ROENTGENDOSIMETRY OF INTERCALATED $TlGaSe_2$ SINGLE CRYSTALS

S.N. Mustafaeva, M.M. Asadov

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

The roentgendosimetric characteristics of the pure and lithium-intercalated $TlGaSe_2$ single crystals were investigated. Compared to pure single crystal intercalated single crystal $TlGaSe_2$ <Li^+> is more sensitive to roentgen radiation. The ratio of coefficients of roentgencurrent after and prior to intercalation amounts to ~ 3 ÷ 6 at the range of the x-rays energies 25 – 50 keV and dose intensities from 0.8 to 78 R/min.

$TlGaSe_2$ single crystals belong to the number of layer semiconductors that can be intercalated with foreign ions, atoms or molecules. The effect of metal intercalation on the physical properties of $TlGaSe_2$ single crystals was described in [1 – 3]. It has been revealed that, unlike for non-intercalated $TlGaSe_2$ single crystals, with intercalated crystals the existence of an electric and photoelectric memory is observed, the spectral sensitivity region expands, and new structures appear in the photocurrent spectra [1, 3]. In [2] it was shown that intercalation of $TlGaSe_2$ single crystal with lithium ions leads to a shift of the excitonic peak to longwave spectrum range. This result is evidence in favour of a quality change in exciton characteristics, i.e. their shift to the side of a larger anisotropy.

The aim of this report is the investigation of influence of intercalation on roentgendosimetric characteristics of $TlGaSe_2$ single crystals.

The starting layered $TlGaSe_2$ single crystals were grown by the modified Bridgman method. The samples used for the measurements had thickness of the 55 microns. The specimen contacts were produced from an In – Ga eutectic mixture.

Intercalation was carried out by the method of a pulling electric field applied along the layers of the single crystals. Lithium ions were chosen by us the intercalant inasmuch as they provided effective intercalation without destroying the crystals, owing to their rather small ionic radius (0.68 Å). For the intercalation $TlGaSe_2$ single crystal in the form of a rectangular parallelepiped with a conducting electrode at the butt-end, brought in contact with a column of an 0.5 mole aqueous LiCl solution on the opposite face, with a lower graphite electrode (Fig. 1). This electrochemical cell was connected directly to an external dc source (the negative terminal connected to the $TlGaSe_2$ crystal). Electric field was applied along the layers of $TlGaSe_2$ single crystal, and the ions (Li^+) from the solution enter the interlayer space of the crystal.

Thus, electric current flows trough the created electrochemical cell:

/graphite electrode // 0.5 mole aqueous LiCl solution + $TlGaSe_2$ single crystal // metal electrode/.

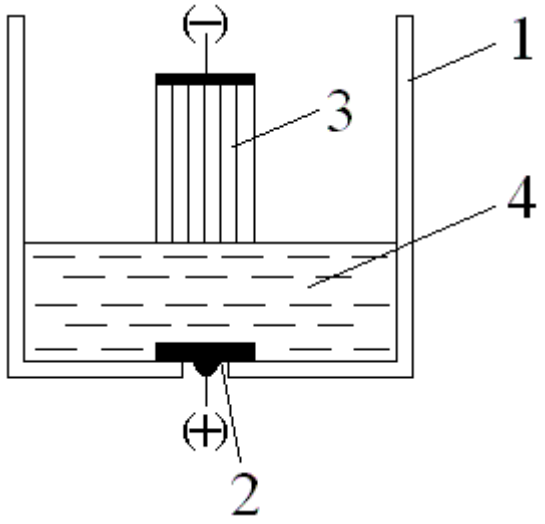

Fig.1. The scheme of electrochemical cell for intercalation:
1 – glass; 2 – graphite electrode; 3 – $TlGaSe_2$ single crystal;
4 – 0.5 mole aqueous LiCl solution

The intercalation degree $j \cdot t$ (j is the current density, t is the intercalation time) amounted to ~ 15 $C \cdot cm^{-2}$.

