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Kittel C. Physical theory of ferromagnetic domains. *Rev. Mod. Phys.* 21:541-83, 1949.
[Bell Telephone Laboratories, Murray Hill, NJ]

Ferromagnetic specimens, except in very small (submicrometer) particle sizes, are not saturated spontaneously as a whole but break up into small saturated regions known as domains. The origin, manifestations, and limitations of the domain concept are treated in this paper. Recent interest has been focused on magnetic recording processes, studies of terrestrial magnetism, and the orientation of magnetotactic bacteria in the magnetic field of the earth. [The *SCI*® indicates that this paper has been cited in over 600 publications since 1955.]

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In the decade of the 1940s physicists everywhere were educated in the principles of ferromagnetism (and learned German besides) from that excellent monograph *Ferromagnetismus*[1] by R. Becker and W. Döring, published in 1939. It was a decade in which many physicists worked in ferromagnetism through the degaussing of ships in wartime; the development of permanent magnet materials; the introduction of the ferrites, magnetic resonance, and the gyrator; and the widespread development of magnetic recording media and processes, as well as the important geophysical discoveries that followed the discovery of the periodic reversal of the magnetic field of the earth.

Becker and Döring was an exciting and thorough book. There was a problem running through all of *Ferromagnetismus*, like the cliché of *Hamlet* without the Prince of Denmark: there was no domain theory, no theory of the origin, size, or shape of domains. Yet the basic problem of the origin of domains had been solved by L. Landau and E. Lifshitz[2] in 1935 in a paper in English in the principal Soviet physics journal. Becker told me later that this journal was not available in the Germany of 1935-1939, yet it held the key to all that happened later. My *Classic* review article in a direct sense was conceived as an annex to the German monograph viewed in the light of the Landau-Lifshitz paper and with account taken of some splendid experimental work accomplished in the late 1940s.

I learned of the Landau-Lifshitz paper in 1945 while at the Massachusetts Institute of Technology, where the physics library had the journal. An obvious extension of the domain viewpoint follows when we ask how small a particle must be in order that it be a "single domain particle," a particle with no domain boundaries. The results of the study[3] were published in 1946 under the title "Theory of the structure of ferromagnetic domains in films and small particles." (L. Néel reached similar conclusions in work published later.)

My 1946 paper was the first published account of the single domain world and explained in one shot a host of experimental results that had been collecting in the journals; in a very formal sense only, it is the published basis for the magnetic recording industry, which is comparable in size with the semiconductor industry. The paper created a fair amount of excitement in what was then the small world of magnetic recording on fine particles. One of the most satisfying applications of the single domain viewpoint was the understanding[4] it brought to the magnetic properties of Alnico V, then the gem of permanent magnet materials. The single domain paper stimulated many beautiful experiments and even educational films, in a great shower of activity that perhaps lasted until the 1960s in this country and is still going on in Japan.

Which brings us back to the review paper: with domain theory well established, verified, and productive, there was an obvious need to complete the story told so well by Becker and Döring. The review was extended in 1956 in collaboration with J.K. Galt,[5] and since then there have been many pertinent specialized monographs in several languages. The field of ferromagnetic domains has split into many subfields. Recently, J. Degauque[6] reviewed the physical origins of energy losses in soft metallic ferromagnetic materials.

1. **Becker R & Döring W.** *Ferromagnetismus* (Ferromagnetism). Berlin, Germany: Springer-Verlag, 1939. 440 p. (Cited 355 times since 1955.)
2. **Landau L & Lifshitz E.** Theory of the dispersion of magnetic permeability in ferromagnetic bodies. *Phys. Z. Sowjetunion* 8:153-69, 1935. (Cited 520 times since 1955.)
3. **Kittel C.** Theory of the structure of ferromagnetic domains in films and small particles. *Phys. Rev.* 70:965-71, 1946. (Cited 245 times since 1955.)
4. **Kittel C, Nesbitt E A & Shockley W.** Letter to editor. (Theory of magnetic properties and nucleation in Alnico V.) *Phys. Rev.* 77:839-40, 1950.
5. **Kittel C & Galt J K.** Ferromagnetic domain theory. *Solid State Phys.* 3:437-564, 1956. (Cited 110 times.)
6. **Degauque J.** Les pertes d'énergie dans les ferromagnétiques métalliques doux: origines physiques (Energy losses in soft metallic ferromagnetic materials: physical origins). *Mem. Etud. Sci. Rev. Metal.* 82:5-23, 1985.

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