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D. N. Mirlin. Optical Studies of Surface Vibrations in Ionic Dielectrics and Semiconductors. This paper sets forth the results of a joint study made with V. V. Bryksin, Yu. M. Gerbshteĭn, and I. I. Reshina. A spectroscopic method was used to observe surface optical vibrations in crystals and investigate them in detail. In accordance with the phenomenological treatment, such vibrations arise in the frequency range between ω_{TO} and ω_{LO}—the limiting frequencies of transverse and longitudinal optical phonons—where the dielectric constant is negative (the range of "residual rays"). The studies were made on a series of ionic dielectrics and semiconductors with the structure of NaCl, CaF_2, and TiO_2, and on InSb and α-SiO_2. The experimental part of the work was done using a modification of the disturbed total internal reflection (DTIR) method, which made it possible to investigate the absorption in a nonradiative region of the spectrum, i.e., at $k_x > \omega/c$ (where k_x is the wave vector of the surface vibrations). DTIR spectra were calculated for the configuration of the experiment. Dispersion relations for the surface vibrations were obtained experimentally for the first time, and the influence of anharmonicity on their characteristics was studied. It was shown that satisfactory agreement between the calculated and observed frequencies requires consistent consideration of the anharmonic contribution to the dielectric constant of the crystal. Splitting of the surface-vibration frequencies was detected in thin films: in this case, two surface-phonon branches were observed. Mixed surface plasma-phonon modes were investigated in degenerate semiconductors, dispersion and concentration dependences of the frequencies were recorded, and the damping of the surface plasmons was measured. (In InSb, it was found to be 2—3 times stronger than the damping of bulk modes.)

The influence of anisotropy on the conditions under which surface vibrations appear and on their characteristics was investigated. The existence of two types of surface-vibration branches in uniaxial crystals was established experimentally: one of them exists only in the polariton region of the spectrum and has no analog in isotropic crystals. As the k_x of these "anomalous" surface excitations increases, they mix with the bulk spectrum and attenuate.

Surface waves at the boundary between two dielectrics were also investigated, and extinction of these waves at a boundary with a metal was observed. "Boundary" plasmon-phonon modes at metal (semiconductor)-dielectric boundaries were studied. Various manifestations of the surface phonons can be expected in study of transport phenomena in thin films, in the surface layers of single crystals, in multilayered structures, in tunnel spectroscopy, etc. In particular, surface-phonon manifestations can be expected in Raman spectroscopy of semiconductors with excitation beyond the edge of the fundamental band, where the light penetrates only to a small depth.

The basic results discussed in the paper were set forth in the following articles:

V. V. Bryksin, Yu. M. Gerbshteĭn, and D. N. Mirlin, Fiz. Tverd. Tela **13**, 2125 (1971); **14**, 543 (1972) [Sov. Phys.-Solid State **13**, 1779 (1972); **14**, 453 (1972)]; Phys. Stat. Sol. **B51**, 901 (1972).

V. V. Bryksin, D. N. Mirlin, and I. I. Reshina, ZhETF Pis. Red. **16**, 445 (1972) [JETP Lett. **16**, 315 (1972)]; Fiz. Tverd Tela **15**, 1118 (1973) [Sov. Phys.-Solid State **15**, 760 (1973)]; Sol. State Comm. **11**, 695 (1972).

I. I. Reshina, Yu. M. Gerbshteĭn, and D. N. Mirlin, Fiz. Tverd. Tela **14**, 1280 (1972) [Sov. Phys.-Solid State **14**, 1104 (1972)].

G. A. Askar'yan, V. A. Namiot, and M. S. Rabinovich. Use of Ultracompression of Matter by Light Reaction Pressure to Obtain Microcritical Masses of Fissile Elements, Ultrastrong Magnetic Fields, and Particle Acceleration. The possibility of obtaining very high pressures by vaporizing metal[1] with a powerful light or charged-particle flux ($p \approx I/v$, where I is the power density of the incident radiation causing vaporization and v is the outflow velocity of the matter) has recently been put to use to obtain ultracompression[2]—an increase in the density of matter by hundreds and thousands of times—under quasismooth (without shock-wave formation) isostatic compression by a vaporization pressure $p \approx 10^{11}$—10^{12} atm. At such densities and pressures, matter behaves like a degenerate electron gas whose pressure is determined by quantum motion of the electrons: $p \sim n_e\epsilon$, where we have from the indeterminacy principle: $\epsilon \approx (\Delta P)^2/2m \approx h^2/2m(\Delta x)^2 \approx \hbar^2 n_l^{2/3}/2m$ and the pressure $p \approx \hbar^2 n_e^{5/3}/2m$, i.e., the effective adiabatic exponent $\gamma = 5/3$ unless the total number of electrons changes appreciably.

The paper[2] proposed the use of ultracompression to lower the threshold for initiation of controlled thermonuclear fusion and to increase its efficiency. We shall consider other aspects of ultracompression—the formation of microcritical masses of fissile elements[3], ultrastrong magnetic fields[3], and acceleration of particles[3].

