a submerged plate: caving in and squeezing out of the plate, a change in the nature of the puncture of the plate by the light beam compared to puncture in air, rupture of the cuvette by shock waves, ejection of the liquid from the place where the plate burns through.

Increasing the absorptive power of the water (by coloration with copper sulfate, which absorbs the ruby laser light quite well) led to a sharp intensification of the photo-hydraulic effects. A strong ejection of liquid, cumulative in nature, was observed (Fig. 3). The height of the ejected stream reached a meter, and on some occasions almost all the water in the cuvette was ejected. Experiments conducted with colored liquids provide models for the effervescence processes in the beam of infrared lasers, the radiation of which is strongly absorbed by water.

The effects considered can increase many fold the amplitude of the pressure waves created in a liquid by a light beam incident on its surface. The amplitude even of the nonshock waves of compression during boiling is determined by the vapor pressure of the liquid at the temperature of local heating and can exceed by a million times the direct light pressure. The subsequent expansion waves can intensify the boiling and breakdown of the liquid.

In conclusion we thank V. S. Zuev and V. K. Konyukhov for their participation in the preliminary experiments on effervescence of aerated liquids carried out in the summer of 1962.

Translated by L. M. Matarrese
339

---

# *ABRUPT CHANGE IN PROBABILITY OF THE MÖSSBAUER EFFECT AT THE PHASE TRANSITION IN FERROELECTRICS*

PHAM ZUY HIEN, A. S. VISKOV, V. S. SHPINEL', and Yu. N. VENEVTSEV

Nuclear Physics Institute, Moscow State University, and L. Ya. Karpov Physico-chemical Institute

Submitted to JETP editor March 28, 1963

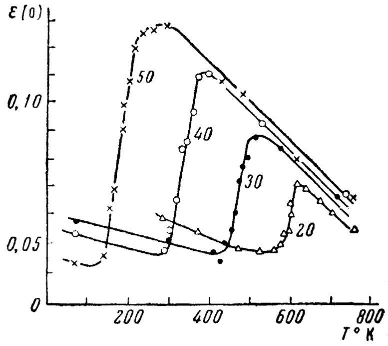
J. Exptl. Theoret. Phys. (U.S.S.R.) **44**, 2182-2183 (June, 1963)

It is known that a ferroelectric phase transition is accompanied by a change in the structure and in some of the physical properties of crystals. In such a transition one would expect anomalous changes of the parameters of the resonance absorption of $\gamma$ rays (for example, the probability of recoilless resonance absorption, shift of the resonance energy, etc).

We have attempted to detect such anomalous changes in the series of solid solutions $BiFeO_3 - SrSnO_3$. Bismuth ferrite is a ferroelectric antiferromagnet (Curie and Néel points 850 and 360°K, respectively[1,2]), while strontium stannate is a compound without any special dielectric and magnetic properties. Both compounds have the perovskite structure. One would therefore expect to find a continuous series of ferroelectric solid solutions for this system over a wide range of composition on the $BiFeO_3$ side. X-ray analysis shows that at room temperature, up to approximately 45 mole % of $SrSnO_3$, just as in pure $BiFeO_3$, the solid solutions are in the rhombohedral, ferroelectric modification.

The source for the measurements of resonance absorption of $\gamma$ quanta was the $Sn^{119*}$ isomer contained in $SnO_2$.[3] The absorbers of the different solid solutions contained the same weight (17 mg/cm$^2$) of $SrSnO_3$. The resonance absorption in a $SrSnO_3$ crystal had been studied earlier.[4] Figure 1 shows the temperature dependence of the maximum absorption $\epsilon(0)$ for these absorbers. A sharp change in $\epsilon(0)$ for the solid solutions was found at certain temperatures which decreased with increasing concentration of $SrSnO_3$. The widths of the spectra taken at temperatures immediately above and below the region of the "transition" do not differ noticeably. This means that the sharp change in $\epsilon(0)$ at the temperature of the "transition" is almost entirely caused by an

FIG. 1. Temperature dependence of maximum absorption $\epsilon(0)$ for absorbers of solid solutions of $BiFeO_3-SrSnO_3$ (absorber contains 17 mg/cm$^2$ of the $SrSnO_3$ component). The numbers on the curves give the mole % of $SrSnO_3$.



abrupt change in the probability for recoilless resonance absorption f′. The jumps in f′ have unusually large values. For example, for a solid solution of 50% $BiFeO_3$ – 50% $SrSnO_3$,

$$\frac{f'(T \geqslant T_c)}{f'(T \leqslant T_c)} = 4.1.$$

The abrupt change in f′ which was observed is caused by the transition of the solid solution from the paraelectric to the ferroelectric state. In fact, x-ray photos of the samples with 20—45 mole % $SrSnO_3$ confirm this conclusion. Figure 2 shows the dependence of the transition temperature, as determined from the resonance absorption, on the $SrSnO_3$ concentration. The crosses on the graph show the Curie temperatures for the samples from 20 to 45 mole % of $SrSnO_3$. The slight difference in the Curie points determined by the two methods may be explained by the fact that the x-ray method determined the upper limit of the transition region (Curie region), whereas in treating the results of the resonance absorption measurements we used values for the transition temperature corresponding to the middle of the transition regions. We should also mention that the widths of the transition regions reach sizeable values, and increase with the $SrSnO_3$ content.