Quite identical plates were obtained from the same area of $TlGaSe_2$ single crystal by cleavage along the natural cleavage plane. One of the plates was preintercalated with lithium by a pulling electric field. In order to perform a comparative analysis, identical pair of specimens was prepared from a part of this plate prior to intercalation. The characteristics of appropriate pairs of specimens obtained both from intercalated and non-intercalated initial $TlGaSe_2$ single crystals were measured under the same conditions. 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 contacts was equal to ~ 0.15 cm for different samples. Electric conductivity of obtained samples has been measured at T = 300 K. Intensity of applied constant electric filed is corresponding to ohmic section on volt-ampere characteristics. For measurements the samples have been placed in a screened chamber.

The roentgendosimetric characteristic measurements are carried out in low load resistance regime at 300 K. The source of roentgen radiation is the installation URS – 55a with the tube BSV – 2 (Cu). Intensity of roentgen radiation (E) is regulated by the 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. The registered range of the x-rays energy was 25 ÷ 50 keV and the range of the measured power was 0.8 ÷ 78 R/min.

The roentgenconductivity coefficients K_σ characterizing roentgensensitivity of investigated crystals are determined as the relative change of conductivity under roentgen radiation per dose: $K_\sigma = \Delta\sigma / (\sigma_0 \cdot E)$, where σ_0 is conductivity in the absence of roentgen radiation (dark conductivity); $\Delta\sigma = \sigma_E - \sigma_0$; σ_E is conductivity under the effect of radiation with the dose intensity E.

There have been determined values of characteristic coefficients of the roentgenconductivity as of the initial single crystal $TlGaSe_2$ as of $TlGaSe_2$ <Li^+> at the different values of accelerating voltage (V_a) on the tube and corresponding doses of roentgen radiation. In Fig. 2 there have been presented the dependences of relative change of $TlGaSe_2$ and $TlGaSe_2$ <Li^+> conductivity ($\Delta\sigma / \sigma_0$) under the effect of radiation on dose intensity.

