QuartzCom
the communications company

From natural quartz to precision time keeping

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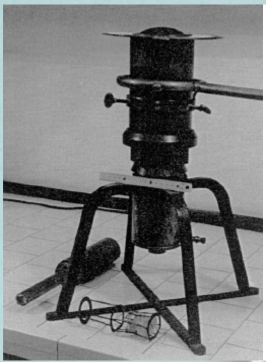
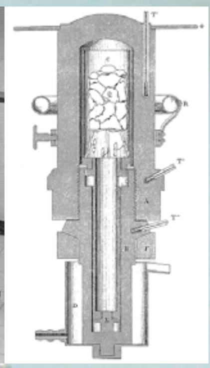
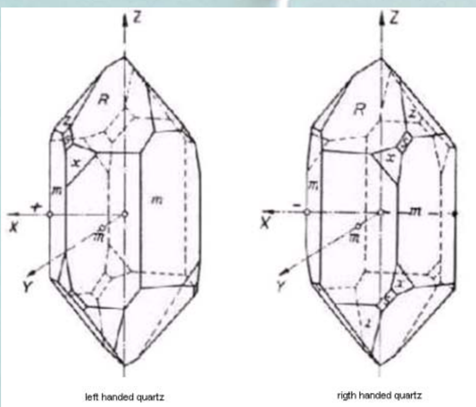
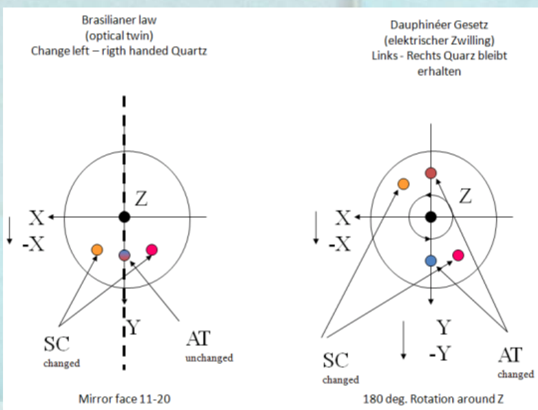
The Piezoelectric effect was described by Curie brothers in 1880. This was the fundamental knowledge needed to start a new age of time measurement and frequency control.



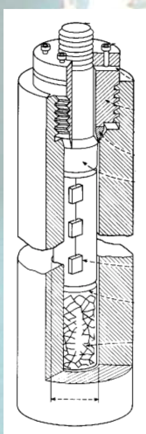


Natural quartz was used as raw material up to the 1960s for the production of quartz crystals. But Giorgio Spezia discovered already in 1900 at the University of Turin in Italy the hydrothermal growing of quartz. His autoclave was small and gas heated. He produced the first usable synthetic quartz stones. The growing of quartz can not be done from the melted material. Quartz has an inversion point at 573°C where the structure changes from low temperature alpha quartz (piezoelectric) to the high temperature beta quartz (no more piezoelectric). On the way from high to low temperatures, the crystal goes back to the alpha quartz structure. But from the alpha quartz exist two crystallographic versions, the right handed and the left handed crystal. This produced twins, means parts of the crystal are left handed and another part is right handed. This gives a totally different behavior of the final product. Such crystals are no more of use to the crystal industry.





To start the growing of a new crystal, a seed of very good material is necessary. The seed quality determines the quality of the grown crystal. The seeds of first generation are mostly produced from natural quartz crystals. So a small number of natural stones is used in the process.



Today's autoclaves have much greater dimensions, up to a height of several 10 meters and one or more meters in diameter. The inner conditions have stayed the same for more than 100 years, pressure of 2000 bars and temperatures of 370°C. Electric heat provide the right temperature and the growing time runs from several weeks up to one year, depending on the size and quality of the final stones. The consumption of electrical power makes the main part of the material price.

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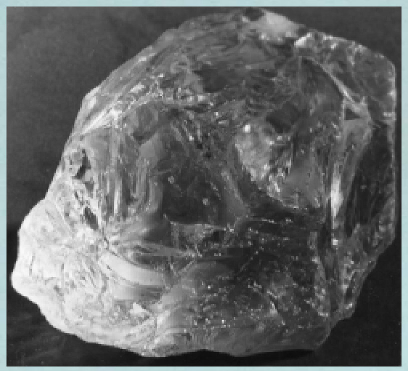
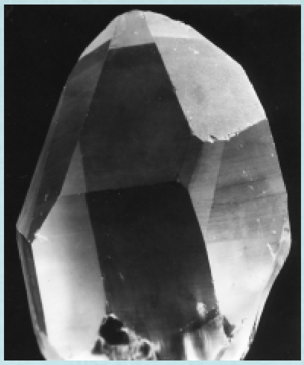
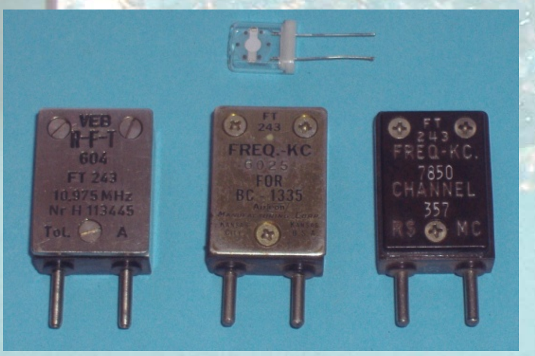
Synthetic quartz crystals have a lot of advantages to the natural stones. Only one type, the right handed quartz, is produced. In this case, all crystallographic directions and the directions for the cuts are totally clear. There are less inclusions, no twins and a guarantee of the Q-value. On a natural crystal, that looks like an egg, the main axes with optical methods have to be found. This is followed by the search for inclusions and afterwards cutting and slicing with X-ray control. A control for twins by etch pictures must be done too. That takes a lot of time. The yield is not reproducible.





