OPTICAL BREAK-DOWN IN ALKALI-HALOID SINGLE CRYSTALS BY LASER FOCUSED RADIATION: THE STAGE OF LOCAL THERMAL EXPLOSION

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Based on the results of experimental studying the pore formation kinetics and morphology in KCl single crystals under conditions of optical break-down by laser focused radiation were studied. It was shown that with observed parameters of the seats of energetic bursts and the dynamics of their formation, the optical break-down is similar to a powerful point explosion. In the heated area, a shock wave is generated. Having the velocity more than by an order exceeding the acoustic speed, the shock wave comes to the single crystal boundary earlier than other lattice disturbances and initiates formation of crowdions and their movement along atomic close-packed rows parallel to <110> type directions in both sublattices. From the condition of self-consistency between the flows of generated crowdions initiated by the supersonic shock wave and ones passing into unstressed crystal, it follows that the crowdion velocity would be also supersonic that was earlier predicted (A.M. Kosevich and L.S. Kovalyov). An assumption on possible participation of cumulative effect in the process has been made.

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INTRODUCTION

Behavior of materials under extreme conditions is of great attention for many decades [1–5]. This is caused not only by hardening the on-earth exploitation conditions of materials but also by the necessity of their utilization under outer space conditions in the regime of long-term work with absolute confidence in their high reliability [3]. Extreme conditions are high temperatures, pressures, impact loads and shock waves [4, 5], vibrations, irradiation [6–8] and other factors.

The widest spreading of laser facilities and technology requires proper and detailed studying the physic regularities and consequences of interaction between laser radiation and substance in various states and conditions. When the laser radiation with high energy flux densities is passing through transparent materials, formation of local destructions as pores and cracks takes place. This phenomenon is known as optical break-down [9]. Because of its general-physical and practical importance [10], there have been carried out a lot enough of investigations on mechanisms of laser radiation absorption resulting in the break-down [9], the morphology peculiarities of the destruction zone [11], character of the generated plasma radiation [12, 13], sources and mechanisms of radiation, as well as on studying the substance transport mechanisms causing the formation of pores and cracks [14]. In [14, 15], the relaxation processes near concentrators were studied and the assumptions were made on the possibility of crowdion mass-transfer mechanism participation in these processes. In [16], on the base of quantitative evaluations, this point of view has been confirmed and the assumption was made that the crowdion mass-transfer process forwent the dislocation one. In [17] this point of view was developed and experimentally confirmed.

The objective of the work is studying the mechanisms of mass transfer from the area locally heated and stressed in KCl single crystal under laser focused irradiation resulting in the optical break-down causing destruction and micro-cavity formation, on the base of consideration of the pulse process as a heat local explosion in the crystal.

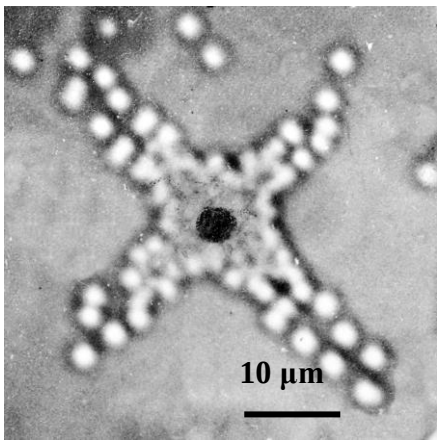
EXPERIMENT END RESULTS

In order to compare the morphology of destruction areas and dislocation structures near pores of similar sizes, the experiments were carried out under two strongly different laser pulse durations $5 \cdot 10^{-8}$ and 10^{-3} s. Observed characteristic pictures of dislocation structures formed around the pores are shown in Fig. 1.