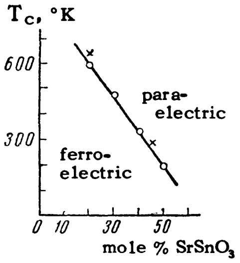


FIG. 2. Phase diagram of solid solutions of $BiFeO_3$–$SrSnO_3$

The character of the change in f′ at $T \approx T_C$ indicates that there is a first-order phase transition at $T_C$, and that the appearance of the spontaneous polarization at this point is accompanied by a sharp decrease in the effective elastic constants of the crystals. From the thermodynamic point of view, in the transition from paralectric to ferroelectric there is, in our opinion, a discontinuous decrease in the part of the internal energy associated with the thermal motion of the lattice. This has as a direct consequence the lowering of the "effective" upper limit of the phonon spectrum and, consequently, a marked drop in f′. For example, if we approximate the phonon spectrum in these crystals by a crude Debye model, at the transition from the paraelectric to the ferroelectric phase for the (50%$BiFeO_3$ – 50%$SrSnO_3$) solution there is an extremely sharp drop in the Debye temperature from 290 to 110° K.

---

[1] Fedulov, Venevtsev, Zhdanov, Smazhevskaya, and Rez, Kristallografiya **7**, 77 (1962).

[2] Kiselev, Ozerov and Zhdanov, DAN **145**, 1255 (1962), Soviet Phys. Doklady **7**, 742 (1963).

[3] Pham Zuy Hien and V. S. Shpinel', JETP **44**, 393 (1963), Soviet Phys. JETP **17**, 768 (1963).

[4] Pham Zuy Hien, Shpinel', Viskov and Venevtsev, JETP **44**, 1889 (1963), this issue p. 1271.

Translated by M. Hamermesh
340

---

# *CONTRIBUTION OF REGGE POLES TO THE TOTAL CROSS SECTIONS AT HIGH ENERGIES*

V. I. NIKANOROV

Joint Institute for Nuclear Research

Submitted to JETP editor April 2, 1963

J. Exptl. Theoret. Phys. (U.S.S.R.) 44, 2184-2185 (June, 1963)

In this paper results are presented of a simultaneous analysis of the experimental data on the total cross sections for the $\pi^-p$, $\pi^+p$, $K^-p$, $K^+p$, $pp$, $\bar{p}p$, and $pn$ interactions, undertaken to assess the contribution of Regge poles to the imaginary part of the amplitudes of the corresponding processes for t = 0 (where t is the square of the four-momentum transfer in the c.m.s.). Results of experiments carried out at energies greater than 3 BeV [1-5] were used for the analysis.

If we limit ourselves to the contribution of the quasi-vacuum $\omega$ and $\rho$ poles, the total cross section can be written in the form:

$$\sigma(\pi^-p) = (aE + bE^q + cE^\rho)/\sqrt{E^2 - \mu^2}, \qquad (1)$$

$$\sigma(\pi^+p) = (aE + bE^q - cE^\rho)/\sqrt{E^2 - \mu^2}, \qquad (2)$$

$$\sigma(K^-p) = (eE + fE^q + gE^\omega - hE^\rho)/\sqrt{E^2 - m^2}, \qquad (3)$$

$$\sigma(K^+p) = (eE + fE^q - gE^\omega + hE^\rho)/\sqrt{E^2 - m^2}, \qquad (4)$$

$$\sigma(pp) = (kE + lE^q - nE^\omega - rE^\rho)/\sqrt{E^2 - M^2}, \qquad (5)$$

$$\sigma(\bar{p}p) = (kE + lE^q + nE^\omega + rE^\rho)/\sqrt{E^2 - M^2}, \qquad (6)$$

$$\sigma(pn) = (kE + lE^q - nE^\omega + rE^\rho)/\sqrt{E^2 - M^2}, \qquad (7)$$

where E is the laboratory energy of the incident particle; $\mu$, m, and M are the masses of the $\pi$ meson, K meson, and nucleon, respectively; and q, $\omega$, and $\rho$