Proceedings of the Iowa Academy of Science

Volume 23 | Annual Issue Article 30

1916

# On the Variation in the Reflecting Power of Isolated Crystals of Selenium and of Tellurium with a Variation in the Azimuth of the Incident Plane Polarized Light

L. P. Sieg
*State University of Iowa*

## Recommended Citation

Sieg, L. P. (1916) "On the Variation in the Reflecting Power of Isolated Crystals of Selenium and of Tellurium with a Variation in the Azimuth of the Incident Plane Polarized Light," *Proceedings of the Iowa Academy of Science, 23(1),* 179-186.
Available at: https://scholarworks.uni.edu/pias/vol23/iss1/30

# ON THE VARIATION IN THE REFLECTING POWER OF ISOLATED CRYSTALS OF SELENIUM AND OF TELLURIUM WITH A VARIATION IN THE AZIMUTH OF THE INCIDENT PLANE POLARIZED LIGHT.

L. P. SIEG.

The reflecting power of a surface is defined as the ratio of the intensity of the light reflected at perpendicular incidence to the intensity of the incident light. There are two ways of determining the reflecting power of a metallic surface. One is by a direct, or photometric (dioptric) method. The other is by an indirect (katoptric) method. In the latter an analysis is made of the elliptically polarized light coming from the surface in question, upon which plane polarized light is incident. This analysis yields what are called the optical constants of the substance. These constants are the index of refraction, the absorption index, and the reflecting power. Both methods have been used repeatedly and the concordance of the results gives us such faith in the indirect method, that, in view of the fact that the absorption index and index of refraction of the metal constituting the surface are much more easily determined by the second method, we generally employ this indirect method. Nevertheless it is always desirable when possible to check the results by some direct experimental attack.

Most of the work done on metallic surfaces has been done, not only by the indirect method, but also on rather large polished surfaces of the metals in question. In view of the fact that metals are essentially crystalline, it becomes at once an open question as to whether the optical constants determined from large polished surfaces represent the real facts. For unless the crystals constituting the metal belong to the cubic system, one should certainly expect a set of optical constants depending on the orientation of the crystalline axis. In this view, then, the constants ordinarily determined can represent only, except in the case of metals of the cubic system, certain mean values of the actual constants.

With this view in mind, some two years ago, the writer set one of his students, Mr. C. H. Skinner, at work to determine the optical constants by a katoptric method of an isolated crystal of selenium. Although selenium is not regarded as a metal, it has, nevertheless, optically speaking, many qualities of a metal. The crystals are optically very dense and offer brilliant reflecting surfaces. Skinner succeeded in proving definitely that there were distinct differences in the optical constants, depending upon whether the long axis of the hexagonal crystal was vertical or horizontal. This work is not yet published in full, but an abstract has recently appeared[1]. Some years ago Drude[2] and Müller[3] worked on isolated crystals of antimony sulphide, and proved that from one cleavage plane, (0 1 0) two distinct sets of optical constants were obtained. Other work has been done, notably by G. Horn[4], on the absorption of certain crystals, but the writer is not aware that any work on *elemental* metallic crystals with the exception of a determination of the absorption of bismuth and antimony by the latter author, has been done. The reason for this is not far to seek, for usually the crystals of metals are microscopic in size. The difficulty in working with such small surfaces by the ordinary methods led the writer to suggest this task of obtaining a special method to another of his students, L. D. Weld. The latter has succeeded admirably in this problem, and a preliminary report of the work is presented to the Academy of Science at this meeting.

Aside from the importance of crystals in yielding us the true constants of various substances, there is good reason for believing that the crystalline surface should be better adapted for the purpose than any artificially formed polished surface. If this is correct, then even the cubic crystals should be re-examined by this method. The one reliable trait of all crystals seems to be their maintaining of constant angles, and even if there seem to be striations on some of the surfaces, it may be that these irregularities would not seriously affect the optical constants. Then too where it is possible to obtain a fresh surface by cleavage, one should expect the most relia-

---

[1] C. H. Skinner, Phys. Rev. 7, 1916, 285.
[2] P. Drude, Ann d. Phys., 34, 1888, 489.
[3] E C. Müller, N. Yahrb, f. Miner. Beil. Bd., 17, 1903, 187.
[4] G. Horn, N. Yahrb. f. Miner. Beil. Bd., 12, 1899, 269.

ble results. Drude[5] and Müller[6] both found that a fresh surface of antimony sulphide deteriorated rapidly after coming into contact with the air.

