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CONOSCOPE AND METHOD OF USING THE SAME

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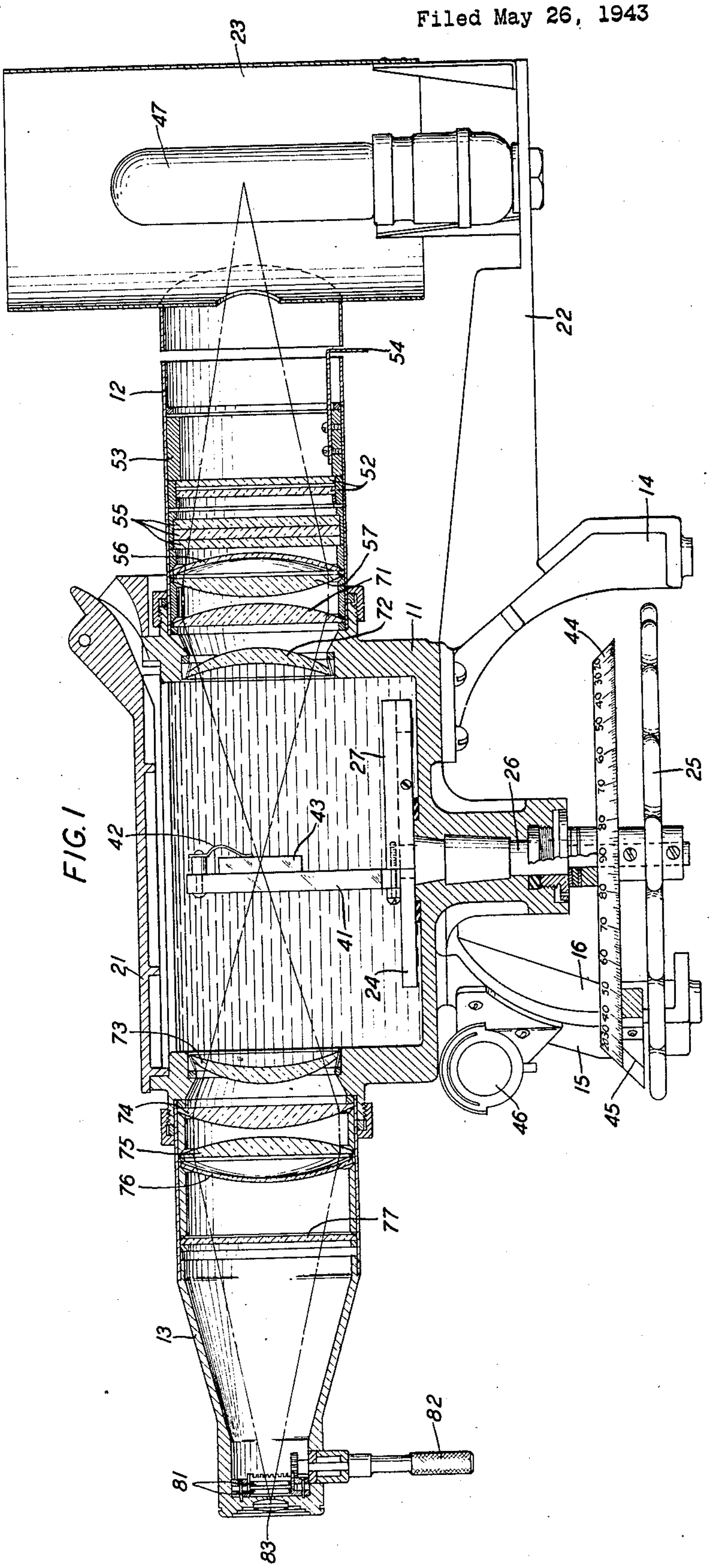

FIG. 1

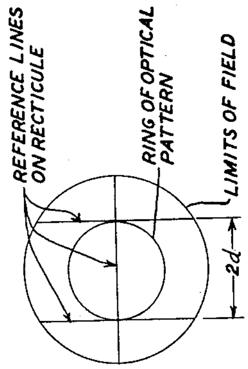

FIG. 3

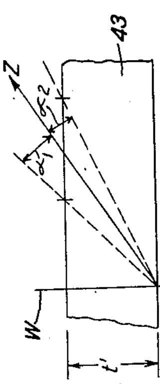

FIG. 2

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CONOSCOPE AND METHOD OF USING THE SAME

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2 Claims. (Cl. 88—14)

This invention relates to a conoscope of the immersion type and to a method of using the same.

