Nov. 24, 1959 W. H. CHARBONNET 2,914,389

METHOD FOR GROWING QUARTZ

Filed May 27, 1955

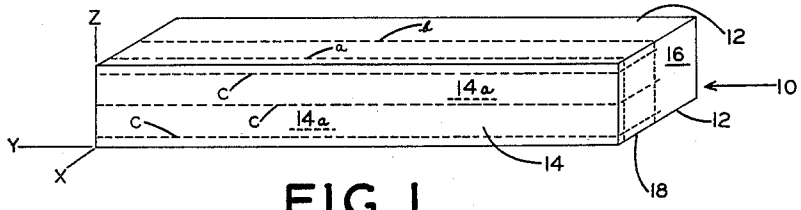


FIG. 1

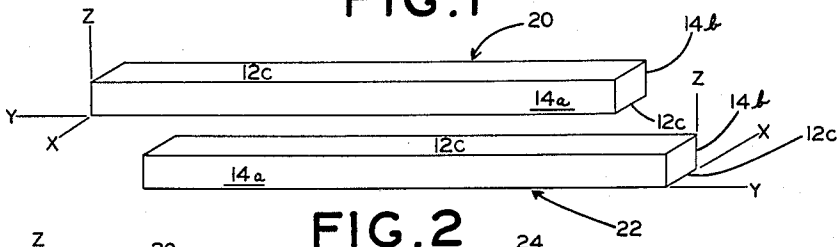


FIG. 2

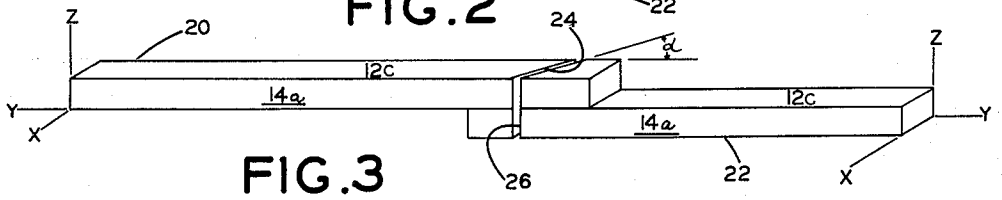


FIG. 3

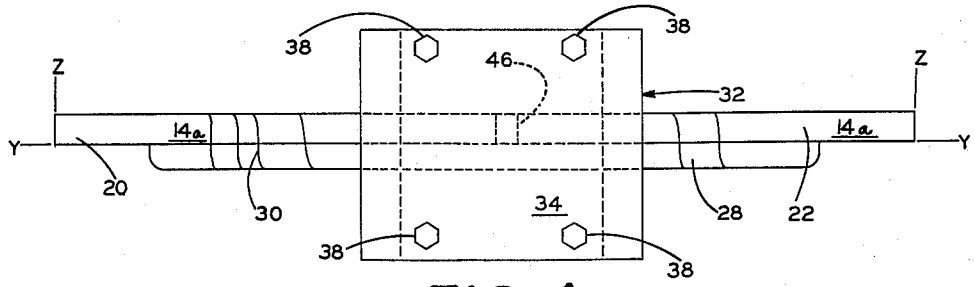


FIG. 4

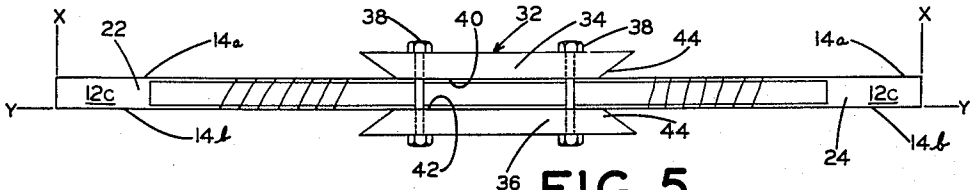


FIG. 5

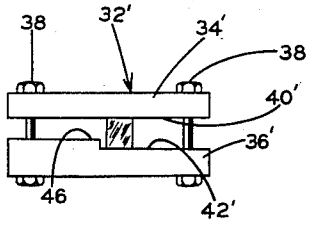


FIG. 7

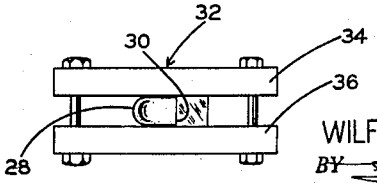


FIG. 6

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United States Patent Office 2,914,389 Patented Nov. 24, 1959