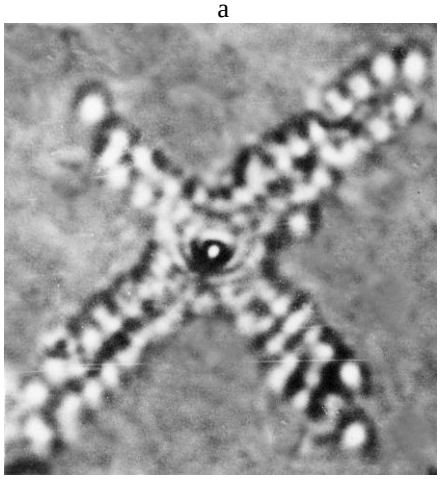
Practically absolute identity of both destruction morphology and dislocation structures between the pictures obtained for the given extreme laser pulse durations was established. Evidently, it follows that processes of the thermal burst in the crystal and further relaxation ones take place during the time interval of the order or less than the shortest pulse duration ($5 \cdot 10^{-8}$ s) [17].

ANALYSIS OF MASS-TRANSFER DYNAMICS IN THE AREA OF THE OPTICAL BREAK-DOWN

Physical state of the crystal, where in the zone of local absorption of the laser radiation, successive processes of crystal local melting, evaporation, and formation of light-emitting plasma occurred (that was experimentally established), is schematically shown in Fig. 2. The dotted line shows the arbitrary boundary of the high temperature area (A). The temperature in this area was taken as 5500 K by averaged data from analysis of emitting spectra under similar conditions [12, 13, 18]. Atoms in the (A) area are disordered as in gas, and – by the thermal interaction intensity – are the gas consisting of atoms and molecules of the evaporated single crystal with certain extent of dissociation and ionization and with thermal self-energy and elastic repulsive energy significantly higher than binding energy between atoms [19]; but the atoms remain closely packed as in the solid – being cramped under high pressure in the single crystal surrounding the (A) area.



a



b

Fig. 1. Typical micro-images of dislocation structures near pores in KCl single crystals. Duration of a laser pulse: a – $5 \cdot 10^{-8}$, b – 10^{-3} s

If mentally let the (A) area (remaining in crystalline state) to expand under heating to T = 5500 K, the volume jump would be $\Delta V/V = 3\alpha\Delta T$. But due to such volume jump the area (A) becomes compressed by surrounding crystal, so the pressure within (A) increases to about $P^* = K(\Delta V/V)$ (K – modulus of dilatation, $\Delta V/V$ – temperature jump of the substance volume within a void). Substituting the numerical values $K = 1.78 \cdot 10^{10}$ N/m^2, $\Delta V/V = 0.75$, coefficient of thermal expansion $\alpha = 48 \cdot 10^{-6}$ K^{-1}, and $\Delta T = 5200$ K, we obtain $P^* \approx 10^{10}$ N/m^2. This evaluation is of course approximate and evidently understated. This only takes into account that at T_{boil}, atoms are not scattered but remain compactly packed; but it does not take into consideration the repulsive forces between atoms when the temperature increases that means increasing the pressure [19]. For example, it is known from experiments that under heating the aluminium at constant volume to 1000 K (that is only by 70 K higher than T_m) the pressure within bulk increases to $0.51 \cdot 10^{10}$ N/m^2 [19].

Thus, the pressure P^* in the (A) area admittedly exceeds the crystal ultimate stress, therefore in crystal, basically, relaxation processes would develop intended to decreasing the pressure in the (A) area. Local heating and growing the pressure in (A) area occur headily during time interval not more than the laser pulse duration ($5 \cdot 10^{-8}$ s). By evaluation of [17] this time interval is even less: 10^{-13} s. Therefore, evidently, the relaxation processes behavior will depend in many respects on the correlation between rates of heating and relaxation.