An object of the invention is to facilitate the use of the immersion type conoscope and to improve the results obtained therewith from the standpoint of accuracy.

A further object of the invention is to facilitate the production of quartz piezoelectric crystal plates and to improve the quality thereof.

An immersion conoscope of a type in connection with which the present invention is particularly applicable is described in Patent No. 2,352,072, issued to me June 20, 1944, entitled "Conoscope"; this type of conoscope as described in detail in the patent referred to may comprise an immersion tank, a rotatable work supporting platform within the tank, and two optical systems which are arranged horizontally with respect to the tank and which include, respectively, a light polarizer and an analyzer. The crystal to be examined is positioned within the tank on the rotatable platform and is immersed in a fluid which has the same, or approximately the same, index of refraction as the crystal being examined. Immersion of the crystal being examined in this fluid prevents refraction, and hence bending, of the light rays as they pass through the surfaces of the crystal.

A conoscope of the type referred to may be used for making various tests on natural quartz crystals as well as on sections and partially completed piezoelectric plates which have been cut from the natural crystal. For example, the conoscope may be used to accurately locate the Z (optic) axis of a Z-cut piezoelectric section by a method which comprises the steps of lapping the crystal on one side as nearly as possible perpendicularly to the optic axis (which is approximately determined in advance) and sawing a section from the crystal, the cut being substantially parallel to the lapped side. The section is now placed on the platform in such a position that the convergent polarized light passes therethrough along what is assumed to be the optical axis. The position of the section is adjusted until a system (or optical pattern) of divergent or convergent interference rings is seen through the conoscope eyepiece, the "centering" of this pattern indicating that the position of the crystal is such that the converged polarized light is exactly parallel to the optic axis of the crystal.

In the use of conoscopes of the nature referred to, "corrections" in the readings must be made under certain circumstances. In the first place, if the refractive index of the immersion fluid does not exactly match that of the crystal being examined, the light rays will be bent in passing between fluid and crystal and all readings will be subject to "correction." Secondly, if the section being examined is not a true Z section, the ring pattern will be non-concentric and after a ring of the pattern has been centered a "correction" must be applied to the reading.

In accordance with a novel feature of the present invention, the refractive effect is caused to annul the ring eccentricity error by utilizing an immersion fluid the refractive index of which is an accurately precomputed amount away from a perfect match with the refractive index of the quartz crystal being examined.

A complete understanding of the novel method and arrangement contemplated by the present invention as well as appreciation of the various valuable features thereof may be gained from consideration of the following detailed description and the annexed drawing, in which:

Fig. 1 is a side elevational view of an immersion conoscope, a portion thereof being shown in section in order to illustrate certain parts more clearly;

Fig. 2 is an enlarged view of a portion of a quartz piezoelectric section; and

Fig. 3 is a representation of one ring of an optical pattern and the "hair-lines" of the conoscope reticule.

Referring now to Fig. 1, the conoscope illustrated includes immersion tank 11, two lens tubes 12 and 13 arranged horizontally with respect to tank 11 and terminating in respective ports provided at diametrically opposite points in the wall thereof and three supporting legs 14, 15 and 16 for supporting the conoscope assembly. Tank 11 is provided with cover 21 which is hinge supported to permit movement between closed and open positions. Supporting leg 14 carries horizontal extension arm 22 which supports lamp housing 23.