2,914,389

METHOD FOR GROWING QUARTZ

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Application May 27, 1955, Serial No. 511,614

12 Claims. (Cl. 23—301)

This invention relates to the growing of synthetic single crystals of quartz and particularly to methods and apparatus for growing "Y-bar" type crystals and seeds therefor.

In the following specification the "Standards on Piezoelectric Crystals" (1949) of the Institute of Radio Engineers as set forth in the Proceedings of the I.R.E., vol. 37, pp. 1378–1395, are adhered to.

The term "Y-bar" as used herein in conjunction with seeds and crystals is intended to denote seeds or crystals, as the case may be, of the general type disclosed in the copending application of Hans Jaffe and Thaddeus J. Turobinski, Serial No. 459,052, filed September 29, 1954, and assigned to the same assignee as the present invention. Broadly speaking, a Y-bar seed is one which is elongated in the direction of the Y crystal axis and has a width and thickness, i.e., cross-sectional dimensions, much smaller than its length, for example, in the ratio of 1 to 20 or more. A Y-bar crystal is one grown from Y-bar seed and is similar in length to the seed but larger in the other dimensions.

The term "extra-length" or "extended" is used herein to describe Y-bar seeds and crystals having a length in the direction of the Y-crystal axis exceeding that which it has been possible to obtain in electronic grade heretofore either with natural or synthetic quartz crystals.

As set forth in detail in the aforementioned application, quartz crystal plates have for many years been used extensively as frequency-controlling elements in radio frequency oscillators, electrical filters, and the like. In consequence of continuing and growing requirements of the electronics industry for such plates much research and development work has been performed in an effort to evolve methods of and apparatus for synthesizing large single crystals of quartz from which such plates may be fabricated.

Among the more important recent advances in the field of synthesizing quartz crystals was the discovery and development of the Y-bar seed disclosed in the aforementioned application. The length of the Y-bar seed (within the limits imposed by availability as hereinafter explained) and the period of crystal growth are so selected that the resulting Y-bar crystal is characterized by a unique and highly advantageous configuration in which the primary prism faces, which retard growth and render large sections of quartz crystals unusable for cutting plates, are developed only to a moderate extent during the growing period. Consequently, Y-bar crystals properly grown according to the disclosure of said application are elongated in the direction of the Y axis and possess an intermediate portion of substantially rectangular cross-section in the plane of the X and Z crystal axes which portion extends for about 4 inches of the customary 6 inch length of such crystals. Thus, the intermediate portion of the Y-bar crystal constitutes a regularly shaped block or rectangular parallelepiped of quartz about 4 inches long, practically all of which is dimensionally and

geometrically suitable for crystal plate blanks; for example, the entire block may be cut along spaced parallel planes disposed at an angle of about 35° 15′ to the Z crystal axis to obtain the extensively used AT plates.