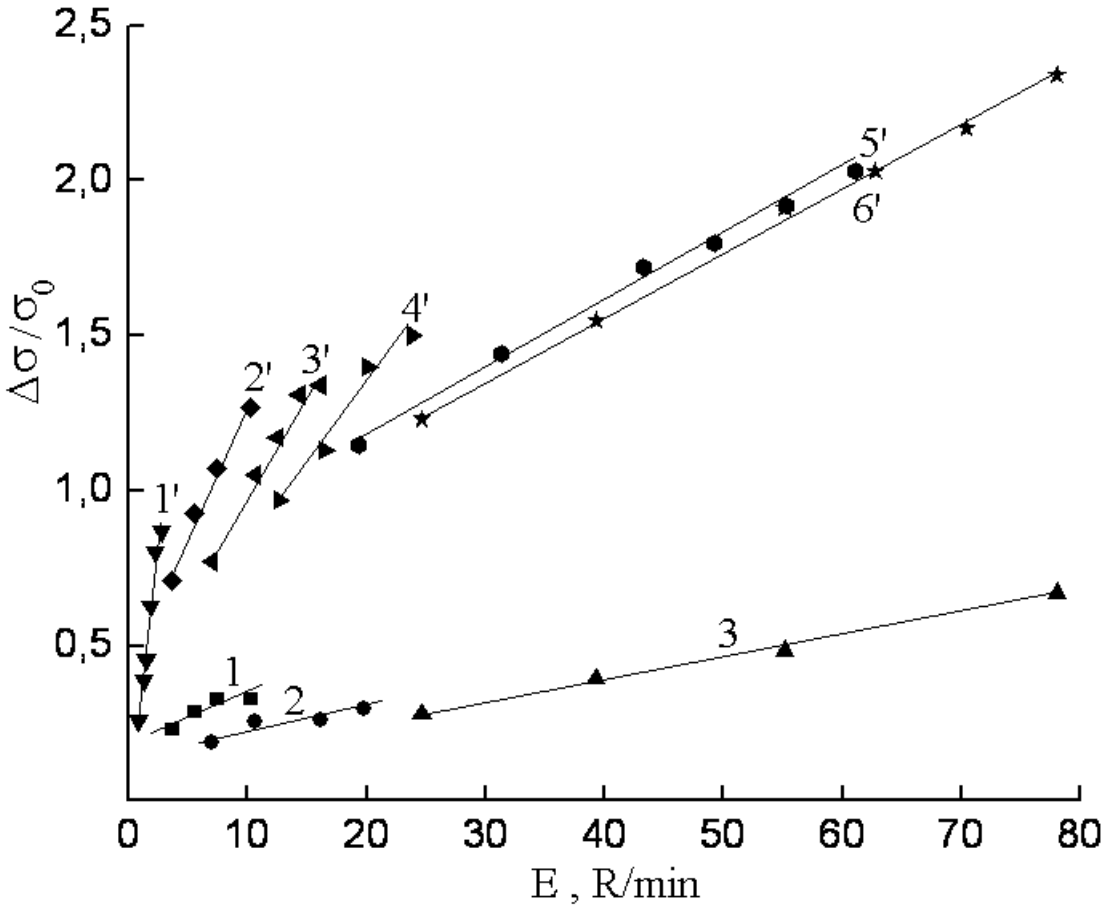

Fig. 2. Dependences of relative change of conductivity on dose intensity for $TlGaSe_2$ (curves 1 – 3) and $TlGaSe_2$ <Li^+> single crystals (curves 1' – 6') at various values of accelerating voltages V_a, keV: 1' – 25; 1 and 2' – 30; 2 and 3' –35; 4' – 40; 5' – 45; 3 and 6' – 50. T = 300 K.

As it is seen from Fig.2 the slopes of $\Delta\sigma/\sigma_0$ vs E dependences are regularly decreased as with the rise of dose as with the increase of values of accelerating voltage V_a on roentgen tube. The tangent of angle of slope of dependence $\Delta\sigma/\sigma_0$ on V_a is roentgensensitivity coefficient K_σ. Fig. 3 demonstrated the dependence of K_σ vs V_a for $TlGaSe_2$ (curve 1) and $TlGaSe_2$ $<Li^+>$ (curve 2) single crystals.