Platform 24 is rotatably supported inside tank 11; the platform may be rotated from the exterior of tank 11 by means of handwheel 25, the platform and handwheel being coupled by shaft 26. Suitable bushings and packing are provided to prevent leakage of fluid from tank 11 around shaft 26. Table 27 is removably supported on platform 24 and is rotatable therewith. The table is also slidable forward and backward on platform 24 so that the center-point of a thin plate being examined may be brought to the intersecting point of the light beams. Transparent reference plate 41 is attached to table 27 and, in conjunction with spring clip 42, provides convenient means for supporting such small and relatively fragile objects as quartz piezoelectric section 43 which is illustrated.

The angular position of platform 24 within the tank may be determined by observing the relative positions of graduated dial 44 (rotatable with shaft 26) and fixed vernier 45. Lamp 46 is provided for illumination of the dial and vernier.

A suitable drainage valve (not shown) may be provided in the base of tank 11.

Coming now to the optical system, let us consider first the contents of lens tube 12. Starting at the end of the tube nearest to light source 47, which may be, for example, a lamp of the mercury-vapor type, and moving toward tank 11, we first encounter light polarizer 52 which may comprise a polarizing film mounted between two plates of glass. Polarizer 52 is mounted in carriage 53; carriage 53 and polarizer 52 may be rotated, within limits, inside tube 12 by means of lever 54.

The next item of the optical system encountered is light filter 55 which comprises three glass filter elements properly cut and polished; in the present example filter 55 is arranged to isolate and transmit only "green" light so that when the optical system is illuminated by light source 47 only green mercury light passes beyond light filter 55.

We next encounter in order concavo-convex lens 56, a pair of plano-convex lenses 57 and 71 arranged back to back, and concavo-convex lens 72.

In general the functions of that portion of the optical system located in lens tube 12 are to polarize the light produced by source 47, to filter out all portions of the light except the green light and to cause the polarized green light to converge and to enter the crystal being examined in a cone of rays.

Considering now the portion of the optical system housed in lens tube 13, we encounter in order concavo-convex lens 73, a pair of plano-convex lenses 74 and 75, arranged back to back, concavo-convex lens 76 and reticule 77 (the "cross-hairs" element). Reticule 77 may comprise, for example, a glass disc having fine, straight lines scratched thereon at the desired places and filled with black pigment. These lines may include, for example, two spaced vertical lines as shown in Fig. 3 and are used as fiducial marks during observance of the optical ring pattern produced during operation of the conoscope.

The next element of the optical system is analyzer 81 which may comprise a polarizing film mounted between glass plates. Analyzer 81 is mounted in a rotatable carriage and may be rotated, on occasion, by means of handle 82 which is coupled to the carriage by suitable gearing.

Eyepiece 83 is positioned at the end of lens tube 13.

The purpose, in general, of that portion of the optical system which is housed in lens tube 13 is to correct the divergence of the light rays so that the eye may focus them for the retina and to analyze the light rays.

Both sets of lenses, i. e., the set in lens tube 12 and the set in lens tube 13, act to cause convergence of a diverging group of light rays.

It will be assumed that the conoscope is to be used to accurately locate the position of the Z or optic axis of quartz piezoelectric section 43 which, it will be assumed, is a Z-cut section prepared as described above, i. e., by lapping the crystal on one side as nearly as possible perpendicularly to the optic axis (which has been approximately determined in advance) and sawing a section from the crystal the cut being substantially parallel to the lapped side. Section 43 is clamped against glass reference plate 41 by spring clip 42 and tank 11 is filled with a suitable immersion fluid. The reading on dial 44 after the ring pattern has been centered on reticule 77 would be in accordance with the angle between the optic axis of the section and the normal to the surface thereof.

Quartz, as is well known, is a uniaxial crystal, i. e. has a single optic axis, and is birefringent, i. e. is characterized by the power of double refraction.