While the Y-bar seed and the crystals grown therefrom are significant improvements over previously known seed and crystal shapes as regards the proportion of usable quartz in a crystal, the ratio of grown crystal to seed weight, and the number of crystal plate blanks that can be cut from a single crystal, there is still room for considerable improvement in the way of increased yields and decreased production costs. The length of Y-bar seed known and used up to the time of the present invention, extending as it does transversely to the long or Z direction of growth of the whole single quartz crystal, is limited to the relatively small dimension of the single crystal in the Y direction. Since natural quartz crystals of electronic grade having a Y-axis dimension of 6 inches or more are rare, they are correspondingly expensive, i.e., costing hundreds or thousands of dollars for a single good specimen. Natural crystals of electronic quality having a Y-axis dimension much over 8 inches are hardly obtainable at any price. The foregoing limit concomitantly has limited the length of Y-bar crystals to about 6 inches. In such crystals the usable intermediate portion 4 inches long constitutes about 67% of the length of the crystal. The ends of the crystal, constituting the remainder, carry and are rendered unsatisfactory for plates by the characteristic rhombohedral or prism faces formed thereon during growth of the crystal and, consequently, much of this must be trimmed as scrap.

In cutting oscillator plate blanks an extremely high degree of precision is required. Consequently, each individual crystal must be mounted, trimmed, the cutting tool adjusted, a trial plate cut and subjected to X-ray examination to determine the accuracy of the cut, and correcting adjustments made to the cutting apparatus before cutting the remaining crystal into plates. It will be immediately evident to those conversant with the art that an inordinate amount of time is spent in painstaking set-up procedures preparatory to cutting up a block of material only 4 inches long and yielding, perhaps 100 plates. The entire procedure must be repeated for each crystal.

Another handicap heretofore characteristic of production of synthetic quartz crystals is the fact that each seed must be individually loaded into a seed holder for placement in an autoclave which subjects it to the proper chemical and physical environment for growth, for example, as described in United States Letters Patent No. 2,675,303 granted to Andrew A. Sobek and Danforth R. Hale and assigned to the same assignee as the present invention. Inasmuch as quantity production considerations dictate large autoclaves, efficient operation thereof frequently requires the loading of 200 or more 6 to 8 inch Y-bar seeds into suitable holders for a single run, an operation which involves a considerable amount of expensive labor.

An effective solution to the foregoing problems resides in the production of longer Y-bar crystals, which entails the use of longer Y-bar seeds than can be cut from natural quartz crystals which it has been possible to obtain or any synthetic crystals which it has been possible to grow up to the present time. In a copending application of Thaddeus J. Turobinski, Serial No. 511,667, filed on even date herewith and assigned to the same assignee as the present invention, an effective means for growing extra-length quartz Y-bar crystals is disclosed and claimed. This involves the splicing of conventional Y-bar seeds to produce extra-length seed bars which procedure, for best results, requires precise alignment, in two directions, of the atomic planes of the crystal bodies to be

joined. Inasmuch as, in commercial practice, crystal plates are cut to within an accuracy of two minutes of arc for frequency control applications, the alignment of the atomic planes in splicing Y-bar crystal bodies should be at least as accurate, and more so for a perfect composite crystal. A further requirement for effective splicing of Y-bars is that they be cut from optically similar crystals, that is, that they be of the same handedness.

The present invention, in its broadest aspects, contemplates a method of Y-bar seed bodies which comprises dividing a Y-bar crystal slab longitudinally into at least two Y-bar seed bodies having at least two pairs of planar, parallel major longitudinal surfaces, disposing the seed bodies in end-to-end relation with their Y-axes collinear, and aligning their atomic planes by alignment of their major longitudinal surfaces. The seed bodies, so disposed and aligned are subjected to a chemical and physical environment conducive to crystal growth. The invention also contemplates a method for providing complementary planar surfaces of optimum growth characteristics on the ends of the seed bodies to be joined and apparatus for clamping the ends of the seed bodies to be joined so that they are completely immobilized and the atomic planes precisely aligned during the growing process and unwanted dissolution of crystal material in the vicinity of the joint is effectively precluded.

With the foregoing in view, it is the general object of the present invention to provide novel means and methods for growing extra-length Y-bar seeds and crystals.

It is another important object of the invention to provide novel methods for cutting and aligning Y-bar seed bodies preparatory to splicing them which insures optimum conditions of alignment of the atomic planes of the seed bodies.

