4.62	0.058		25.34	0.027
	5.53	0.052		31.29	0.027
	6.44	0.053		37.24	0.028
	7.42	0.047		43.26	0.028
	8.33	0.047		49.21	0.027
	9.31	0.045		55.23	0.027
	10.22	0.047		61.18	0.026
35	3.75	0.053	50	13.50	0.024
	5.18	0.048		17.01	0.025
	7.00	0.046		24.64	0.025
	8.82	0.042		32.27	0.028
	10.64	0.041		39.90	0.029
	12.46	0.042		47.53	0.030
	14.28	0.043		55.16	0.030
	16.10	0.042		62.79	0.029
	17.92	0.039		70.42	0.029
	19.74	0.038		78.05	0.028

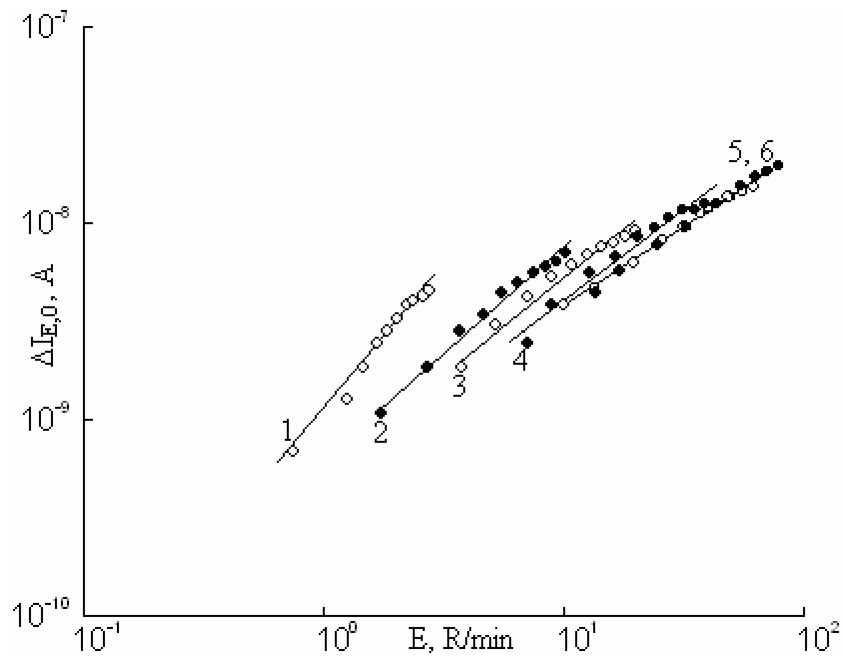

Fig. 4 Roentgen-ampere characteristics of $TlGaS_2$ single crystal at various effective hardnesses: 1 – 25; 2 – 30; 3 – 35; 4 – 40; 5 – 45; 6 – 50 keV (T = 300 K)

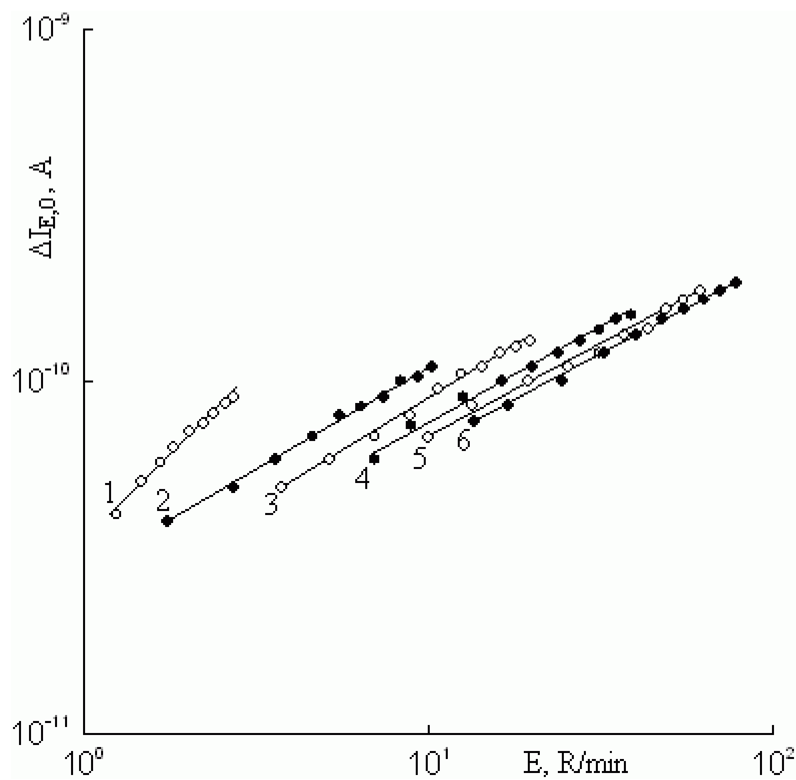

Fig. 5 Dependences of $\Delta I_{E,0}$ vs E for $TlGaS_2$<Yb> at $V_a = 25\div50$ for curves 1–6.

Ratio of given dependence α is determined graphically from roentgen-ampere characteristics as the tangent of angle of slope of dependence lg $\Delta I_{E,0}$ vs lg E. α – values for investigated crystals vs effective hardness V_a are shown in Fig. 6. As it is seen from Fig. 6 with partial Ga→Yb substitution in $TlGaS_2$ single crystals, roentgen-ampere characteristics tend to linearity (α=1) in the range of low intensities of

soft (low V_a) roentgen radiation. In the range of comparatively high intensities of harder (high V_a) roentgen radiation $\alpha \to 0.5$ as for initial as for doped by Yb $TlGaS_2$ single crystals.