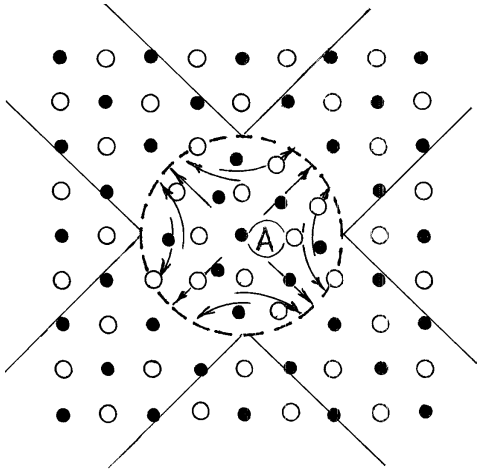


Fig. 2. The scheme of KCl single crystal with a high temperature area (A) (Shon by dotted line). Light lines at ± 45° limit the areas of possible transport of substance from the stress area along <110> directions (arrows indicate possible lines of flows)

In our case, the relaxation time τ_{relax}, can be taken as the time period during which the acoustic wave transverses the area of destruction. If the size of the area is of the order of 10^{-4} m, and $\upsilon_{acoust} \approx 4.5 \cdot 10^3$ m/s, then $\tau_{relax} \approx 10^{-8} \ldots 10^{-7}$ s (that satisfies the conditions of a thermal explosion [20]). As experiments show [16, 17], near 95% of substance is forced out from the heated area into crystal bulk during the time interval shorter than the laser pulse duration ($\tau_{pulse} \approx 5 \cdot 10^{-8}$ s). Final formation of the destruction picture and the void (see Fig. 1) occurs during cooling the crystal in time period significantly longer than τ_{pulse} [16–18].

SHOCK WAVE IN THE CENTER OF OPTICAL BRAEK-DOWN AND ITS CHARACTERISTICS

High dynamics of the process determines the character and the rate of mass-transfer near the explosion seat. At small under-acoustic velocities of substance flow, the values describing the flow (velocity, density, pressure, etc.) are continuous functions of coordinates and time. In the case of explosion processes and high velocities of flows (about acoustic velocity or higher), there occur the motions under which, on some moving surfaces, there appear discontinuities in distributions of hydrodynamic values (velocity, density, pressure, etc.) called shock waves. At that, the velocity of discontinuity surface (shock wave) motion is not connected with the speed of the gas particles (medium) motion. The gas particles may pass through this surface during their motion. Analysis has shown (W.J. Rankine, 1870; H. Hugoniot, 1885) that on the discontinuity surfaces, the conditions of dynamical compatibility should be fulfilled – continuity conditions for fluxes of substance, energy and momentum (Hugoniot conditions). In the coordinate system

connected with the discontinuity surface and moving together with it, these are the following:

$$\rho_1 \upsilon_1 = \rho_2 \upsilon_2 \equiv J \equiv \upsilon_1/V_1 = \upsilon_2/V_2; \quad (1)$$

$$P_1+\rho_1 \upsilon_1^2 = P_2+\rho_2 \upsilon_2^2; \quad (2)$$

$$U_1 + \upsilon_1^2/2 + P_1/\rho_1 = U_2 + \upsilon_2^2/2 + P_1/\rho_2, \quad (3)$$

where the subscript 1 concerns to the side in front of, and 2 – to the side behind the shock wave; υ_1, υ_2 are gas velocities normal to the discontinuity surface; ρ_1, ρ_2 and $V_1 = 1/\rho_1$, $V_2 = 1/\rho_2$ are densities and specific volumes of gas; P_1 and P_2 are gas pressures; U_1 and U_2 are internal energies per mass unit of gas; J is density of flux through the discontinuity surface. For equation (3) it was taken into account that the thermal function W (total thermal energy) is $W = U + PV$. These relationships can be described in differential form. They have absolutely general significance independently on the aggregation state of the substance over which the wave propagates [19].