Still another object of the invention resides in the provision of novel methods and apparatus for aligning, splinting and clamping Y-bar crystal seed bodies preparatory to and during the period of crystal growth.

These and ancillary objects of the inventions and the manner of their accomplishment will be readily apparent to those conversant with the art from a reading of the following description of exemplary embodiments thereof in conjunction with the subjoined claims and annexed drawings wherein like reference characters designate like parts throughout the several views and in which

Figure 1 is a perspective elevational view of a slab of quartz crystal prior to preparation according to the present invention;

Figure 2 is a perspective elevational view of a pair of Y-bar seed bodies cut from the quartz slab shown in Figure 1 in accordance with the present invention;

Figure 3 is a perspective elevational view of the seed bodies shown in Figure 2 subsequent to an additional step in the novel method disclosed herein;

Figure 4 is a plan view of the Y-bar seed bodies shown in Figures 2 and 3 subsequent to still another step of the novel method and showing apparatus for aligning the atomic planes of and immobilizing the seed bodies;

Figure 5 is a side elevational view of the structure shown in Figure 4;

Figure 6 is an end elevation of the structure shown in Figures 4 and 5.

Figure 7 is a view similar to Figure 6 but illustrating a modified form of apparatus of the invention.

Referring to the drawings, Figure 1 shows an elongated flat slab **10** of quartz crystal having its Y crystal axis, so designated in the drawing, running in a generally longitudinal direction. The shape of slab **10**, preferably, approximates a rectangular parallelepiped which has been illustrated so oriented relative to the crystal axes X, Y and Z that the upper and lower surfaces **12** of the slab are approximately perpendicular to the Z axis, the side surfaces 14 (one shown) are roughly perpendicular to an X axis and the end surfaces **16** (one shown) are generally perpendicular to the Y axis. This orientation of the slab about its Y axis is preferred but it is to be understood this may be varied and that, in addition, the position of the X and Z axes has been selected arbitrarily for purposes of example only and may be reversed one for the other in the practice of the invention as hereinafter described.

In a practical application of the invention, the slab **10** would ordinarily be approximately six to eight inches in length, i.e., along the Y crystal axis, and its cross-sectional dimensions would be great enough to permit cutting of at least two Y-bar seed bodies therefrom, as hereinafter described, with an allowance for trim. The seed bodies to be cut from slab **10** according to the present invention are preferably ½″ x ⅝″ in cross section although any reasonable dimensions can be used.

The first step in the novel method contemplated by the present invention for splicing Y-bar seeds involves the division of the crystal slab **10** longitudinally in the direction of its Y crystal axis into at least two substantially identical Y-bar seed bodies having at least two pairs of planar, parallel, major longitudinal surfaces. Preferably this would be accomplished by mounting slab **10** in a suitable cutting apparatus, for example, a gang saw (not shown) having a pair of spaced parallel cutting blades. By means of such apparatus, slab **10** is cut lengthwise in parallel planes indicated by dotted lines *a* and *b*, Figure 1, substantially perpendicular to the upper surface **12**, the cut in plane *b* severing a block **18** from the original slab which block has planar major longitudinal surfaces **14***a* (Figure 2) exactly parallel to planar major longitudinal surfaces **14***b* by virtue of the fact that they are simultaneously produced by parallel saw blades. Block **18** is then remounted in a gang saw having three equally spaced parallel blades and cut longitudinally substantially perpendicular to planes *a* and *b*, as along planes indicated by dotted lines *c*, the center saw blade dividing the block into two substantially identical seed bodies **20** and **22** (Figure 2), while the side blades simultaneously trim the outer side surfaces of the respective bodies thus producing pairs of parallel major longitudinal surfaces **12***c* on each seed body. From the foregoing it will be understood that each of the seed bodies possesses two pairs of parallel major longitudinal surfaces, the parallelism of which is assured by reason of their having been cut simultaneously by parallel cutters. Preferably, as in the present example, the surfaces **14***a* and **14***b* of seed bodies **20** and **22** are perpendicular to the X crystal axis and accordingly may be termed X surfaces. Inasmuch as X is a polar axis in quartz and it has been observed that X^+ and X^- surfaces have dissimilar growth rates, a distinction is made in the reference characters applied thereto, surfaces **14***a* being arbitrarily taken as X^+ surfaces and **14***b* as X^- surfaces. Surfaces **12***c*, preferably perpendicular to the Z crystal axis, are in like manner known as Z surfaces; however, since the Z axis is non-ploar and the surfaces have the same growth rate, no distinction is made among the various Z surfaces. While these major longitudinal surfaces are preferably X and Z surfaces, it is to be understood that this need not be the case, i.e., these surfaces need not be perpendicular to the respective X and Z crystal axes. Furthermore, while the seed bodies illustrated are rectangular in cross-section, this likewise is not mandatory; it is only necessary that each seed body have at least two pairs of parallel planar surfaces matching corresponding surfaces of the same orientation in regard to the crystallographic axes on the other seed body or bodies.