1. Microcritical masses of ultracompressed fissile elements. Back in 1943, Neddermeier (a reference to his work appeared only recently, in[4]) took note of the possibility of lowering the critical masses of fissile elements by explosive compression, but modest blast pressures did not open the possibilities inherent in ultracompression, which produces critical dimensions and masses so small that they can be accommodated in the small regions occupied by concentrated high-density radiation.

In fact, the critical dimension $R_{cr} \approx l_f \sim 1/n_i$, while the critical mass $M_{cr} \sim n_i R_{cr}^3 \sim 1/n_i^2$, whence it follows that even hundredfold density increases reduce the critical mass by a factors in the tens of thousands. The concentration of the nuclei then reaches $n_i \approx 10^{25}$ cm^{-3}, which corresponds to an ionization multiplicity $Z_{eff} \approx 10$. Ultracompression permits the use of an ultradense reflecting layer to reduce the critical size still further. The equation describing the development of the neutron avalanche is

$$\frac{4\pi}{3} R^3 \frac{dn_n}{dt} \approx \frac{4\pi}{3} R^3 n_n n_i \sigma_f (\nu - 1) v_n - 4\pi R^2 n_n v_n (1 - \alpha),$$

where α is the coefficient of back reflection from the reflecting layer.

It is possible to make $\alpha \approx 1 - e^{-n_i \sigma_s l'}$, since the concentration of light atoms in the reflecting layer may be an order higher than the concentration of the ultracompressed heavy element at a given pressure, which gives $n_1' \sigma_s' l' \sim 1$ at $\sigma_s' \approx 1$ barn even when $l' \approx 10^{-2}$ cm. Back scattering and a starting burst of neutrons can be provided, for example, by using deuterium or LiD. We note that $\langle \sigma_f V \rangle$ decreases very little on a decrease in neutron velocity, but this is undesirable because it could protract the multiplication process in time. From the above equation we obtain

$$R_{cr} \approx \frac{3(1 - \alpha)}{\sigma_f n_i (\nu - 1)},$$

$$M_{cr} \approx 10^2 \frac{(1 - \alpha)^3 m_i}{[\sigma_f (\nu - 1)]^3 n_i^2}.$$

This strong dependence of the critical mass on the multiplication and reflection parameters makes it easier to find conditions under which it is possible to guarantee small critical values. Estimates indicate the possibility of obtaining $R_{cr} \approx 10^{-2}$ cm and $M_{cr} \approx 10^{-2}$ g. The energy necessary to effect this compression may exceed the energy to compress this mass:

$$\int p\, dV \approx \frac{p_{\max} V_{\min}}{\gamma - 1},$$

since most of the energy goes into vaporization when the pressure is maintained for a sufficiently long time. The required energy is estimated at $\mathscr{E}_0 \approx 10^2$ kJ for the most efficient of the available working substances. We note that the vaporized jacket can be made from any material (for example, Pb), thus lowering the consumption and the necessary amounts of fissile material.

Since most of the energy release occurs in the last few generations of the neutron-multiplication avalanche (we note that the time to breed a generation $t_1 \approx 10^{-11}$ sec), there is not time enough for any appreciable change in the radius of the ultracompressed matter, and hence no time for loss of avalanche-development efficiency (the expansion time is $\sim 10^{-10}$ sec because of the high density of the ultracompressed matter). For example, even at one percent reacted nuclei, we obtain an energy release $\sim 10^4$ kJ and emission of $\sim 10^{18}$ neutrons in 10^{-11} sec. Such high-density neutron fluxes are of great interest for a number of physical experiments and applications. Such a burst could also be used to produce a powerful neutrino source.

2. Production of ultrastrong magnetic fields by ultracompression of matter; particle acceleration. The high pressures attainable can be used to produce ultrastrong magnetic fields $H \approx \sqrt{8\pi p} \approx 5 \cdot 10^9$ Oe at $p \approx 10^{12}$ atm by compressing dense highly conductive matter in which a magnetic flux is confined or frozen. (The largest cross-section transformation coefficients are possible when a hollow body is compressed.) Since the compression time $t \sim R/c_s \sim 10^{-9}$ sec is smaller than the skin time $t_{skin} \approx 4\pi R^2 \sigma / c^2 \gtrsim 10^{-7}$–$10^{-6}$ sec, the entire confined flux is compressed and $H \approx H_0 R_0^2 / R^2$. An abrupt change in a very large field will give rise to strong inductive fields $E \approx RH/2c \approx 3 \cdot 10^9$ V/cm at $R \approx 10^{-2}$ cm, $H \approx 5 \cdot 10^9$ Oe, and $\tau \approx 10^{-10}$ sec, fields that can be used to accelerate charged particles. Using the invariant $P^2/H \approx$ const in the varying magnetic field (P is the momentum of a particle of any energy), we find that the final relativistic particle energy

$$\mathscr{E} \approx Pc \approx ZeHR \approx Z \cdot 10 \text{ GeV}.$$

It would be simplest to accelerate electrons and ions in a cavity in the compressed substance, which could be chosen at will.

In the case of substances in which reactions on charged particles are used, the inductive fields may enhance thermal or epithermal processes and yields.

The problems set forth above are discussed in a paper that we submtited to "JETP Letters" in August of 1972. Six months later, Winterberg's independent paper[5], which was concerned only with microcritical masses of fissile matter, made its appearance.

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