The writer thought it to be highly desirable to determine the reflecting power of certain of these crystals by a direct method. If these results should show definitely a difference in the reflecting power with difference in azimuth of the incident plane polarized light, then there would be a larger amount of reliability to be placed in the results that are being obtained in this laboratory by the more exact, but indirect methods.

The plan of the experiments was very simple, but the execution has been rather difficult. The first arrangement was an apparatus by which plane polarized light from a monochromator, varying in wave length throughout the visible spectrum, could be thrown upon a linear thermopile, and secondly reflected upon this thermopile by reflection at nearly normal incidence from the crystalline surface. The ratio of the second deflection of the connected galvanometer to the first would give at once the reflecting power. By rotating the crystal in the plane of its surface through 90°, and repeating the above experiment, one could get the reflecting power from this azimuth. The results were, however, unsatisfactory because not enough energy could be obtained from the small crystalline areas to give reliable deflections of the galvanometer.

A second attempt was made in which a crystal of selenium, connected in a Wheatstone's bridge, was substituted for the thermopile. The effect of light on the selenium is to decrease its resistance, and it was thought in view of the fact that a selenium receiver is much more sensitive in the visible spectrum than the thermopile that definite results could be obtained. However, the crystal employed, although more sensitive than the thermopile, proved unfortunately to be more erratic and unsteady in its action. While perseverance would no doubt have led to a more satisfactory crystal receiver, it was decided for the time being to abandon this plan of attack and to use a spectrophotometric method. The apparatus was arranged in several different ways which need not be gone into here, before what proved to be a satisfactory method was found. The plan is shown in figure 15. Light from a Nernst glower, *G*

---

[5] P. Drude, loc. cit.
[6] E. C. Müller, loc. cit.

(later a nitrogen filled tungsten lamp was employed) placed in a light-tight box is focused by a lens, $L_5$ at the points $N_1$ and $H$. This division of the light was accomplished by means of a mirror $M_1$ partly intercepting the light. $N_1$ is a Nicol prism which can be set at any desired angle. Passing through $N_1$ the light meets the lens, $L_2$ and by it would be brought to a focus at $A$ were it not for the crystal plate at $X$. This latter returns the light through the totally reflecting prism, $P$ and it is finally focused on the lower half of the slit of the monochromator $PSE$. The other portion of the original beam of light passes through $L_1$ to the mirror $M_2$, thence through the lens $L_3$, the Nicols $N_2$ and $N_3$, the latter with an attached circular scale and vernier, and lastly is focused by means of the lens $L_4$ upon the upper half of the slit of the monochromator. These two beams pass through the instrument and form on the emergent slit two images of the front slit, one above the other, and formed by light coming along the two separate paths. The wave length for which one wishes to make an examination is obtained by setting the graduated screw $S$. The instrument had of course been calibrated. These two images are viewed through the eyepiece $E$. The procedure is to set $S$ for a wave length at one end of the visible spectrum, then to rotate the Nicol, $N_3$, until the two images are matched in brightness. By proper

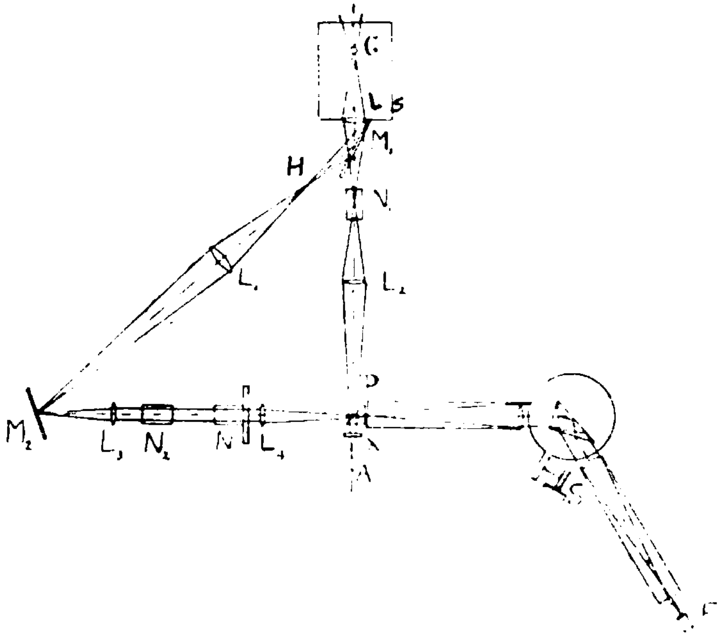

FIG. 15.

adjustment of the mirror $M_1$, the light coming by the longer path can always be made, with the Nicols parallel, more intense than that by the shorter path, so that it is always the one to be reduced in intensity for an intensity match.