After cutting seed bodies **20** and **22**, it is important that their original relative orientation about respective crystal axes be preserved or at least that they be suitably marked for easy and positive identification, particularly of the X^+ and X^- surfaces, once they are removed from the cutting machine. The next step of the novel method is the provision of complementary planar end surfaces on the seed body ends which are to be spliced. This is accomplished

conveniently by relative axial displacement or translation of the seed bodies as they appear in Figure 2, without change in the relative orientation about their Y axes, so that the seed bodies are disposed with opposite ends overlapping each other by a predetermined fraction of their length, substantially as shown in Figure 3.

With the seed bodies disposed in this condition and the adjacent side surfaces (which in this case are Z surfaces **12***c*) of the overlapping ends in surface contact and clamped together, they are remounted in a suitable cutting machine and the overlapped ends of seed bodies cut through in a plane disposed at an acute angle "α," to the Y axis and preferably perpendicular to surfaces **12***c* of the seed bodies, substantially as shown in Figure 3. The angle at which the seed bodies are cut is important to the extent that there are certain factors militating against certain angles and making others more desirable as will now be pointed out. An angle "α" of 30° is undesirable because this is the angle of a natural *m* face of a quartz crystal and as well known in the art growth on *m* faces is extremely slow. It would not, therefore, be conducive to joining together of new growth if the seed bodies were spliced along *m* faces. For the same reason, angle α should not be 90° because this also would produce *m* faces on the ends of the seed bodies to be joined. It has been found in practice that an angle "α" of approximately 60° which is midway between the angles of natural *m* faces is very satisfactory because the well-known tendency of growing quartz crystals to fill out their natural *m* faces results, at this angle, in a maximum growth of the seed body ends toward each other. What has been said above concerning the angles of natural faces applies when the plane of the cut is perpendicular to the Z surfaces **12***c* of the seed bodies. When this plane is not perpendicular, care should be taken to avoid parallelism with other natural faces of the quartz crystal.

At this stage of the process seed bodies **20** and **22** possess a pair of oppositely disposed complementary planar end surfaces **24** and **26**. Due to the tendency of these ends to fill out to an "*m*" face, extreme accuracy is not too important in cutting these end surfaces; the method outlined above serves primarily to produce complementary surfaces which have the desired growth characteristics and also are so related to the side surfaces of the seed bodies that general orientation and alignment of the atomic planes of the bodies is accomplished when these end surfaces are placed in confronting relation.

