III. *On the Optical Phenomena of certain Crystals.* *By* H. F. Talbot, *Esq. F.R.S.**

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SOME time ago I had the honour to communicate to the Royal Society an account of my invention of the polarizing microscope†. This instrument possesses so great a power of developing the internal structure of transparent bodies, even in their minutest visible particles, that I feel confident the employment of it will lead to many new and interesting results. At present I mean to confine myself to the description of a phenomenon which shows strikingly the beautiful order and regularity with which nature disposes the fabric of some of her minutest visible works.

The object I speak of is a kind of minute crystallization which may be obtained in peculiar circumstances, and I doubt not, in many different ways; but the manner in which it has presented itself to my observation is as follows.

A crystal of borax is placed in a drop of phosphoric acid, somewhat diluted, upon a plate of glass, and then moderately heated until the crystal dissolves in the acid. It is then set aside to crystallize. It is well to prepare a number of these plates at once, varying the relative proportion of the acid and salt, in order that the desired kind of crystallization may be found in one or other of them; for there is a considerable variety in the crystalline forms obtained by this method, some of which indeed are very singular. But when that kind of crystallization takes place which it is more particularly my intention to speak of, the field of view of the microscope is seen covered with minute circular spots, each of which is like a tuft of silk radiating from a centre, and is composed of a close assemblage of delicate acicular crystals forming a star. But besides these, are seen interspersed among them a number of circular transparent bodies, which are evidently modifications of the former, being, in fact, tufts or stars of acicular crystals in such close assemblage as to be in optical contact with each other and to produce the appearance of a single individual. Now let us suppose a group of these circles to be under examination with the polarizing microscope, and when the polarizers‡ are crossed, we observe the following phenomenon. The field

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† See London and Edinburgh Philosophical Magazine, vol. v. p. 321.

‡ By this term, for the sake of brevity, I here designate the polarizing and analysing prisms of single-image calcareous spar, or the plates of tourmaline which may be employed in their stead.

of view being dark, the little circles become luminous, and we see upon each of them a well-defined and dark cross, dividing the crystal into four equal parts. All these crosses are placed similarly, and are parallel to each other, and their direction remains unaltered when the crystals are turned round in their own plane by revolving the plate of glass upon which they stand. This beautiful appearance can be seen with a moderate magnifying power. I measured the diameter of some of the larger crystals, which I found to be from $\frac{1}{300}$ to $\frac{1}{600}$ of an inch. But there are many much smaller, and indeed they may be seen decreasing in size, until nothing remains visible of their structure but the four luminous quadrants, appearing like four minute dots of coloured light placed close together.

I proceeded to examine the circles with a high magnifying power, and under favourable circumstances of illumination, and I observed in them a very admirable structure.

Each circle has upon it one or more coloured rings arranged concentrically, but the number as well as the colour of these rings is different in different individuals.

The innermost ring is deeply coloured or black, and incloses a central space of white light, which is traversed by the arms of the cross intersecting in the centre. This part of the cross, which stands within the innermost ring, is beautifully well de-defined, and perfectly black. The general appearance resembles the figure 98, in Brewster's Optics, which is a representation of the rings seen in uniaxal crystals. It especially resembles it in the circumstance above mentioned, viz. the more defined outline of the part of the cross which is within the innermost ring.

We have hitherto supposed the polarizers to be crossed, but if we place them in a parallel position we shall see a phenomenon complementary to the above. The circle now presents four patches of coloured light, one in each quadrant; and we generally see near the centre four black or obscure spots, which correspond to the arms of the cross in the other position.

Such is an outline of the microscopic appearances presented by these little crystals, which are probably the minutest bodies in which so complicated an optical structure has hitherto been witnessed. I find that the smaller the circles are, the more perfect is their form and the brighter their colours.

These crystals, as I have already observed, probably consist of spicula diverging from a point, but which are in the closest possible contact, and in a state of complete mechanical cohesion. It seems to follow as a consequence from such a structure that their density must increase from their circumference towards their centre. Now it is worthy of remark, that Sir DAVID BREWSTER has discovered very similar phenomena by polarized light in the crystalline lenses of certain fishes, which are known by direct experiment to increase in density towards the centre. Indeed the figure which he has given of the lens of the codfish in the Philosophical Transactions for 1816 (Plate XII. fig. 1.) is so like the appearance of one of the crystals which I have described, that it might be supposed to have been intended for a representation of it.

Having pointed out this resemblance, I may also mention another class of facts to which I think those I have described possess a considerable analogy. I mean the optical figures which BREWSTER has discovered in spheres of glass whose density was rendered variable by heating them.

He says* that, "if we take a cold sphere of glass and immerse it in a trough of hot oil, placed in a polarizing apparatus, we shall observe *a black cross with four sectors of polarized light.* If the sphere is turned round it will exhibit in every position the very same figure. If we now suppose the trough to be filled with such spheres they will exhibit the same phenomena in whatever direction the polarized light is transmitted through them, and even if they were in a state of motion. A fluid composed of such spherical particles would exhibit the same polarizing structure in every possible direction, and even if it were in a rapid state of gyration. If the particles possessed the structure that produces circular polarization the fluid would develop the phenomena exhibited by oil of turpentine, &c."

And again†, "The structure of the particles of a circularly polarizing fluid must be exactly the same along every one of its diameters; that is, the structure must be symmetrical round the centre of the particle, or analogous to that which takes place in common polarization when a sphere of glass has its density regularly increasing or regularly diminishing towards its centre."

I have quoted these remarkable passages at length, because it appears to me that what is there advanced merely as a hypothesis, acquires a considerable degree of probability from the facts which I have stated, since I have succeeded in rendering actually visible circular particles of excessive minuteness, in each of which the microscope detects the very structure imagined by BREWSTER, viz. the black cross and four sectors of light. So that it appears not improbable that the circular-polarizing properties of fluids may be owing to the presence of multitudes of particles similar to these, which they hold in solution.

* Library of Useful Knowledge, art. "Polarization of Light," p. 51.

† Ibid. p. 45.