THE TRANSPARENCY OF SODIUM FLUORIDE AND LITHIUM FLUORIDE IN THE EXTREME ULTRAVIOLET

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Abstract

Artifically prepared single crystals of sodium and lithium fluorides were tested for transparency to extreme ultraviolet light by means of a one meter concave grating vacuum spectrograph. The source used was a highly condensed spark discharge through a Pyrex capillary. These crystals were expected to be more transparent than calcium fluoride (fluorite) due to their lower indices of refraction. Lithium fluoride was transparent to 1083A (132A below the limit of fluorite) which is the practical limit to be expected. Sodium fluoride was transparent to 1320A, which is not thought to be the limit of the pure material. Crystals of these salts have been made as much as 5 cm in diameter, and they are rather insoluble and easily cut and polished being very similar to fluorite.

RESEARCH work in the extreme ultraviolet part of the spectrum has been handicapped by a lack of transparent materials. The most transparent material known was calcium fluoride (fluorite) which Liefson[1] found transparent to 1215A (this is exceptional and fluorite that transmits to 1400A is very scarce). Lyman[2] has tested a great number of naturally occuring crystals; he found none as good as fluorite and that fluorite varied greatly in its transparency. Therefore research work has been directed towards the preparation of large single crystals from pure salts.

Crystals have several advantages in spectrographic work. A prism spectrograph gives a much brighter spectrum than a grating spectrograph. Crystals have greater dispersion than glasses near the transmission limit; so if prisms of various crystals were available one could obtain high dispersion in any desired part of the spectrum. Achromatic lenses can be made when crystals are obtainable that have about the same transmission limits. Crystals that transmit far into the extreme ultraviolet have high dispersion in the near infrared.

There were several reasons for the choice of sodium and lithium fluorides. They are cubic crystals, which make the preparation of lenses and prisms simpler than from other classes of crystals. Calcium fluoride was the most transparent solid known, and since the fluoride ion was the chief determining factor the fluorides were given the most consideration. Lithium fluoride was first prepared because the lithium ion is smaller and has fewer electrons than the calcium ion. Since the index of refraction is closely related to the absorption or transmission of light, a plot of the dispersion curves of cubic crystals was thought worthwhile; all that had been measured were those of calcium

[1] S. W. Liefson, Astrophys, J. **63**, 73 (1926).
[2] T. Lyman, Astrophys. J. **25**, 45 (1907).

fluoride, sodium chloride, and potassium chloride. Since then Gyulai[3] has measured the dispersion curves for five alkali halides. All the measurements are shown in Fig. 1. The fact that the curves do not cross and are of the same general shape was used to limit the research to crystals which showed the most promise, since a single measurement of the index of refraction fixed its relative position in the plot and indicated how transparent the pure crystal would be in the extreme ultraviolet. Sodium fluoride has the lowest index of refraction (1.328 for N_D) for any cubic crystal and therefore should be the most transparent in the extreme ultraviolet. The only other cubic crystal that might have as low a value for N_D is potassium fluoride which is very deliques-

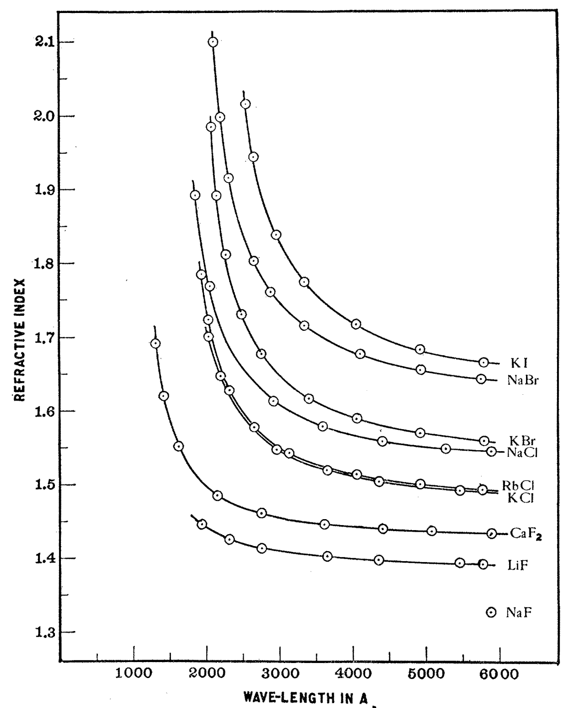

Fig. 1.