Having run through the spectrum with the crystal $X$ set say with its long axis agreeing with the electric vector from the Nicol $N_1$, the latter is now revolved through 90°, and the operations are repeated. Then to make certain that this changed azimuth of the polarized light does not cause changes in intensity due to the monochromator as well as due to a difference in the reflecting power of the crystal, two more settings are employed. The crystal is rotated through 90°, and the electric vector from $N_1$ is first vertical, and secondly horizontal. From these four sets of readings one is in a position to calculate the reflecting power of the crystal with two different azimuths of plane polarized light. The present work was not designed as an attack on the absolute reflecting power of the surfaces, but merely to obtain the differences due to these two different azimuths of the incident light. In order to get absolute results one must know the area illuminated, and then substitute for $X$ a substance of the same area and of known reflecting power—silver for instance. This was done in the present case by using black glass, and only carefully enough to make certain that the light reflected from the silver-backed glass mirror $M_2$ represented nearly constant reflecting power through the spectrum. This agrees with published results[7].

In the near future it is planned to obtain the absolute reflecting power of these and of other crystals. Not the greatest confidence can be placed in the variation of the reflecting power through the spectrum, that is as to whether there are any slight maxima, or minima, for the uncertainties in matching brightness make absolute reliability in this regard only to be obtained through extremely long and careful experimentation. However, the fact of the variation in magnitude of the reflecting power with the azimuth of the incident plane polarized light stands out clearly, and this was the prime object of the research up to the present point.

The first crystal tried was a hexagonal crystal of selenium[8] made by sublimation in an atmosphere of hydrogen. The curve

---

[7] Wood, Physical Optics, Ed. 2, p. 466.

[8] The writer is much indebted to Dr. F C. Brown for the crystal of selenium, and to Mr. W. E. Tisdale for the crystal of tellurium, mentioned

shown in figure 16 represents typical results of these experiments. The method of using four settings was not adopted at the time these first experiments were performed, so although the differences in the reflecting power are genuine, there are undoubtedly corrections that should be made. It will be noticed that the reflecting power is practically constant throughout the spectrum. This is in a way substantiated by direct observation, for the light reflected from these brilliant surfaces is free from any observable trace of color. It will be noted that the reflecting power is greatest when the electric vector is along the long axis of the crystal. This is in agreement with what we should expect, because it is along this axis that the elasticity is greatest. The intensities of the reflected light are taken as proportional to the square of the cosine of the angle through which the Nicol $N_3$ is turned from its position parallel to the Nicol $N_2$. The direct results here given corroborate the results obtained by the indirect method, and so no doubt add to the confidence in the latter.

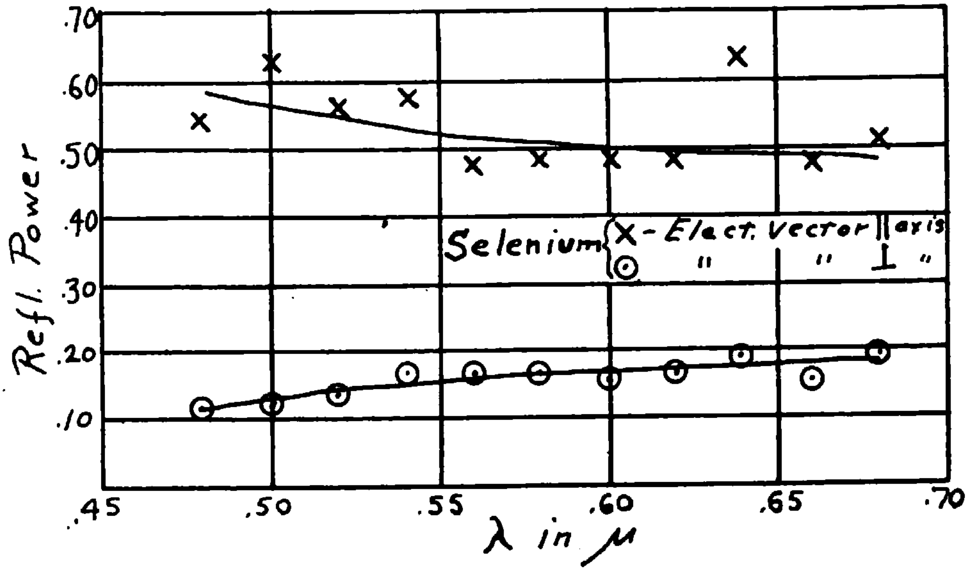

FIG. 16.

