Discovery of the Piezoelectric Phenomenon: Curie and Langevin

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In 1880, the brothers Pierre and Jacques Curie predicted and demonstrated piezoelectricity. They showed that crystals of tourmaline, quartz, cane sugar, and Rochelle salt generate electrical polarization from mechanical stress; quartz and Rochelle salt exhibited the most piezoelectricity. Twenty natural crystal classes exhibit direct piezoelectricity. Converse piezoelectricity was mathematically deduced from fundamental thermodynamic principles by Lippmann in 1881. The Curies immediately confirmed the "converse effect" and proved the complete reversity of electroelastomechanical deformations in piezoelectric crystals: development of charge on a crystal is proportional to an applied mechanical stress. The converse effect: the geometric strain of a crystal is proportional to an applied voltage.

The major contributions of Pierre Curie are discovery of piezoelectricity, invention of the piezoelectric quartz, formulation of the principle of symmetry, invention of the Curie scale, establishing Curie's law, and establishing the theoretical relationship between crystallography and physics. To assist in his experiments, Curie constructed several delicate pieces of apparatus, such as balances, electrometers, and piezoelectric crystals. Quartz piezoelectric transducers consist of thin slabs or plates cut in a precise orientation to the crystal axes depending on the application.

Paul Langevin was born in Paris on January 23, 1872. He had been supervised by Pierre Curie during his laboratory classes at the ESPCI school (Ecole Supérieure Physique Chimie Industrielles) in Paris (1898–1902). Later, he became Professor of Physics at the College de France and director of the ESPCI and was elected to the Academy of Sciences in 1934. A contemporary of Marie Curie, Albert Einstein, and Hendrik Lorenz, he was noted for his work on the molecular structure of gas and his theory of magnetism and was very active in spreading relativity theory in France. During World War I, he was inventor of the underwater sonar for submarine detection, with very important work on piezoelectricity and on piezoceramics. He created the first quartz sandwich transducer in 1915. The experiment has a watch in which the quartz dilatation is proportional to the applied tension:

$$A = \&U$$

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where A = centimetric dilatation, U = potential difference in volts, and & = $2.16 \cdot 10^{-10}$.

If U corresponds to 10 000 volts, A will be 0.02 μm. This piezoelectric phenomenon is thus very small and it would be necessary to apply very high electric tension to have sufficient ultrasonic power. If the quartz is covered with two steel blades (Langevin), all the unit has to vibrate only one block. There will be a quartz thickness reduction because it is the triplet thickness, which must be equal to the half-length wave. Moreover, the triplet amplification will be multiplied by a factor of 25 and the necessary tension is reduced 30 fold. The quartz sandwich transducer is thus the ideal electroacoustic transformer. This transducer has been upgraded by the use of mosaic of small identical quartzs (easier to obtain), then with piezoelectric ceramics transmitters (barium titanate) presenting an piezoelectric coefficient 300 times superior to quartz. During reception, the Langevin triplet behaves like a radio antenna and the ultrasonic wave will cause a difference in potential appearance. It should be noted that during the reception it would be possible to detect ultrasound whose amplitude is a million times smaller than at the emission. By calculating the exact crystal frequency resonance, by using harmonics, and new ceramics, great progress could be carried out.

The history of piezoelectricity could have been somewhat different if Pierre Curie had not died accidentally early in April 1906 (after his Nobel Prize award in 1903). His wife, Marie Curie, continued her work on radioactivity and the discovery of polonium and radium. But the year 1911 must have been for her a terrible year (in spite of the fact she was awarded the Nobel Prize in Chemistry) because she was rejected by the Academy of Sciences; also, she was involved in the "Langevin affair," a love triangular affair with Mrs. Langevin.

> "I believe that there is no connection between my scientific work and the facts of private life . . . I cannot accept the idea in principle that the appreciation of the value of scientific work should be influenced by libel and slander concerning private life." (Marie Curie, 1911)

The list of applications of piezoelectric instrumentation continues to grow and now includes ultrasound in medicine, phonograph pickups, air transducer microphone remote controls, underwater transducers and sonars, aerospace, ballistics, biomechanics, engine testing, engineering, and industrial and factory applications.