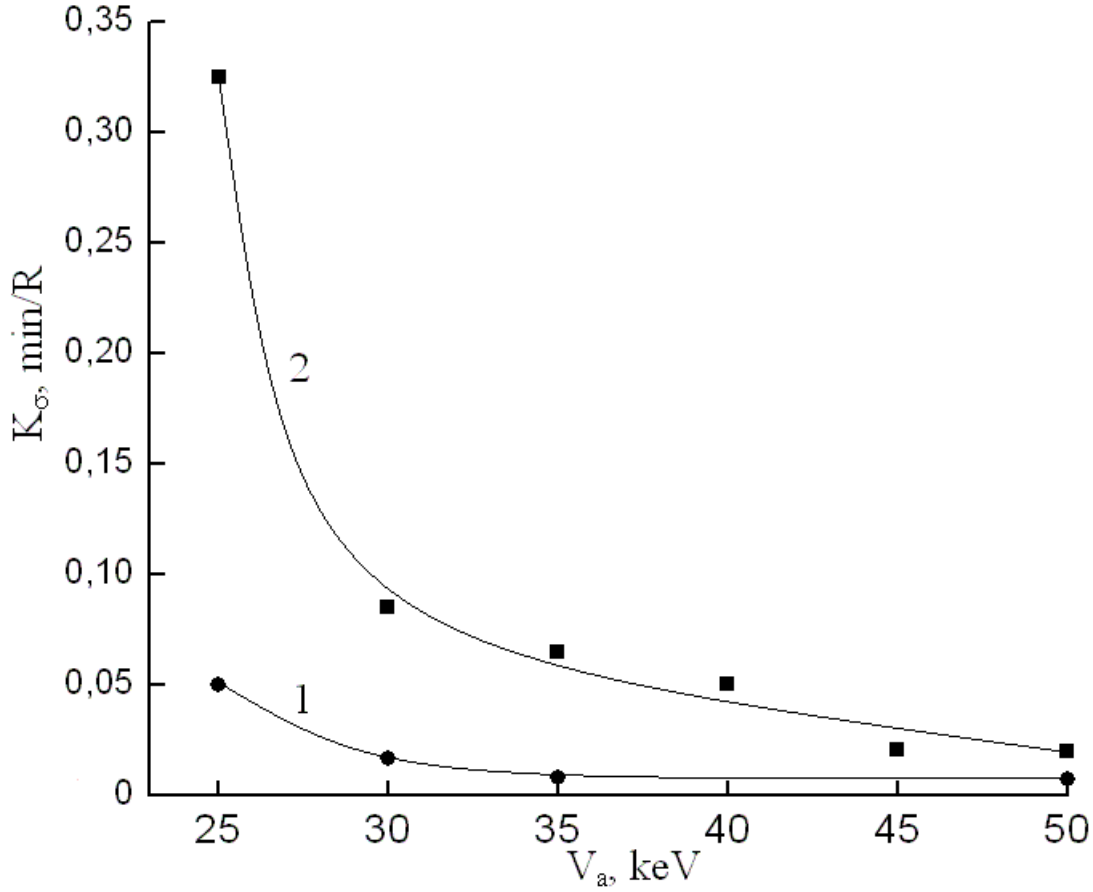

Fig. 3. $K_\sigma(V_a)$ – dependences for $TlGaSe_2$ (curve 1) and $TlGaSe_2$ $<Li^+>$ (curve 2) single crystals.

In Fig. 4 and 5 there have been presented dependences of K_σ on dose intensity for $TlGaSe_2$ and $TlGaSe_2$ $<Li^+>$ single crystals. Curves 1 – 6 correspond to various values of effective hardness of radiation V_a from 25 to 50 keV. It is seen from the Fig. 4 and 5 that roentgensensitivity of $TlGaSe_2$ single crystal changes in interval $0.0086 \div 0.116$ min/R, but in $TlGaSe_2$ $<Li^+>$ $K_\sigma = 0.03 \div 0.357$ min/R, i.e. roentgenconductivity coefficient of $TlGaSe_2$ $<Li^+>$ crystal is increased comparing with K_σ of $TlGaSe_2$ crystal. The ratio of coefficients of roentgensensitivity after and prior to lithium intercalation amounts approximately to $3 \div 6$ at the interval of dose intensities $0.8 \div 78$ R/min and at the x-rays energies from 25 to 50 keV.