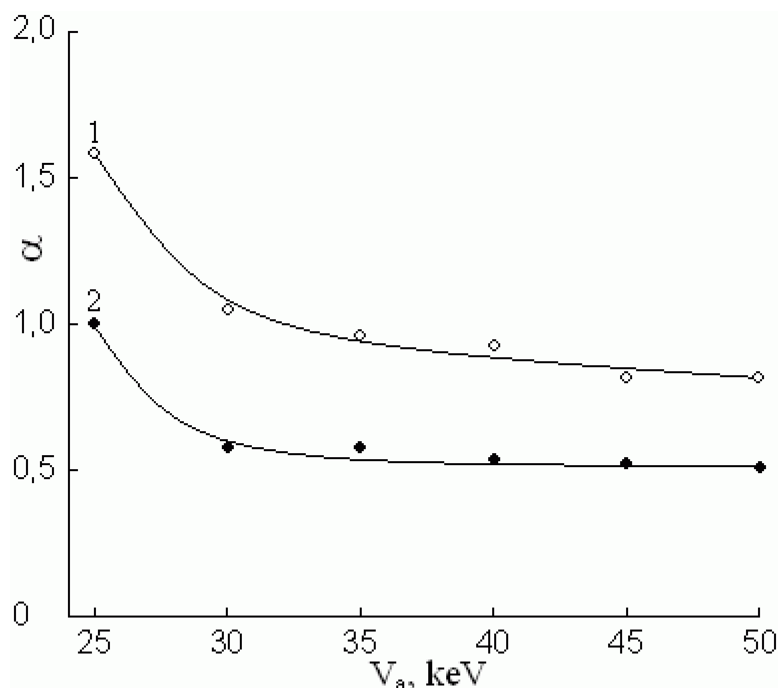

Fig. 6 $\alpha(V_a)$ – dependences for $TlGaS_2$ (curve 1) and $TlGaS_2$<Yb> (curve 2) single crystals

Obtained results show that $TlGaS_2$<Yb> single crystals have high roengensensitivity and can be used for the creation of roentgendetectors.

References

1. S.N. Mustafaeva, V.A. Aliev, M.M.Asadov, Fiz. Tverd. Tela (St. Petersburg) 40(4), 612 (1998) [Phys. Solid State 40, 561 (1998)]
2. A.U. Sheleg, K.V. Iodkovskaya, N.F. Kurilovich, Fiz. Tverd. Tela (St. Petersburg) 45(1), 68 (2003) [Phys. Solid State 45, 69 (2003)]
3. S.N. Mustafaeva Fiz. Tverd. Tela (St. Petersburg) 46(6), 979 (2004) [Phys. Solid State 46 (6), 1008 (2004)]

РЕНТГЕНОДОЗИМЕТРИЧЕСКИЕ ХАРАКТЕРИСТИКИ ДЕТЕКТОРОВ НА ОСНОВЕ МОНОКРИСТАЛЛОВ $TlGaS_2$<Yb>

С.Н. Мустафаева, Э.М. Керимова, П.Г. Исмаилова, М.М. Асадов

Изучено влияние частичного замещения Ga на Yb в монокристаллах $TlGaS_2$<Yb> на рентгенодозиметрические характеристики выращенных монокристаллов. Анализ полученных экспериментальных результатов показал, что коэффициент рентгенопроводимости (K_σ) исследованных кристаллов закономерно уменьшается с ростом дозы (E) и энергии (V_a) рентгеновского излучения. В результате частичного замещения Ga→Yb в $TlGaS_2$ K_σ увеличивается, а рентген-амперные характеристики ($\Delta I_{E,0} \sim E^\alpha$) стремятся к линейности (α=1) в области малых интенсивностей мягкого (низкие V_a) рентгеновского излучения. В области сравнительно высоких интенсивностей жесткого (высокие V_a) рентгеновского излучения $\alpha \to 0.5$ как для $TlGaS_2$, так и для $TlGaS_2$<Yb>.

$TlGaS_2$<Yb> MONOKRİSTALI ƏSASINDA HAZIRLANMIŞ RENTGEN DETEKTORLARININ RENTGEN DOZİMETRIK XARAKTERİSTİKALARI

S.N. Mustafayeva, E.M. Kərimova, P.H. İsmayılova, M.M. Asadov

Yetişdirilmiş kristallarda Ga→Yb qismən əvəz olunmasının rentgen dozimetrik xarakteristikalarına tə’siri öyrənilmişdir. Alınmış eksperimental nəticələr göstərdi ki, tədqiq olunan kristallarda rentgen keçiricilik əmsalı (K_σ) dozanın (E) və rentgen şüasının enerjisinin (V_a) artması ilə qanuna uyğun olaraq azalır. $TlGaS_2$-də Ga→Yb qismən əvəz olunması nəticəsində K_σ yüksəlir, rentgen-amper xarakteristikalar isə ($\Delta I_{E,0}$~E^α) yumşaq rentgen şüasının (kiçik V_a) aşağı intensivli oblastında xəttiləşir (α=1). Sərt (yüksək V_a) rentgen şüasının yüksək intensivlikli oblastında $TlGaS_2$-də olduğu kimi $TlGaS_2$<Yb>-də $\alpha\to0.5$ olur.