From the expressions above, Hugoniot's adiabatic equation follows:

$$U_2 - U_1 = ½ (P_2+P_1)(V_1 - V_2). \quad (4)$$

The equation (4) establishes the relation between thermodynamic values on both sides of the discontinuous. At given values P_1 and V_1 this determines the relation between P_2 and V_2. From analysis of equations (1)–(4) it follows that $\rho_2 > \rho_1$ and $P_2 > P_1$, that results in occurring the compaction jump behind the shock wave (from the side (2)).

We deal with a problem of a local thermal explosion in isotropic single crystal. Solution of such problem is complicated by the fact that for condensed media, additional determination of all thermodynamic values is necessary because in solids there is also elastic interaction besides the thermal interaction [19]. The gas pressure thermally caused is small ($p = nkT$), that's why the gas is compressed easily and strongly under pressures of decades or hundreds atmospheres. While for compression of even very small solid body, say, by 10% , the pressure of the order of 10^5 atm is necessary, and for compression twice – millions of atmospheres [19].

In our case, the point explosion takes place (local energy emission). The crystal substance quickly turns into the like-gaseous state at high temperature, but being squeezed in the crystal, the gas is under high pressure (see Fig. 2, area A). That is similar to a point explosion in the air, in the sense that large energy emits in the point of heating, and the thermal energy in air increases sharply. In the solid, besides the thermal energy, also the elastic energy constituent increases. The shock wave in both cases is generated near the center of the explosion (or the center of heated area). By moving, the wave reaches the boundary with the single crystal and interacts with it. In the case of the point explosion in air – both the explosion and the shock wave propagation take place in air. These problems, due to their spherical symmetry and similarity of "gaseous"-like initial states just after explosion, are comparable qualitatively by developing the general picture of explosion. Therefore, we, meaning only qualitative estimations, use the known solution on a strong point explosion in air for analysis of main features of the relaxation process and formation of the destruction origin in the single crystal.

The problem of a strong point explosion in air was for the first time solved by L.I. Sedov (1946) [20]. The essence of the simple approach applied by Sedov to obtain the relations describing the shock wave motion is as following. If in some point (in the origin of coordinates), as a result of an explosion, there emits the energy E so high that the pressure increases to $P_2 >> P_1$ (P_1 is the pressure before the explosion), the value P_1 can be neglected. Then the explosion process behavior is found to be determined only by energy E, gas density ρ_1, the coordinate of the observation point in the spherical coordinate system r, and current time t. From these four values we can construct only a single independent dimensionless combination like

$$r (\rho_1 /Et^2)^{1/5}. \quad (5)$$

In this case, for solution we can use the dimensional theory. It may be asserted [20] that some value of β denoting the abovementioned combination (5) would correspond to the position of the shock wave in any instant time. From this, taking into account (5), it follows that for the shock wave with radius R in any instant time t, the relation can be written:

$$R = \beta (Et^2/\rho_1)^{1/5}. \quad (6)$$

Then the shock wave velocity relative to undisturbed gas, i. e. relative to the motionless reference system, will be written:

$$D = dR/dt = (2/5) \beta (E/\rho_1)^{1/5} t^{-3/5}. \quad (7)$$

The constant β depends only on the gas nature determined in this case only by the value $\gamma = C_P /C_V$ (C_P and C_V are heat capacities at constant pressure and constant volume, respectively) and it is determined unambiguously by analyzing the gas motion in the area behind the shock wave. According to calculations, for diatomic gas ($\gamma = 7/5$) the value $\beta = 1.033$ [21].

In the zero instant $t = 0$, the shock wave radius is $R = 0$. The shock wave velocity is infinite. As R increases, the shock wave velocity decreases remaining for some time larger than the acoustic velocity. Thus, the solution on the strong explosion will be true only during the time t^*, as long as the inequality $D >> \upsilon_{acoust}$ (υ_{acoust} is acoustic velocity in medium) is valid. For our case, taking into account that (A) area has density of a solid, and therefore assuming the acoustic velocity in it being the same as in the solid, i.e. $\upsilon_{acoust} \approx 4.5 \cdot 10^3$ m/s, we obtain from (7):

$$t^* \approx [(2/5) \beta (E/\rho_1)^{1/5} \upsilon_{acoust}^{-1}]^{5/3}, \quad (8)$$

Substituting the numerical values in (8), we obtain: $t^* \approx 3.2 \cdot 10^{-5}$ s.