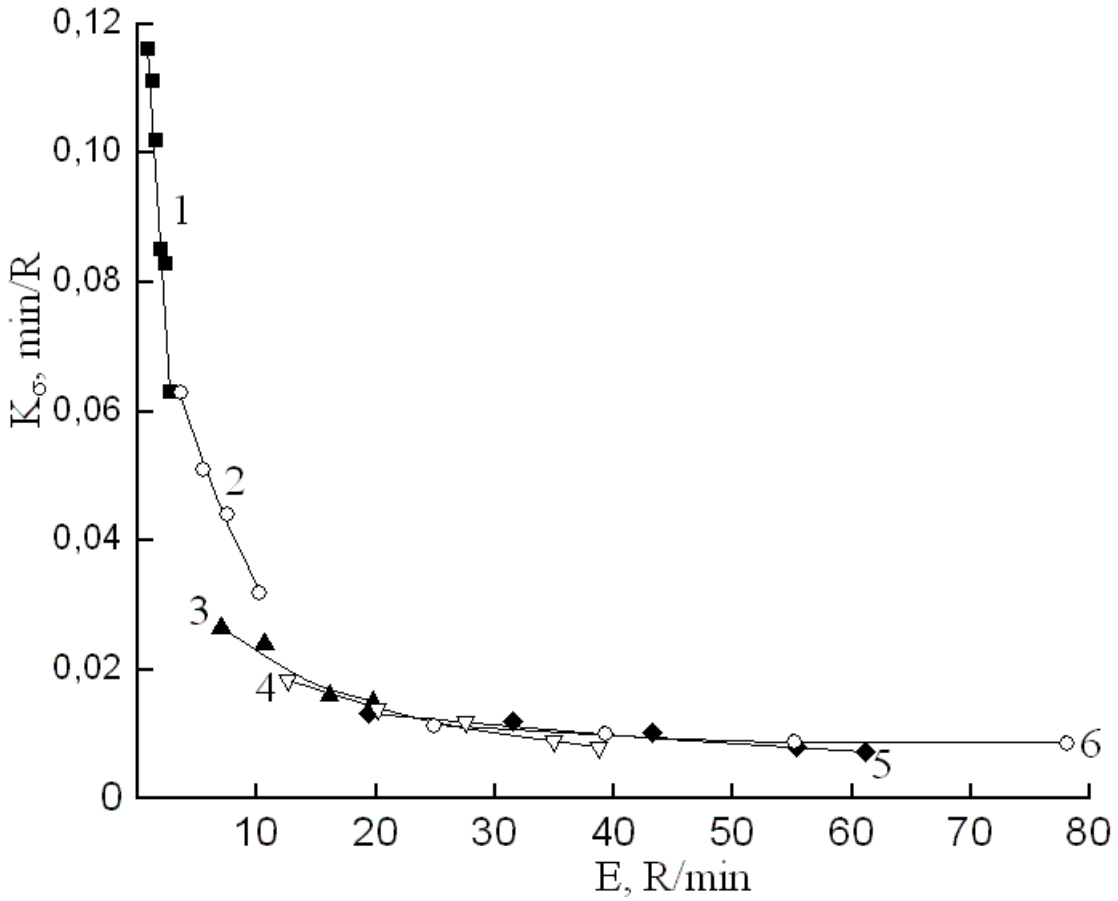

Fig. 4. Dependences of characteristic coefficients of roentgenconductivity on dose intensity for $TlGaSe_2$ single crystal at various values of effective hardness of radiation:
1 – 25; 2 – 30; 3 – 35; 4 – 40; 5 – 45; 6 – 50 keV. T = 300 K.

Analysis of obtained data showed that roentgenconductivity coefficient of $TlGaSe_2$ <Li^+> single crystals are regularly decreased as with the rise of dose as with the increase of effective hardness of radiation. At V_a > 30 keV and E > 20 R/min change of $K_\sigma(E, V_a)$ is slight as in $TlGaSe_2$ as in $TlGaSe_2$ <Li^+> single crystals. One of the possible reason of observed regularities is that roentgenconductivity in studied crystals, especially at comparatively low accelerating voltages is predominantly due to radiation absorption in thin layer of the 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 roentgenconductivity. 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 carries in volume and fraction of incident radiation passing trough the crystal is increased.