The seed bodies, prepared as described above, are then disposed in end to end relation with the complementary end surfaces mated and in close proximity and the respective longitudinal surfaces aligned in common planes. Substantially perfect alignment of the seed bodies in the Z plane is completed by means of a splint bar **28** of steel or other suitable material having at least one accurate planar longitudinal surface **30** (Figure 6). Bar **28** is preferably of a length only slightly shorter than the combined length of the seed bodies and, in use, has its planar surface **30** disposed against Z surfaces of the seed bodies. Bar **28** is securely fastened to the seed bodies as by means of several windings of binding wire **30** or the like arranged so as not to obstruct the central portion of the bar. This automatically accomplishes the requisite alignment of the Y-bar seeds in one direction, viz., in the Z plane. As best appears in Figures 5 and 6, the thickness of bar **28** is less than that of seed bodies **20** and **22** so as not to interfere with the installation of a clamping assembly **32** to be presently described, and so as to be easily removable when said clamping assembly is in place.

The function of splint bar **28** is to effect an exact alignment of the seed bodies in the Z plane and temporarily hold them against dislocation while the clamping assembly **32** is installed.

Clamping assembly **32** consists of a pair of spaced parallel plates **34** and **36** of steel or other suitable material and of sufficient thickness to guarantee a high degree of rigidity. In use, these plates are disposed parallel to each other and are maintained in this condition by a plurality of spaced nut and bolt assemblies **38** passing through suitably aligned holes in the respective plates located near the edges of said plates. The inner, opposed faces **40** and **42** of plates **34** and **36** are accurately ground or machined to a plane and are provided with a layer (not shown) of metallic silver. The silver layer may be plated on or a separate sheet of silver foil may be used. The layer, however provided, should be of sufficient thickness to act as a gasket without loss of the effect of the steel plates. The opposite ends of plates **34** and **36** are beveled as at **44** (Figure 5) so as to slope outwardly away from faces **40** and **42**.

After seed bodies **20** and **22** have been secured by means of splint bar **28**, as described above, they are disposed, bar and all between plates **34** and **36** of clamping assembly **32**, as shown in Figures 4 and 5, with the surfaces **14***a* and **14***b* parallel to the plates and the plates overlapping equally on both sides of the joint **46** formed by confronting end surfaces **24** and **26**. Nut and bolt assemblies **38** are tightened up to exert a sufficient amount of pressure on the joint to align the crystals in the X plane and prevent dislocation of the seed bars and loss of the Z plane alignment without fracture of the crystal. Once plates **34** and **36** are in place and secured, the splint **28**, having no further function, is detached and removed. In this connection it is pointed out that the wire **30** or whatever other means may be used to fasten bar **28** to the seed bodies should not be placed so close to the joint as to interfere with the installation of clamping assembly **32**. Also, the wire must be easily removable without disturbing the clamping assembly once it is installed.

With the seed bodies securely clamped as above described they are subjected for a suitable period to conditions conducive to crystal growth; for example, as by placing them in a suitable holder and into an autoclave as described in United States Letters Patent No. 2,675,303. It is to be understood, however, that the present invention is in no way limited to any particular procedure for inducing crystal growth; any operative process presently known or hereinafter discovered will be satisfactory.

Because of its softness, the silver coating on faces **40** and **42** functions as a gasket to seal off the surfaces covered by plates **34** and **36** from the crystal growing solution and thus precludes the possibility of unwanted dissolution in the region of the joint. Dissolution around the joint is undesirable because it results in loosening of the clamping assembly and consequently, in possible loss of alignment of the seed bodies. The silver also serves to prevent breakage of the seed bars due to pressure of the clamping plates and prevents the clamping plates from adhering to the crystal material deposited during the growing process. The sloping ends **44** of plates **34** and **36** facilitate their removal by preventing crystals from growing over these ends. The nut and bolt assemblies **38** are spaced outwardly near the edges of clamping plates **34** and **36** so as to be clear of the region of crystal growth.

After a suitable growth period, for example, 20 to 40 days, the new joined quartz material, deposited on the fast growing Z surfaces will have grown to a sufficient thickness for cutting off elongated seeds of approximately twice the usual length, i.e., of the order of 12 inches long.

