USING OF CALORIMETERS FOR MEASUREMENT OF ACCUMULATED ENERGY BY CRYSTALS IONS DURING IRRADIATION

Abdula J., Tokzhigitov K., Galaguzova T.A.

Taraz Innovation and Humanitarian University, Taraz, e-mail: tamara5024@mail.ru

Radiation breaches appearing during the interaction of radiation with any hard body cause the change of its properties. The accumulated energy can be determined by changing the heat of a combustion or dissolution on changing its heat-conductivity and parameters of the crystalline lattice. The most wide-spread determination method of the accumulated energy value is the method of annealing. The variety of this method is the method of the differential-thermal analysis (DTA). The method of the differential and thermal analysis are used researcher at study of the hidden energy in alkaline crystals. The purpose of our investigations was to determine whether there is an indicated dependence for another group of ion crystals different from alkaline of the types of the crystalline lattice.

Keywords: irradiation, energy, ionic, crystal, lattices, differential, thermal, analisis, installation

Radiation breaches appearing during the interaction of radiation with any hard body cause the change of its properties. The degree of radiation breaches herewith can be evaluated after changing its determined properties. However such properties may be defective since only definite types of defects are often responsible for the change of that or another property of a hard body.

To form any defect a determined share of the radiation energy is spent. That is why any irradiated body possesses some additional free energy which is accepted to name “accumulated”. The last is the fullest characteristic of the irradiated material state as it itself defines the total breaches which are preserved after the cessation of the radiation action.

The accumulated energy can be determined by changing the heat of a combustion or dissolution on changing its heat-conductivity and parameters of the crystalline lattice [1]. The enumerated methods differ either by their big difficulty or by having some defects and because of that they didn’t get proper spreading.

The most wide-spread determination method of the accumulated energy value is the method of annealing. Its essence is that while heating the irradiated crystal the thermal activation of defects occurs and it is accompanied by annihilation and emitting some energy.

The variety of this method is the method of the differential-thermal analysis (DTA). It is necessary to mention that this method DTA is founded on the measurement of the temperature differences between the standard and the investigated sample $(T_e - T_1)$ and on the measurement of delaying temperature growth (increase) of the sample concerning the temperature of a calorimeter block $(T_e - T_1)$ [1, 2].

Herewith the value of the energy in the temperature interval from τ_0 to τ is calculated according to the formula

$$Q = \int_{\tau_0}^{\tau} \frac{mc(T_2 - T_1)}{(T_e - T)_1} d\tau \left(\frac{J}{kg}\right),$$

where m – sample mass; c – specific heat-capacity of J/g sample.

The full value of the accumulated energy is determined as the difference of the first and second heating of samples in the identical condition. Herewith in the process of the first heating there occurs emitting of the accumulated energy and in the second process there determined the background which is caused not by identification geometry of compared samples and by the difference of their thermal ties with the calorimeter block.

The method of the differential and thermal analysis are used researcher at study of the hidden energy to deformation in metal [1, 3] accumulated energy during the irradiation on graphics [2], in metals [2, 3], carbide-calcium, diamond [1] and in alkaline crystals [2].

The applied calorimeters for measuring accumulated energy according to the DTA method in principal identical. The difference exists only in constructive performance.

We assembled the calorimeter installation for measurement of accumulated energy according to method DTA, which consists of calorimeter itself, block for measurement, system of the vacuum and system of the heating.

The calorimetric installation allows:

– to measure the difference of $(T_e - T_1)$ temperature with an inaccuracy to $4{,}3 \cdot 10^{-3}$ degrees;

– to conduct heating of the calorimeter according to the linear law at 1,5 degree per minute velocity in the interval of temperatures from the room temperature to 600 °C and to reproduce heating with ±5 degrees inaccuracy;

– to measure thermal effects with more than 0,5 *J*/*g* with 15 % inaccuracy;

– to reduce to a minimum the temperature oscillation in the calorimeter because of convectional flow using vacuum.

The investigations conducted in Tomsk Polytechnical Institute determined natural ties of changing the properties by the action of radiation abreast these materials from their chemical composition [1, 2]. Abreast ATC there are more defects in the combination (junction) with great energy of the lattice after the irradiation and consequently the change of their properties are more considerable than in the crystals with weak ion ties in the lattice.

The value of the accumulated energy is bigger in the combination with great energy of the lattice for ATC [2, 3].

The purpose of our investigations was to determine whether there is an indicated dependence for another group of ion crystals different from alkaline of the types of the crystalline lattice.

We have chosen the accumulated energy as a characteristic of the radiation breach degree (Fig. 1).