cent and consequently for practical use out of the question. Lithium fluoride has a value for N_D of 1.384, while calcium fluoride has a value of 1.434. Therefore pure sodium fluoride and lithium fluoride should be more transparent than calcium fluoride.

The single crystals, made by a method previously published,[4] were prepared from repurified C.P. chemicals. The transparency was the best test of the purity. Crystals of sodium and lithium fluorides cleave easier and better than fluorite. They were tested by placing a thin cleavage plate of about 1 mm thickness between the light source and the slit of a one meter concave grating

[3] Z. Gyulai, Zeits. f. Physik **46**, 809 (1927).

[4] H. C. Ramsperger and E. H. Melvin, J.O.S.A. and R.S.I. **15**, 359 (1927).

vacuum spectrograph. The light source used was a condensed spark discharge through a Pyrex capillary at a residual air pressure of about 0.002 mm of Hg; this gave a line spectrum extending to 500A. The crystal window was protected by glass tubes from metal sputtered from the aluminum electrodes.

Results

Spectrograms showing the transparency of the crystals are not published due to the fact that faint lines near the transmission limit are not visible in reproduction. The percentage of light transmitted is difficult to judge due to the type of source used. A description of the results follow.

Lithium fluoride. Four crystals of lithium fluoride were tested. The transmission limits varied between 1083A and 1350A. All the crystals were very transparent to within 200A of their limit. The salts used in preparing the crystals were from different sources which may explain the variations, since the treatment given them was the same in all cases.

Sodium fluoride. Two crystals of sodium fluoride were tested. One crystal transmitted to 1740A with almost no absorption of light, then absorption was complete; the other crystal transmitted to 1320A where absorption set in completely.

Discussion

The limits of transparency varied considerably for both salts. The limit of 1083A obtained for lithium fluoride appears to be the practical limit of transmission for the pure salt based on the curves shown in Fig. 1. This limit is 130A beyond that obtained for the best fluorite. The limit of 1215A for fluorite would seem to be the limit for pure calcium fluoride. As indicated in Fig. 1, sodium fluoride should be more transparent than lithium fluoride, but this was not found to be the case, slight traces of impurities are thought to be the explanation of this. The great absorption that traces of impurities may have is shown in a recent paper by Hilsh and Pohl[5] who measured the dispersion frequencies above 1600A of many alkali halides. They distilled the salts onto a quartz plate to measure their absorption, and found that the layer of salt had to be of the order of 0.001 mm thick to get appreciable amounts of light through the salt below the first absorption wave-length. Thus we see that extremely small amounts of such salts as these would effect the transmission of extreme ultraviolet light very markedly.

Sodium fluoride and lithium fluoride are better than fluorite also in that they do not become colored and opaque with use—some crystal windows were tested many times. These crystals are about as hard as fluorite so that anyone familiar with fluorite can cut and polish them. Single crystals up to 5 cm in diameter have been prepared and there seems no reason why much larger ones could not be prepared. Plates are very easy to cleave and have very good surfaces. Lithium fluoride is rather insoluble—0.27 g per 100 g of water at 10°C—and can be ground and polished in water. Sodium fluoride is more soluble—4.3 g per 100 g of water at 18°C—and so cannot be allowed to stand in water.

[5] R. Hilsh and R. W. Pohl, Ziets. f. Physik 59, 812 (1930).