The next crystal employed was one of tellurium, formed in hydrogen. It is planned in this laboratory to make a careful study of the optical constants of this element, but up to the present time this work is not completed. It was thought, however, important to try these preliminary experiments on this crystal for future reference in the more extended work. The particular crystal used was a very long acicular hexagonal crystal, and was made by sublimation in an atmosphere of hydrogen by Mr. Tisdale of this laboratory. The electric oven in which this was done is described in this volume of the Proceedings, see page 209. The surface of the crystal was about 0.5 mm by 7.0 mm, and was one of the six similar sides of the hexagonal crystal. In these last experiments correction was made for the possibility of a variation of the intensity of the light passing through the monochromator, and also for a variation in the area of the crystal illuminated when it was rotated through a right angle. The corrections were made as follows.

Let $r_1$=the intensity of the reflected light when the electric vector lies along the crystal's long axis.

$r_2$=the intensity of the reflected light when the electric vector is perpendicular to the crystal's long axis.

$a_1$=the reduction factor for the intensity due to the passage through the monochromator when the electric vector is vertical.

$a_2$=the reduction factor when the vector is horizontal.

$b_1$=the fraction of the crystal illuminated when the crystal is vertical.

$b_2$=the fraction illuminated when horizontal.

Then $r_1a_1b_1$, for example, will be the intensity as measured by experiment (square of cosine of the angle of rotation of $N_3$ for an intensity match) of the light reflected from the surface when both the vector and the crystal's long axis are vertical. The other combinations are readily interpreted.

Let $r_1a_1b_1=m$
$r_2a_2b_1=n$
$r_1a_2b_2=p$
$r_2a_1b_2=q$

Solving these we obtain

$$r_1/r_2=(mp/nq)^{\frac{1}{2}}\ ;\ a_1/a_2=(mq/np)^{\frac{1}{2}}\ ;\ b_1/b_2=(mn/pq)^{\frac{1}{2}}$$

In the following table are listed the values of the square of the cosine of the angle of rotation of the Nicol, $N_3$, for the different wave lengths, and for the four positions stated above. It will be seen that the ratio of the two reflecting powers is, as in the case of selenium, practically a constant throughout the spectrum, the one with the electric vector along the long axis being greater than the one at right angles to this in the ratio of about 1.7 to 1. the values of $b_1/b_2$ should come out a constant, and the variation in the table is merely an indication of the experimental errors. The ratio $a_1/a_2$ would not necessarily be a constant, although it so proves to be within the errors of the experiment.

TELLURIUM.

| Wave Length (micra) | $m$ | $p$ | $q$ | $n$ | $a_1/a_2$ | $b_1/b_2$ | $r_1/r_2$ |
|---|---|---|---|---|---|---|---|
| .66 | .48 | .53 | .36 | .25 | 1.14 | .78 | 1.68 |
| .64 | .48 | .57 | .38 | .26 | 1.13 | .74 | 1.70 |
| .62 | .50 | .55 | .35 | .27 | 1.06 | .84 | 1.71 |
| .60 | .50 | .57 | .38 | .25 | 1.15 | .76 | 1.73 |
| .58 | .50 | .59 | .40 | .31 | 1.05 | .81 | 1.55 |
| .56 | .55 | .59 | .36 | .30 | 1.06 | .88 | 1.74 |
| .54 | .52 | .59 | .38 | .27 | 1.11 | .79 | 1.73 |
| .52 | .53 | .57 | .38 | .27 | 1.14 | .81 | 1.72 |
| .50 | .55 | .57 | .38 | .28 | 1.15 | .84 | 1.72 |
| .48 | .55 | .53 | .38 | .28 | 1.19 | .88 | 1.66 |

*Conclusion.*—The importance of a study of isolated crystals has been pointed out and preliminary direct results on the reflecting power of a selenium and of a tellurium crystal have been obtained. These results have supported the original contention, and are, the writer believes, the first direct results published for these two elements to show that they have different reflecting powers. Heretofore these reflecting powers have been determined from large polished mirrors of these elements, and of course only one value for each element for each wave length has been determined. Further work along this line is to be done in the immediate future.

Physics Laboratory,
State University of Iowa.