According to results and evaluations from [17], the main processes on formation of the optical break-down seat in alkali-haloid single crystals occur during the time interval substantially shorter than $t^* \approx 3.2 \cdot 10^{-5}$ s, therefore, application of this solution is thought valid from this point of view.

Calculations of gas parameters for the back side of the shock wave in the case of explosion in air result in following.

The density ρ_2 at the back side of the discontinuity:

$$\rho_2/\rho_1 \approx (\gamma+1)/(\gamma - 1)|_{\gamma=7/5} \approx 6. \quad (9)$$

With approaching to the center, the density ρ drops fast by the law:

$$\rho/\rho_2 \sim (r/R)^{3/(\gamma-1)}|_{r \to 0} \to 0. \quad (10)$$

Thus, a practically empty spherical void remains behind the shock wave, because all the substance becomes pressed to the back surface of the discontinuity. Under certain conditions, when $\gamma >> 1$, in the point of the discontinuity there occurs the expanding spherical area of emptiness [19].

The pressure P_2 at the back surface of the break is defined by the expression:

$$P_2 = [2/(\gamma+1)]\, \rho_1 D^2. \quad (11)$$

Velocity υ_2 at the back wall of the shock wave front relative to the motionless coordinate system:

$$\upsilon_2 = [2/(\gamma+1)]\cdot D. \quad (12)$$

As the pressure P_2 is proportional to $t^{-6/5}$, it decreases with time according to (7) and (11). The pressure P quickly drops with distance from the discontinuity surface, and already at $r/R \approx 0.7\ldots0.8$, the pressure becomes $P \approx (0.4\ldots0.35)P_2$ remaining further at the level about $0.35\ P_2$ up to $r/R = 0$. All variations in the system from the initial state (1) before the front of the shock wave to the state (2) behind the front take place on the surface of the front; therefore, the discontinuity surface may not be any geometric surface [19]. This has a certain "thickness" which value varies over a wide range enough depending on dissipative properties of the medium (mainly viscosity and thermal conductivity) and the process dynamics [19].

In the case when at the shockwave front, phase transitions or chemical transformations take place, the transition zone has two characteristic areas: so called viscous compaction shock (CS) determined by viscosity and thermal conductivity and following by the relaxation area caused by slower relaxation processes (phase transitions, chemical reactions, etc.).

DISCUSSION: PROCESSES OF RELIEF AND RELAXATION UNDER FORMATION OF THE OPTICAL BREAK-DOWN SEAT

Let us consider the processes which will take place when the shock wave reaches the boundary with the single crystal. If we have vacuum instead of the single crystal, compressive stresses would disappear after the shock wave coming out at the surface, and in the backward direction the relief wave should go with acoustic velocity [20], and the substance relieved should get additional velocity in the direction of the shock wave initial motion. If the second medium is air, the moving boundary plays a role of a spherical piston forming an air shock wave ahead, that also results in partial relief of the system. The wave of the partial relief moves to the center of the explosion.

In the case shown in Fig. 2, the explosion area is surrounded by the KCl single crystal where there are certain planes and directions in which the deformation may occur easy enough by motion of defects – carriers of plastic deformation – dislocations and crowdions. In Fig. 2, the section of the crystal by one of crystallographic planes of {100} type is given along with four <110> type directions parallel to which the substance from the stressed area may be forced out into the surrounding crystal, that promotes both stress reducing in the heated area and the relief process followed by gradual attenuation of the shock wave. As it is seen from Fig. 2, there are three such co-perpendicular planes which intersection forms Cartesian coordinate system. So, there are 12 directions of easy slip.