The procedure described above may be carried out repetitively and/or more than two seed bodies spliced initially to obtain Y-bar seed material and, concomitantly, Y-bar crystals of any desired length. The present description has dealt with the joining of two seed bodies merely for convenience of illustration and description; it will be understood that any reasonable number of seed bodies can be spliced together in the manner described.

A modified form of clamping assembly according to the present invention is shown in Figure 7, designated generally by reference character 32'.

Clamping assembly 32' is in all respects identical in structure and function to its counterpart shown in Figures 4, 5, and 6 except that at least one of the inner, silver-coated faces 40' and 42' of its clamping plates 34' and 36' is provided with an aligning shoulder 46 against which Z surfaces 12c on one side of the seed bodies to be spliced are butted prior to tightening nut and bolt assemblies 38. This shoulder aligns the seed bodies in one direction and therefore alleviates the need for splint bar 28. If aligning shoulders are provided on both plates, it is necessary that they be aligned relative to each other and therefore, greater accuracy and close tolerances are required in the nut and bolt assemblies 38 which affect alignment of plates 34' and 36'.

From the foregoing description it will be evident to those conversant with the art that the present invention fulfills its objects, greatly simplifying the procedure for splicing quartz Y-bars and enhancing the quality of the joint.

While there have been described what at present are believed to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is aimed, therefore, to cover in the appended claims all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A method of growing quartz Y-bar seed bodies comprising: dividing a quartz Y-bar slab into at least two seed bodies each having at least two pairs of opposed parallel major longitudinal surfaces; disposing said seed bodies in end-to-end relation with their Y-axes collinearly disposed and adjacent ends in close proximity; aligning the atomic planes of said seed bodies by alignment of said major longitudinal surfaces in common planes; and subjecting said seed bodies, so disposed and aligned, to conditions conducive to crystal growth.

2. A method of growing quartz Y-bar seed bodies comprising: cutting a quartz Y-bar slab longitudinally in the Y direction so as to provide said slab with a pair of parallel, planar, major longitudinal surfaces; dividing said slab into a plurality of Y-bar seed bodies by simultaneously making a plurality of cuts in parallel planes, intersecting the planes of said major longitudinal surfaces, along the entire length of said slab so as to divide it into a plurality of seed bodies each having first and second pairs of parallel planar major longitudinal surfaces; disposing at least two of said seed bodies in end-to-end relation with their Y-axes collinear; aligning the respective atomic planes of said seed bodies by alignment of respective ones of said first and second pairs of major longitudinal surfaces; subjecting said seed bodies so disposed and aligned to a chemical and physical environment conducive to crystal growth until there has been a substantial accretion of new crystal growth thereon; and cutting Y-bar seeds, longer than either of said seed bodies individually, from said new crystal growth.

3. The method defined in claim 2 wherein said first and second major longitudinal surfaces are parallel to the Y crystal axis of said Y-bar slab.

4. The method defined in claim 2 wherein said pairs of major longitudinal surfaces are respectively X and Z cut surfaces.

5. A method of growing quartz Y-bar seed bodies comprising: simultaneously making a pair of cuts in parallel planes in the direction of the Y crystal axis and along the entire length of a quartz Y-bar slab so as to sever a block of quartz having a pair of parallel, planar, major longitudinal surfaces; making a plurality of cuts, simultaneously, in parallel planes and intersecting the planes of said major longitudinal surfaces, along the entire length of said block so as to divide it into a plurality of seed bodies each having first and second pairs of parallel planar major longitudinal surfaces; disposing at least two of said seed bodies in end-to-end relation with their Y-axes collinear; aligning the respective atomic planes of said seed bodies by alignment of respective ones of said first and second pairs of major longitudinal surfaces; fixedly maintaining said seed bodies so disposed and aligned while subjecting them to a chemical and physical environment conducive to crystal growth until there has been a substantial accretion of new crystal growth thereon; and cutting extended length Y-bar seeds from said new crystal growth.