This is different for a synthetic crystal. The yield is not more dependent on the material, only from the used processes. Today's high precision crystals in double rotating cuts require very tight tolerances. High precision in all cutting and lapping processes is necessary and raises the demand on the measurement technique too. Angle tolerances in the range of 0,002 deg in two rotation directions and frequencies with accuracy in the ppb range must be measured in the mass production process. This is much more than in the semiconductor industry. For space applications the material has to pass an additional process, the sweeping. This process is an electro diffusion at high temperatures and removes undesirable ions out of the material. It takes several weeks and is a very difficult process. The process is necessary to reduce the influence of high-level radiation on the frequency of the crystal.
The first use of quartz crystals without an oscillator was the so called electro luminescent crystal. This type of crystal was used to control the frequency of the big LC stabilized radio stations. The crystal in a gas filled environment, in the case of resonance, let pass an electrical current. This allows it to start a gas discharge and the gas starts to glow.

Real use of the crystals started with the development of the electronically oscillator in the 1920s. From this point it was possible to stimulate the mechanical vibration with the electrical field. The stability of the mechanical vibration could now be used. The first resonators and most of the today's used resonators are bulk acoustic wave resonators (BAW). Later on another effect was also used, the surface acoustic wave resonators (SAW). On the SAW the surface propagation of special wave forms is used instead of the volume vibration. SAW's are mostly used for filter applications.



An important period for speeding up progress of the crystal development and production was the World War II and the following Cold War. Crystals were used for the communication systems and radar. Later on the Global Positioning System was built. All this needed a very precise time keeping. One of the first mass produced crystals was the so named "Channel crystal" for communication. It had standard dimensions and was produced from different factories for the same use.
Electronic watches with quartz crystals were used first for astronomical purposes. At the beginning one filled a room. With the development of integrated circuits the watch crystals had to fit in a wrist watch. The production of the miniature tuning forks had started.

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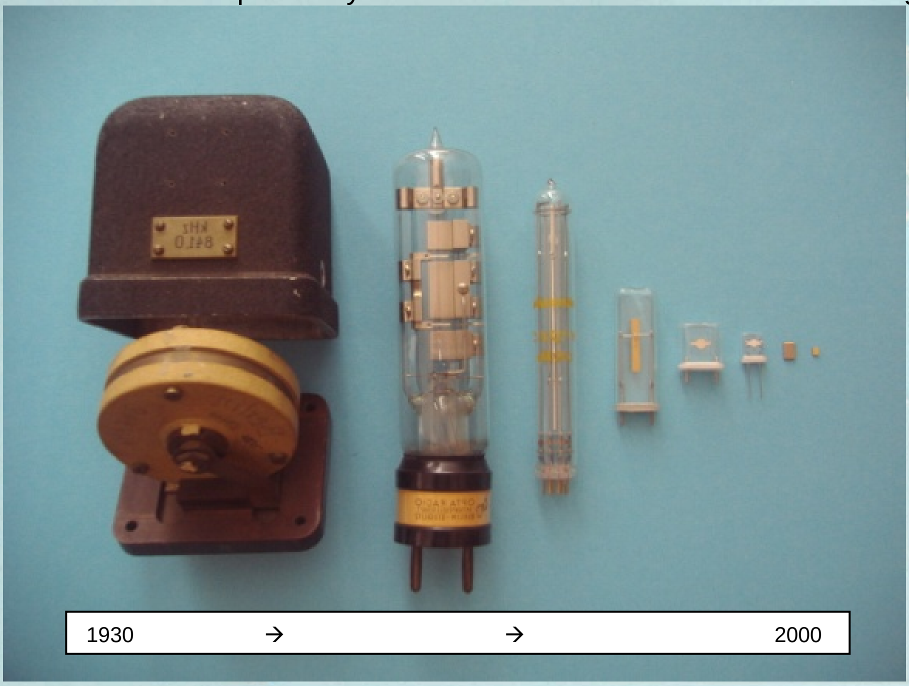
Today's crystal dimensions are standardized and have sizes down to 2x2mm and a height lower than 1mm. Such very small crystals cannot fulfill the same specification as bigger crystals. The application determines the size of the quartz crystal. The BAW resonators cover the range from the low kHz (especially clock crystals) and up to several 100 MHz, and over 1GHz is possible. In the modern world quartz crystals are used in many applications. Starting from the wrist watch over to the mobile phone, computer, TV, washing machine, car, aircraft and up to the satellites we use a minimum of at least one crystal in each application. Today's high precision clocks now use other types of fundamental vibrations. These are no more mechanical vibrations, but are electron transitions on the atomic basis, like rubidium clocks. These clocks have better long time stability. But they don't reach the short time stability (phase noise) of a high precision quartz oscillator.



Combinations of quartz crystals or crystals with multiple electrodes are used as frequency filters with high quality factors. This is mostly used in telecommunication systems for the separation of frequency channels.

Another field of use is the sensor application. Special resonator designs allow the application as a temperature sensor, mass sensor, pressure sensor etc. All these parameters can be linked easily to a frequency change of the vibrator. One very common application is the film thickness sensor in vacuum evaporation systems. Using the effect of frequency change by apply mass, a very simple film thickness measurement is possible. Depending on the fundamental frequency of the crystal vibrator, the mass sensitivity can reach values in the order of atomic layers.

Quartz crystals come our way everywhere in the today's world, but we do not notice them. Only if one of them fails, our mobile phone, washing machine, car won't work. Without quartz crystals all communication in the world would stop. Take a look at this small element with its mechanical accuracies down to the atomic layer and understand for yourself how much work, technology and accuracies is necessary to produce one of these crystals.

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