From experiments [14, 16, 17] and Fig. 1 it follows that the contribution of dislocation mechanism into formation of voids under optical break-down is only 2…4%, hence, the main quantity of substance from the void volume is taken out by crowdions, in spite of the fact that energetic consumption of the system for the substance taking out in the case of crowdions is 3…5 eV (per an atom), but in the case of dislocations – this is less than tenths of electron-volt. To explain this inconsistency by "kinematic" simplicity of crowdion formation is not logic and impossible, as it is seen certainly from the experiment that initially the dislocations of necessary configuration are not generated at all. Dislocations occur only to the end of the relaxation process in very small quantity.

From the given description of properties the of shock wave generated in the area of the point explosion, on the other hand, it follows that the shock wave moves with supersonic speed up to the time $t^* \approx 3.2\cdot10^{-5}$ s. The void in the zone of the optical break-down grows to finish size during time of the order of 10^{-7} s [17]. According to (7), to this time the shock wave speed becomes by an order larger than acoustic velocity ($D \approx 15\ \upsilon_{acoust}$). That means that the shock wave will come to the (A) area boundary, i.e. relaxation zone, much earlier than other disturbances, including the elastic wave moving with acoustic speed and carrying information about the elastic stress field.

This is a first key moment causing undoubted priority of crowdion mass transfer in the processes of stress plastic relaxation in the heated area under optical break-down in connection with the time priority for switching on the crowdion mechanism. The second important factor promoting predominate role of the crowdion mass-transfer is existence of substantial "jump" of compression in the shock wave and the tendency to "pressing down" the substance to the back surface of the shock wave. Under conditions of condensed media with parameters like ours, the value of the compression jump is most likely less than obtained from (9). This depends on temperature and pressure, and its limiting value about 4–5 is reached only under special conditions at very high pressures by several orders exceeding the evaluation P^* and at high temperatures. In [10] the data are given on variation ρ/ρ_0 from ~ 1 to 5 at $T = 7\cdot10^6$ K under changing the pressure from 1 to 10^4 Mbar. In our experiments such conditions did not take place. However, in principle, under laser irradiation, for example in order to provide conditions for thermal-nuclear synthesis, super-high temperatures are possible, then even expression (9) might be applicable [10].

Shock wave atoms moving with velocity υ_2 (see (12)) possesses kinetic energy near 150 eV and able to provide necessary action under collisions with single crystal atoms for generation of crowdions which form crystallographic ordered flows of substance from the stressed area into crystal bulk; these flows (marked by arrows in Fig. 2) move along close-packed atomic rows

in cation and anion sublattices (coinciding with dislocations easy slip <110> type directions).

In [22] it was shown by computer simulation that if in the KCl single crystal an atom gets the momentum in the direction close to the direction with low indices, this momentum through a number of subsequent collisions should be translated for long distances. The easiest for the translation are found to be <110> close-packed directions, in which dynamical crowdions were generated and moved with slow attenuation carrying not only momentum but also substance for long distances.

The fact is a confirmation for reality of crowdion generation in the processes of collisions under action of the shock wave and their participation in mass transfer under such conditions.

At present, active works are carried out on studying the role of crowdions in mass-transfer processes using simulating experiments. So, in [23, 24] authors pointed out to important role of crowdions in thermally activated movement of interstitial atoms. According to [25–27], crowdions also participate in mass-transfer under plastic deformation. In [28] it was shown by computer simulating that for Ni lattice in 2D model, the window of speeds for stable movement of crowdions is in the range $(12…14)\cdot10^3$ m/s, while for 3D model – $(20…50)\cdot10^3$ m/s. At such speeds significantly exceeding the acoustic velocity, a crowdion may move for hundreds of interatomic distances.