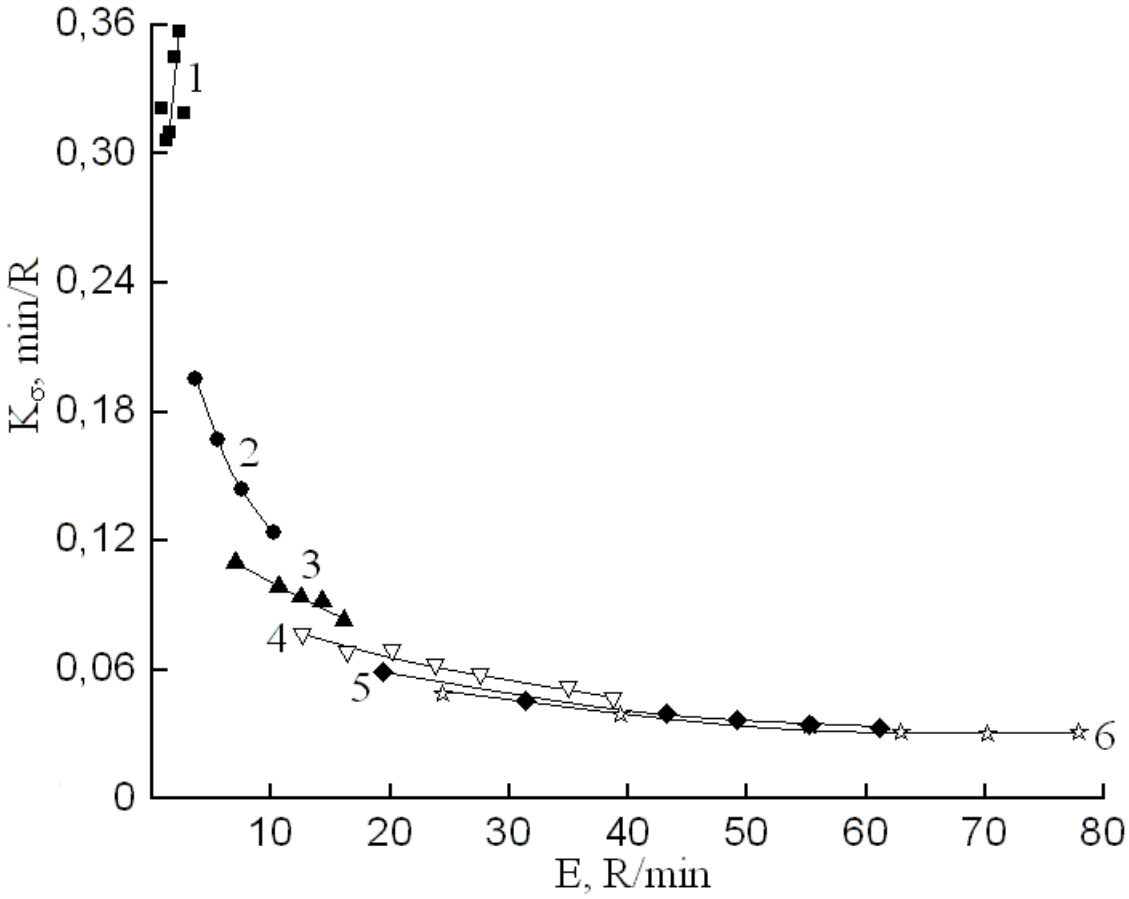

Fig. 5. $K_\sigma(E)$ – dependences for $TlGaSe_2$ <Li^+> single crystal at various values of V_a, keV:
1 – 25; 2 – 30; 3 – 35; 4 – 40; 5 – 45; 6 – 50 keV. T = 300 K.

The operation by the roentgendosimetric parameters of the investigated $TlGaSe_2$ single crystals due to lithium intercalation gives perspective for the use of these materials as sensitive roentgendetectors.

References

1. S.N. Mustafaeva, V.A. Ramazanzade, M.M. Asadov.
Materials Chemistry and Physics. 1995. V. 40. № 2. P. 142 – 145.

2. S.N. Mustafaeva, E.M. Kerimova, N.Z. Gasanov.
FTP-Fizika i techn. Poluprovodn. (St. Petersburg). 1998. V. 32. № 2. P. 145 – 147.

3. S.N. Mustafaeva, N.Z. Gasanov, P.M. Iskenderova.
Fizika. 2001. V. 7. № 1. P. 61 – 63.

РЕНТГЕНОДОЗИМЕТРИЯ ИНТЕРКАЛИРОВАННЫХ МОНОКРИСТАЛЛОВ $TlGaSe_2$

С.Н. Мустафаева, М.М. Асадов

Изучены рентгенодозиметрические характеристики интеркалированных ионами лития монокристаллов $TlGaSe_2$. По сравнению с «чистыми» монокристаллами $TlGaSe_2$ монокристаллы $TlGaSe_2$ $<Li^+>$ были более чувствительны к рентгеновскому излучению. Отношение коэффициентов рентгенопроводимости ($K_\sigma^{инт}$ / $K_\sigma^{неинт}$) после и до интеркалирования $TlGaSe_2$ составляло ~ 3 ÷ 6 в интервале энергий рентгеновских лучей 25 ÷ 50 кэВ и мощности дозы от 0.8 до 78 Р/мин.

İNTERKALYASIYA OLUNMUŞ $TlGaSe_2$ MONOKRISTALININ RENTGENDOZIMETRIYASI

S.N. Mustafayeva, M.M. Asadov

Litium ionları ilə interkalyasiya olunmuş $TlGaSe_2$ monokristalının rentgendozimetrik xarakteristikaları tədqiq edilmişdir. Muqayisəli analiz göstərmişdirki, "təmiz" $TlGaSe_2$ monokristalı ilə muqayisədə $TlGaSe_2$ $<Li^+>$ monokristalı rentgen şüalarına daha çox həssasdır. Rentgen şüalarının enerjisinin 25 ÷ 50 keV intervalında və şüalanma dozasının 0.8 – 78 R/dəq qiymətində $TlGaSe_2$ monokristalının interkalyasiyadan sonra və interkalyasiyaya qədər olan rentgen keçiricilik əmsalının nisbəti ~ 3 ÷ 6 olmuşdur.