Now we will assume for purposes of clearly illustrating the features of the present invention, that two conditions exist, these conditions being commonly encountered in the use of the immersion type conoscope for the purpose described. The conditions to be assumed are, first, that the refractive index of the fluid provided in immersion tank 11 does not exactly match the index of refraction of quartz, and, second, that section 43 is not a true Z cut section. As pointed out above, therefore, it would ordinarily be necessary to make two sets of corrections in the readings of dial 44 after the pattern had been centered, i. e., a refraction correction and a ring eccentricity correction. In accordance with the novel features of the present invention, however, one correction is caused, by computations now to be described, to annul the other, thereby resulting in "zero" correction.

Specifically, this is accomplished by utilizing in tank 11 an immersion fluid the refractive index of which differs from that of quartz (1.5462) by a precomputed amount. The proper refractive index of the fluid required to accomplish the desired object may be computed in the following manner.

Referring for the moment to Fig. 2, which is an enlarged side elevational view of a portion of quartz piezoelectric section 43, the direction of the optic axis is indicated by solid line "z"; a normal to the major surfaces of the section is indicated by solid line "W" and the thickness of the section is indicated by dimension t'. (As will appear from the formulae developed later, the method of measurement is applicable to crystals such as that illustrated in Fig. 2 in which the Z axis is directed at a substantial angle away from the normal to the crystal faces.) Now at an angle of α_1 from the optic axis towards the plate thickness direction the phase relation N_1 (light traveling through a uniaxial crystal such as quartz breaks up into two components that travel at different velocities and vibrate in respectively perpendicular planes and N_1 is the phase difference developed between the "fast" waves and the "slow" waves in the distance t') is:

$$N_1=2\pi\frac{.00917t'\sin^2\alpha_1}{\lambda\cos(\delta-\alpha_1)}\text{ radians}$$

where δ is the angle between the optic axis and normal line W, .00917 is the difference between the refractive indices for the ordinary ray and the extraordinary ray for green mercury light (the type isolated and passed by light filter 55 of Fig. 1) traveling at right angles to the optic axis, and λ is the wavelength in vacuum of the green mercury light, while at the angle of α_2 from the optic axis away from the plate thickness direction the phase relation N_2 is:

$$N_2=2\pi\frac{.00917t'\sin^2\alpha_2}{\lambda\cos(\delta+\alpha_2)}\text{ radians}$$

Whence if these are equal we have:

$$\frac{\sin^2\alpha_1}{\cos(\delta-\alpha_1)}=\frac{\sin^2\alpha_2}{\cos(\delta+\alpha_2)}. \qquad (1)$$

The locus of a set of points fulfilling the conditions expressed by Equation 1 is substantially circular, the points corresponding to phase differences of 2π radians and integral multiples giving rise to an interference pattern consisting of a series of dark rings. When the angle δ is finite, that is, when the plate is cut at an angle other than normal to the Z axis, the pattern defined by Equation 1 consists of a set of eccentric rings. If any of these rings be selected and matched to a pair of vertical fiducial lines of reticule 77 (Fig. 1), as indicated in Fig. 3, the center line thereof deviates from the direction of the optic axis by an angle e where

$$e=\frac{\alpha_1-\alpha_2}{2}$$

the values of α_1 and α_2 being appropriate for the selected ring.

If the separation of the reticule lines corresponds to an angle of $2d$ (Fig. 3) we see that

$$d=\frac{\alpha_1+\alpha_2}{2}$$

so that $\alpha_1=d+e$ and $\alpha_2=d-e$.

The reading of dial 44 at the match of selected ring and fiducial lines referred to above will be

$$R=\tfrac{1}{2}(\delta+\alpha_2+\delta-\alpha_1)=\delta-\frac{\alpha_1-\alpha_2}{2}$$

Hence we have

$$\frac{\sin\,(d+e)}{\sin\,(d-e)}=\sqrt{\frac{\cos\,(R-d)}{\cos\,(R+d)}} \qquad (2)$$

Equation 2 can be given the approximate solution:

$$e=1820\tan^2 d\tan R \text{ minutes, or} \qquad (3)$$
$$e=30.3\tan^2 d\tan R \text{ degrees}$$

(It will be observed that the correction e is independent of the thickness dimension t'.)