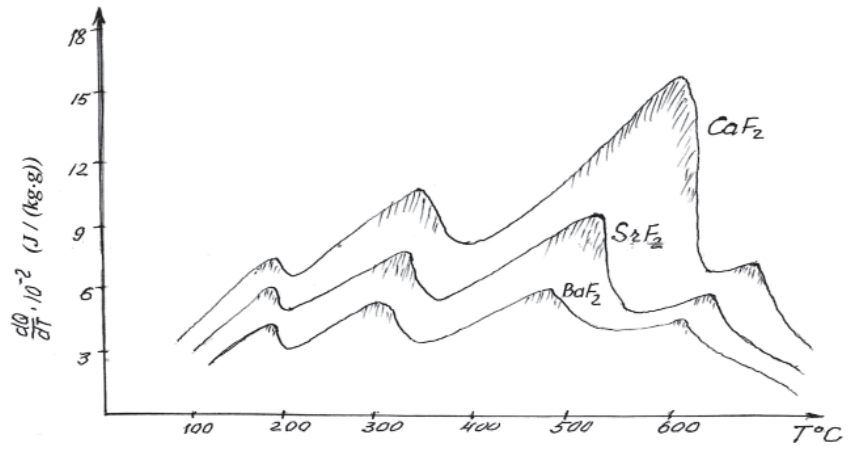

Fig. 1

The Drawing one shows the velocity dependency of emitting the accumulated energy on the temperature for crystals CaF_2, SrF_2, BaF_2 which are irradiated by the identical absorbed dose of γ-ray. The areas limited by curved $\frac{dQ}{dT}$ determine the radiation energy accumulated by crystals.

The radiation energy accumulated in CaF_2 material with great energy of the lattice abreast fluoride is more. It is 6,8 *J*/*g*, SrF_2 is 2,7 *J*/*g*, BaF_2 = 0,9 *J*/*g*.

The concentration of the defects calculated according to an analogy with alkaline-gallic crystals [2] to the value of the accumulated energy and width of the forbidden crystal zone is in $CaF_2 = 10\cdot10^{18}$ sm^{-3}, $SrF_2 = 5{,}8\cdot10^{18}$ sm^{-3}, $BaF_2 = 2{,}3\cdot10^{18}$ sm^{-3}.

The large concentration of CaF_2 defects testifies to more considerable breaches of its crystalline lattice than other crystals which in their turn are accompanied by more powerful change of CaF_2 characteristics under the action of micro hardness radiation of accumulated light sums of the optic absorption.

The emitting spectrums of the accumulated energy in CaF_2 crystals irradiated by γ-rays and others are analogous. It testifies to the analogy of defects created by the radiation in materials which have the same type of the crystalline lattice. At the same time the peak of the accumulated energy emitting in CaF_2 accounts for more high temperatures than others. Full emitting of the accumulated energy (consequently annealing of radiation breaches) in CaF_2 stops in areas with higher temperature.

The dependence of the accumulated energy on the absorbed dose of γ-rays is given (shown) in drawing.

The kinetics of the accumulated energy dependent on the absorbed dose for all three crystals has two staged character. During the first stage we can notice quick increase of the accumulated energy, herewith the velocity of the accumulated energy is the most considerable for CaF_2 and it decreases during the transition from calcium BaF_2. On the second stage there is a tendency of the accumulated energy to saturation.

The quick growth of the accumulated energy on the first stage is caused by the predominance of the process of defect generation over radiation and thermal annealing. The outlet of the accumulated energy for saturation is caused obviously by achieving the dose of radiation of the top concentration of defects beginning with which there is (arranged) a dynamic balance between the number of generated and annihilated defects. The outlet of the accumulated energy for saturation means that the whole energy of the radiation transferred to crystals is completely transformed into other types of energy: light (luminescence), thermal (crystal warming up), chemical (formation of radiolysis products).

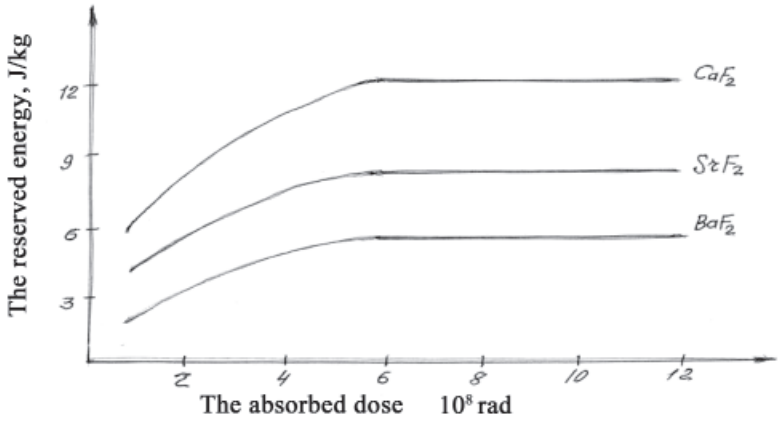

Fig. 2

The Value of the accumulated energy allows to determining its share in the whole absorbed radiation energy by crystals that is to determine the effectiveness of the energy accumulation. The accumulated energy increases with growing the dose of the absorbed energy. How ever the attitude of the accumulated energy to the absorbed one decreases that is the efficiency of the energy accumulation of crystal radiation decreases. In big absorbed doses (10^8 radiant's and more) the accumulated energy makes up tenth percent for CaF_2 and SrF_2 hundredth percent for BaF_2 of the energy absorbed by crystals, that is 99 percent of the energy is spent uselessly.

References

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