This Week's Citation Classic™

Néel L. Propriétés magnétiques des ferrites: ferrimagnétisme et antiferromagnétisme. (Magnetic properties of ferrites: ferrimagnetism and antiferromagnetism.) *Ann. Phys. Paris* **3**:137-98, 1948.
[Faculté des Sciences, Univ. Grenoble, France]

This report introduced and studied a new category of magnetic substances, ferrimagnets, which are added to those already known: the diamagnets, paramagnets, and ferromagnets. Ferrimagnetism plays an important part in industrial applications. [The *SCI*® indicates that this paper has been cited in over 595 publications since 1955, making it the most-cited paper ever published in this journal.]

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"Since 1947, the magnetic properties of spinel ferrites (the general formula Fe_2O_3MO, where M is a bivalent metal) have remained completely unexplained. The article in question, which was accepted with only a bit of reticence by the editorial committee of the *Annales de Physique*, gives a complete and quantitative interpretation of these properties, based on a large number of outside experimental results. It shows that there exists a new category of magnetism: *ferrimagnetism*. In classical ferromagnets, like iron or nickel, the interactions between atomic magnetic moments tend to align themselves parallel to each other in the same sense; that is, at low temperature all these moments become parallel. On the contrary, in ferrimagnets, the magnetic atoms are shared between two distinct A crystalline and B crystalline sub-lattices. At low temperature, the macroscopic spontaneous attraction is equal to the difference of spontaneous attraction of the two sub-lattices.

"*Antiferromagnetism*, of which I predicted the existence as early as 1932,[1,2] before the discovery in 1938[3] of bodies possessing such properties, is a particular case of ferrimagnetism where the two sub-lattices are identical, with equal spontaneous magnetizations, and opposed to all temperatures.

"My work of 1948 predicted the existence of substances of which the spontaneous attraction presents very unusual abnormal thermal variations. All these anomalies were ultimately retrieved experimentally, as, for example, those where the spontaneous magnetization counterbalance, in a sense, is at a certain *compensation* temperature. At this temperature, the spontaneous A magnetizations and B magnetizations are equal and opposed to each other. Lithium-chrome ferrite[4-6] as well as some garnets[7] are examples of this.

"In 1954,[8,9] the theory of ferrimagnetism contributed a great deal to the discovery of a new and very rich family of ferrimagnetic substances: the rare earth garnet ferrites[7] of the form $Fe_5T_3O_{12}$, where T is a rare earth and where a trivalent element can be substituted for Fe. Many samples from this family have found interesting applications, such as yttrium garnets.

"Since 1948, thousands of publications have been written on the subject of ferrimagnetism and one can also say that their magnetic properties are better understood than those of metallic ferromagnets. Considering the great interest in ferrimagnetism for basic physics and the knowledge of the different types of magnetic interactions, the importance and the variety of applications are considerable. Many of these bodies are insulators, and even excellent electrical insulators, such as garnets. They can thus be used in very high frequency methods, such as in radar. These applications are facilitated by the possibility of preparing them in large monocrystals.

"For this discovery, I won the Nobel prize in 1970, as well as other distinctions."

1. **Néel L.** Influence des fluctuations du champ moléculaire sur les propriétés magnétiques des corps. *Ann. Phys. Paris* **18**:5-105, 1932.
2. **Néel L.** Theory of constant paramagnetism. Application to manganese. *CR Acad. Sci. Paris* **203**:304-6, 1936.
3. **Bizette H, Squire C F & Tsaï B.** Transition point of magnetic susceptibility of MnO. *CR Acad. Sci. Paris* **207**:449-50, 1938.
4. **Gorter E W.** Saturation magnetization and crystal chemistry of ferrimagnetic oxides. *Philips Res. Rep.* 9:295-320, 1954. (Cited 250 times since 1955.)
5. ----------------. Saturation magnetization and crystal chemistry of ferrimagnetic oxides. 2. Theory of ferrimagnetism. *Philips Res. Rep.* 9:321-65, 1954. (Cited 100 times since 1955.)
6. ----------------. Saturation magnetization and crystal chemistry of ferrimagnetic oxides. 3. Saturation moment and physical chemistry of ferrimagnetic spinels containing titanium. *Philips Res. Rep.* 9:403-43, 1954. (Cited 135 times since 1955.)
7. **Néel L, Pauthenet R & Dreyfus B.** The rare earth garnets. *Prog. Low Temp. Phys.* 4:344-83, 1964.
8. **Pauthenet R & Blum P.** Thermomagnetic study of gadolinium ferrite. *CR Acad. Sci. Paris* **239**:33-5, 1954.
9. **Néel L.** The interpretation of the magnetic properties of the rare earth ferrites. *CR Acad. Sci. Paris* **239**:8-11, 1954.