6. A method of growing quartz Y-bar seed bodies comprising: simultaneously making a pair of cuts in parallel planes in the direction of the Y crystal axis along the entire length of a quartz Y-bar slab so as to sever a block of quartz having a pair of parallel, planar, major longitudinal surfaces; making a plurality of cuts, simultaneously, in parallel planes and intersecting the planes of said major longitudinal surfaces, along the entire length of said block so as to divide it into a plurality of seed bodies each having first and second pairs of parallel planar major longitudinal surfaces; disposing said seed bodies with their respective Y axes parallel, with the same relative orientation about said Y axes as in said block, and with opposite ends of said seed bodies overlapping each other by a predetermined fraction of the length of said bodies; simultaneously cutting through the overlapped ends of said seed bodies in a plane extending at an acute angle to said Y axes whereby complementary planar end surfaces are provided on said ends of said seed bodies; disposing said seed bodies in end-to-end relation with said complementary end surfaces in confronting relation and with their Y-axes collinear; aligning the respective atomic planes of said seed bodies by alignment of respective ones of said first and second pairs of major longitudinal surfaces; and fixedly maintaining said seed bodies so disposed and aligned while subjecting them to a chemical and physical environment conducive to crystal growth.

7. The method of growing quartz Y-bar seed bodies defined in claim 6 wherein said major longitudinal surfaces lie in X and Z planes and said angle is such that the plane of said end surfaces is not parallel to any natural quartz crystal face.

8. The method of growing quartz Y-bar seed bodies defined in claim 7 wherein said acute angle is approximately 60° and the plane of said end surfaces is perpendicular to one pair of said major longitudinal surfaces.

9. A method of growing quartz Y-bar seed bodies comprising: simultaneously making a pair of cuts in parallel planes in the direction of the Y crystal axis and along the entire length of a quartz Y-bar slab so as to sever a block of quartz having a pair of parallel, planar, major longitudinal surfaces; making a plurality of cuts, simultaneously, in parallel planes and intersecting the planes of said major longitudinal surfaces, along the entire length of said block so as to divide it into a plurality of seed bodies each having first and second pairs of parallel planar major longitudinal surfaces; disposing at least two of said seed bodies in end-to-end relation with their Y-axes collinear; aligning the corresponding atomic planes of said seed bodies in one direction by alignment of one major longitudinal surface of one of said seed bodies with the corresponding major longitudinal surface of another of said seed bodies; aligning the corresponding atomic planes of said seed bodies in a second direction by simultaneously aligning a pair of major longitudinal surfaces on one of said seed bodies, said pair not including said one major longitudinal surface, with corresponding major longitudinal surfaces of a pair of said surfaces on said other said seed body; fixedly maintaining said seed bodies so disposed and aligned while subjecting them to a chemical and physical environment con-

ducive to crystal growth until there has been a substantial accretion of new crystal growth thereon; and cutting extended length Y-bar seeds from said new crystal growth.

10. The method of growing quartz Y-bar seed bodies defined in claim 7 wherein said acute angle is approximately 60° and the plane of said end surfaces is perpendicular to the major longitudinal surfaces lying in the plane.

11. A method of growing synthetic single crystals of quartz comprising: disposing a plurality of Y-bar seed bodies of the same handedness in end-to-end abutting relation with their Y-crystal axes collinear and corresponding major longitudinal faces in common planes; and maintaining the abutting ends of said seed bodies so disposed against relative motion while exposing said seed bodies to conditions conductive to crystal growth until the abutting ends thereof grow together and integrate said seed bodies.

12. A method of joining quartz crystal Y-bar seed bodies comprising: disposing the seed bodies to be joined in end-to-end abutment with their Y crystal axes collinear and corresponding major longitudinal surfaces aligned; securing said seed bodies together in such disposition so as to preclude relative movement thereof; and then exposing said seed bodies while so secured to a chemical and physical environment conducive to crystal growth until there has been a substantial accretion of new crystal growth on said seed bodies integrating the ends thereof.

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