It is necessary to note that in our experiments, the processes of crowdion generation and their leaving should be internally self-consistent. But as the shock wave has supersonic speed, the crowdions would move with supersonic speed too. Possibility of such movement was predicted in [29] and as it is seen, is confirmed also in abovementioned model experiments.

Important question is connected with stability of the shock wave [30]. There are many factors resulting in instability. First of all, there is considered the possibility of the wave front distortion (embossing instability). There is also converse connection between the shock wave intensity initiating heat emission and the thermo-emission rate; this connection results in pulsing structure with cross-clamping the lines of current in backside of the front, as well as instability from the medium inhomogeneity by viscosity, by thermal conductivity, external factors, etc. In our case also many of mentioned causes are possible and, first of all, embossing instability related with inhomogeneity of plastic relaxation over the front of the shock wave when coming out into the single crystal. Nevertheless, the results which we observe (see Fig. 1) are reliable and reproducible. We connect this with the fact that the duration of plastic relaxation stage under action of the shock wave initiating the crowdion mass-transfer is short (of the order of 10^{-7} s), and the factors disturbing the stability of the shock wave have no time to work. After the time about 10^{-7} s, to the point of plastic relaxation an elastic wave moving with acoustic speed already comes. The field of elastic stress occurs and there appear dislocations. As it follows from experiments [16, 17], this takes place when the void occupied by heated substance reaches the size of the order of pore size observed in the experiment. The heated area, as it was shown in [16], has been just filled not by plasma but condensed liquid melt with temperature about 1100 K; and under significantly lower pressure $P \approx 2\cdot10^9$ N/m^2, emission of dislocations responsible for the abovementioned 2…4% volume of the formed void takes place. The described process of plastic relaxation is the relief process, and the relief wave moves with acoustic speed to the center of the optical break-down area.

The fact that from the very beginning of the plastic relaxation stage there took place the crystallography ordered crowdion flow which did not disturb the object single-crystallinity, is confirmed not only by dislocation structures shown in Fig. 1, but also by the elastic stress pictures given in Fig. 3 obtained by photo-elasticity method in circulairement polarized light. From Fig. 3 it is seen that along the direct lines passing through the center of the void and coinciding with <110> directions, there is one color (corresponding to compression of the substance as it was established) and on each of sides – another color – corresponding to tensile stress. Along the perpendicular line the colors interchange the positions (due to phase jump). Crystal structure in these areas is single-crystalline.

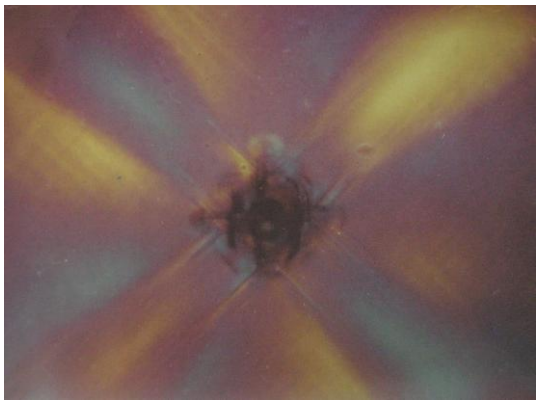


Fig. 3. The picture of residual stress distribution around the seat of a local heat burst and the formed pore; obtained by the method of photo-elasticity in circulairement polarized light

Finally, let us direct attention also to the following. In connection with limitedness of the plastic relaxation zones by twelve “channels” of easy slip in which the substance may be forced out, at the entrance into these “channels” some convergence of the flows is observed. This fact as it is known [31] is the crucial for cumulative effect. Therefore, in principle, we can expect the cumulative effect to some extent also in the cases of optical break-down generation in single crystals.

CONCLUSIONS

Experimental results have been analyzed and evaluations have been done on the dynamics of energy emission and heating of the local area in the crystal. These processes have been shown to be explosion-like and promoting generation of the explosion shock wave in the heated area.

