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This Week's Citation Classic®

Cochran W. Crystal stability and the theory of ferroelectricity.
Advan. Phys. 9:387-423, 1960.
[Crystallographic Laboratory, Cavendish Laboratory, Cambridge, England]

The phenomenon of ferroelectricity was discussed in terms of lattice dynamics. It was shown that ferroelectric and antiferroelectric phase transitions can be regarded as resulting from an instability of the crystal for a particular mode of vibration. [The *SCI*® indicates that this paper has been cited in over 715 publications.]

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In 1958-1959 I spent a year's academic leave working with Bertram N. Brockhouse and A.D.B. (Dave) Woods at Atomic Energy of Canada in Chalk River, Ontario. It was an excellent time to be there as Bert was perfecting the technique of neutron spectroscopy as a means of studying the dynamics of atoms in crystals. In our work on the lattice dynamics of alkali halides,[1] we found that some variants of the "shell model" that we were using to interpret the results were unstable against certain modes of vibration. This gave me the idea that the ferroelectric transition, in $BaTiO_3$, for example, could be understood as an instability of the crystal against a transverse optic mode of wave vector zero. Later I found that much the same idea had occurred independently to several other people. I have traced its history in a conference paper,[2] in which I also speculate on why earlier suggestions had very little impact. My own contribution was not exactly received with acclamation in 1959, when a short note to *Physical Review Letters*[3] was initially recommended for rejection by the referee with the remark: "The theory actually explains nothing...."

Following my return to Cambridge, I organised an experiment on a crystal of $SrTiO_3$, kindly loaned by the National Lead Company—the first of several. Using Bert's equipment at Chalk River, Roger A. Cowley[4] showed experimentally that such a temperature-dependent transverse optic mode occurs in that material. I was at that time Roger's research supervisor. On completion of his PhD, he joined the group at Chalk River and later became my professorial colleague in Edinburgh. Contact and collaboration with Chalk River therefore continued for several years and survived my own retirement from active research. Neutron spectroscopy of condensed matter has become a branch of big science in the intervening years, but of course I am convinced that the pioneering stage was the most interesting one!

The "soft mode" concept—I do not know where this description originated—has been found to apply to a considerably wider range of phase transitions than I originally envisaged,[5] and my paper, together with that of P.W. Anderson,[6] has been cited in many experimental studies.

Of the varied recognitions to which this and related work have led, I particularly value the recent award of the Howard N. Potts Medal of The Franklin Institute.

1. **Woods A D B, Cochran W & Brockhouse B N.** The lattice dynamics of alkali halide crystals. *Phys. Rev.* 119:980-99, 1960. [See also: **Woods A D B.** Citation Classic. *Current Contents/Physical, Chemical & Earth Sciences* 25(16):18, 22 April 1985 and *Current Contents/Engineering, Technology & Applied Sciences* 16(16):18, 22 April 1985.]
2. **Cochran W.** Soft modes, a personal perspective. *Ferroelectrics* 35:3-8, 1981.
3. --------------. Crystal stability and the theory of ferroelectricity. *Phys. Rev. Lett.* 3:412-14, 1959. (Cited 135 times.)
4. **Cowley R A.** Temperature dependence of a transverse optic mode in strontium titanate. *Phys. Rev. Lett.* 9:159-61, 1962. (Cited 90 times.)
5. **Bruce A D & Cowley R A.** Structural phase transitions. *Advan. Phys.* 29:1-322, 1980.
6. **Anderson P W.** Qualitative considerations on the statistics of the phase transition in $BaTiO_3$-type ferroelectrics. (Skanavi G I, ed.) *Fizika dielektrikov.* Moscow: Akademii Nauk SSSR, 1960. p. 290-4. (Cited 195 times.)