Considering now, for the moment, the immersion fluid which is provided in tank 11 (Fig. 1), the difference between the refractive index of quartz section 43 and that of the fluid is:

$$H=n_q-n_l$$

(where n_q and n_l are the refractive indices of quartz and of the fluid, respectively).

Now by the law of refraction

$$n_l\sin R=n_q\sin\,(R-\mu)$$

(where R is the angle of incidence and $R-\mu$ is the angle of refraction as light enters the quartz from the fluid).

Whence

$$H=n_q\frac{\sin\mu}{\tan R}-(1-\cos\mu)$$

and if μ is small

$$H=\frac{n_q\sin\mu}{\tan R} \qquad (4)$$

Since for small angles $\sin\mu$ is closely equal to μ, the deviation of a ray emerging from the quartz plate at an angle R is given by:

$$\mu=\frac{H\tan R}{n_q}$$

Comparing this with Equation 3 it will be seen that the deviation varies with the angle of incidence in the same manner as does the eccentricity error. Consequently, the two deviations may be made to neutralize each other for any chosen ring, the correct value for H for this purpose being given by:

$$H=0.530\tan^2 d$$

Taking d equal to 10 degrees this would make $H=.0255$ from which it follows that in order to attain "zero correction" in accordance with the novel features of the present invention we should use in tank 11 (when quartz material such as section 43 is being examined and when $d=10$ degrees), an immersion fluid the refractive index of which is 1.5207, that is, 1.5462 (refractive index of quartz) minus .0255. The computed value for H would be different, of course, for different values of d.

The proper immersion fluid is usually obtained by blending two different fluids one having an index of refraction higher than the desired value and the other having an index lower than the desired value. Among immersion liquids which applicant has found satisfactory for use during examination of quartz is a mixture in proper proportions of dimethyl phthalate and dichlor naphthalene.

The method of the invention is applicable not only in connection with the examination of sections that are only slight departures from true Z sections but is applicable as well when the departure from a true Z section is considerable; it is believed that the method is capable of accurate use even though the section departs at least as much as 60 degrees from a true Z section.

While a specific embodiment of the invention has been selected for disclosure and detailed description, the invention is not, of course, limited in its application to the embodiment disclosed. The embodiment disclosed should be looked upon as illustrative of the invention and not as restrictive thereof.

What is claimed is:

1. In an immersion type conoscope for examining a quartz crystal, an immersion tank, means within said tank for supporting a quartz crystal being examined, means for passing rays of polarized light through said tank, a reticule, an eyepiece for viewing said reticule, a pair of spaced, vertical guide lines on said reticule with which the optical ring pattern obtained during use of the conoscope is aligned, and an immersion liquid in said tank, said liquid having an index of refraction which is less than the refractive index of quartz by an amount equal to $.530\tan^2 d$ where d represents one-half of the angle corresponding to the separation of said vertical guide lines on said reticule.

2. In the procedure of analyzing a birefringent crystal with respect to the location of the optic axis which includes the steps of immersing the crystal in an immersion fluid contained in the tank of an immersion conoscope, passing rays of polarized light through the fluid and the crystal to produce an optical ring pattern, viewing the pattern through an eyepiece and moving the crystal to center the selected ring of the optical ring pattern with respect to the optical axis of the conoscope, the method of correcting for eccentricity of the optical ring pattern produced which comprises employing an immersion fluid in the conoscope having a refractive index which differs in magnitude from that of the crystal material by an amount such that the deviation of the central ray of the selected ring of the optical ring pattern due to refraction at the crystal face as the ray enters the immersion fluid is equal in magnitude and opposite in direction to the deviation of said central ray within the crystal from the optic axis of said crystal.

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