Using the known solution of the problem on the point violent explosion, the basic parameters of the shock wave such as velocity, its time variation, and distribution of substance behind the front of the shock

wave were determined. It has been shown that the shock wave velocity quickly drops with time; reaching the single crystal – the boundary of the heated area – the shock wave has the velocity by a factor 15 larger than acoustic speed therefore it reaches the relaxation area earlier than other possible excitations, and during the acts of collisions with atoms of crystalline lattice the crowdions are generated. The flows of crowdions bring the substance out of the single crystal stressed area – along close-packed atomic rows (in both sublattices) coinciding with <110> type easy slip directions – into unstressed area, as a result there takes place stress relaxation in the first – quick – stage and generation of the relief wave moving with acoustic speed to the center of the heating.

It was shown that from conditions of internal self-consistency between the flow of crowdions generated under action of the supersonic shock wave and the crowdion flow going away, it follows that crowdions would move with supersonic speed; such possibility for the first time was mentioned in the work by A.M. Kosevich and L.S Kovalyov (1973).

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ОПТИЧЕСКИЙ ПРОБОЙ ЩЕЛОЧНО-ГАЛОИДНЫХ МОНОКРИСТАЛЛОВ СФОКУСИРОВАННЫМ ИЗЛУЧЕНИЕМ ЛАЗЕРА: СТАДИЯ ЛОКАЛЬНОГО ТЕПЛОВОГО ВЗРЫВА

В.Г. Кононенко, М.А. Волосюк, А.В. Волосюк

Основываясь на результатах экспериментального изучения кинетики образования и морфологии пор в монокристаллах KCl в условиях оптического пробоя кристалла сфокусированным излучением лазера, показано, что при наблюдаемых параметрах очагов энергетических вспышек и динамики их образования этот процесс аналогичен сильному точечному взрыву. В разогретой области возникает ударная волна. Имея скорость более чем на порядок выше скорости звука, ударная волна приходит к границе монокристалла раньше других решеточных возмущений, инициируя образование краудионов и их движение по плотноупакованным рядам атомов, параллельным направлениям типа <110>, в обеих подрешетках. Из условия самосогласования потоков рождения краудионов, спровоцированного сверхзвуковой ударной волной, и их ухода в ненапряженный кристалл следует, что скорость движения краудионов должна быть также сверхзвуковой, что предсказывалось ранее (А.М. Косевич, Л.С. Ковалев). Высказано предположение о возможном участии в процессе кумулятивного эффекта.

ОПТИЧНИЙ ПРОБІЙ ЛУЖНО-ГАЛОЇДНИХ МОНОКРИСТАЛІВ СФОКУСОВАНИМ ВИПРОМІНЮВАННЯМ ЛАЗЕРА: СТАДІЯ ЛОКАЛЬНОГО ТЕПЛОВОГО ВИБУХУ

В.Г. Кононенко, М.А. Волосюк, А.В. Волосюк

Виходячи з результатів експериментального вивчення кінетики утворення і морфології пор у монокристалах KCl в умовах оптичного пробою кристала сфокусованим випромінюванням лазера показано, що при спостережуваних параметрах очагів енергетичних спалахів і динаміки їх утворення цей процес аналогічний сильному точковому вибуху. У розігрітій області виникає ударна хвиля. Маючи швидкість більш ніж на порядок вищу за швидкість звуку, ударна хвиля приходить до границі монокристалу раніше за інші пружні збурення решітки, ініціюючи утворення краудіонів і їх рух по щільноупакованих рядах атомів, паралельним напрямам типу <110>, в обох підрешітках. З умови самоузгодження потоків утворення краудіонів, спровокованого надзвуковою ударною хвилею, і їх переміщення в ненапружений кристал витікає, що швидкість руху краудіонів повинна бути також надзвуковою, що передбачалося раніше (А.М. Косевіч, Л.С. Ковальов). Висловлено припущення про можливу участь в процесі кумулятивного ефекту.