Erratum: The Microwave Spark

[Phys. Rev. 73, 496 (1948)]

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In the above article, the last statement in the caption under Fig. 3 should read "Average P_m lowering, 30 percent" instead of "Average P_m, 30 percent."

Microwave Resonance Absorption in Ferromagnetic Semiconductors

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The high resistivity of ferrites suggests that measurements of ferromagnetic resonance absorption in these compounds may be of particular interest. The magnitude of the absorption effect is expected to be large in comparison with that in conducting ferromagnetic materials, because in a ferrite the greater skin depth caused by its higher resistivity permits a relatively large volume of the specimen to participate in the absorption process.

On a thin plane (0.0117 in. thick) specimen of zinc-manganese-ferrite $(ZnO)(MnO)\cdot 2Fe_2O_3$ having a resistivity of 2350 ohm-cm, an initial permeability of 1700 at 1000 cycles, and a saturation magnetization M_s of 200, measurements were made at 23958 megacycles with the specimen fitted across the wave guide. The real and imaginary parts of both the permeability and the dielectric constant were separated as shown in Fig. 1.

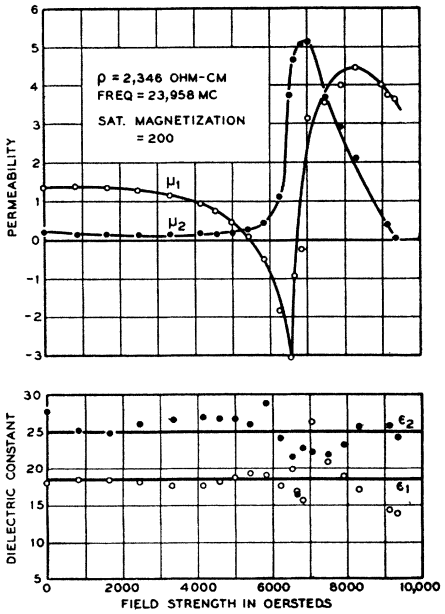

Fig. 1. Variation of real and imaginary parts of permeability and dielectric constant of $(MnO)(ZnO)\cdot 2Fe_2O_3$ as a function of applied external magnetic field (without correction for demagnetization).

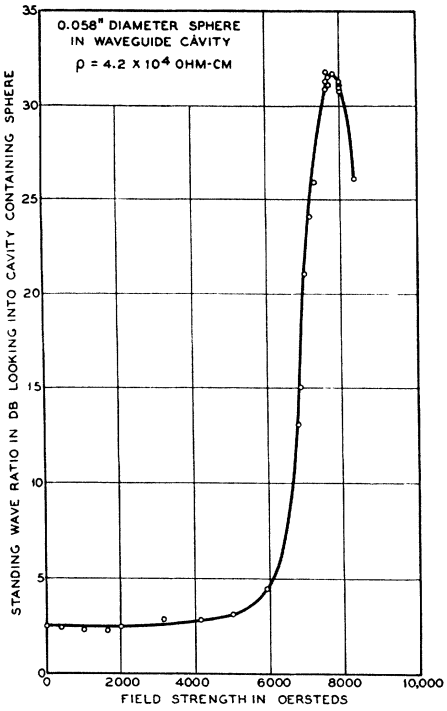

Fig. 2. Standing wave ratio of resonant cavity with $(MnO)(ZnO)\cdot 2Fe_2O_3$ sphere as a function of applied external magnetic field.

The field of an electromagnet was located parallel to the plane of the specimen and parallel to the narrow side of the wave guide. The sample was backed, in turn, by a short and by a quarter wave-length section. The input impedance looking into the specimen was determined as a function of the applied magnetic field for both circuit conditions by means of standing wave measurements. Using these data, and equations developed by W. A. Yager, the curves of Fig. 1 were obtained. The equations have more than one solution; of the possible solutions we selected that one for which $\epsilon=\epsilon_1-j\epsilon_2$ and $\mu=\mu_1-j\mu_2$ had the expected behavior as functions of H. The approximate constancy of ϵ_1 and ϵ_2 as functions of the magnetic field intensity is a check on the accuracy of the separation of the components. The high value of ϵ_2 suggests the possibility of Maxwell-Wagner losses in the sample used. Using $\omega_0=\gamma(BH)^{\frac{1}{2}}$, where $\gamma=ge/2mc$ and H (corrected for demagnetization) is the field strength at which μ_2 is maximum, we find a g value of 2.12. This is in the range of values previously observed for other materials. Yager and Bozorth[1] have reported 2.17 for Supermalloy.

It is interesting to note that using the values plotted in Fig. 1 the phase constant, β (part of the propagation constant) is negative for most of the field strength range in which μ_1 is negative. When β is negative, the direction of phase velocity of a traveling wave is opposite to the direction of attenuation.

With a small sphere (1.47-mm diam.) of a similar ferrite with a higher resistivity (4.2×10^4 ohm cm.) a g value of 2.16 is obtained using $\omega_0=\gamma H$. The sphere was located

at the $\lambda/2$ point in a cavity one wave-length long. Figure 2 shows the standing wave ratio looking into this cavity *vs.* the static field H. The frequency at maximum absorption was 23730 megacycles. The g value 2.16 for the sphere as calculated from the sphere equation $\omega_0=\gamma H$ is fairly consistent with the g value 2.12 for the plane specimen calculated from the plane equation $\omega_0=\gamma(BH)^{\frac{1}{2}}$. These equations were derived by Kittel.[2] The measurements on the sphere may therefore be considered as an approximate confirmation of the theory.

Sincere thanks are due Dr. C. Kittel and Mr. W. A. Yager for valuable suggestions and discussion, and to Mr. F. J. Schnettler who supplied the ferrite samples.

[1] W. A. Yager and R. M. Bozorth, Phys. Rev. **72**, 80 (1947).
[2] C. Kittel, Phys. Rev. **73**, 155 (1948).

Note on Zero-Zero Transitions*

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ZERO-ZERO nuclear transitions have been suggested by Sachs[1] as an explanation of long lived isomers. He computed the energy spectra and transition probabilities for two-electron and two-quantum emissions. Stimulated by preliminary results of experiments by Goldhaber, Muehlhause, and Turkel[2] on the isomeric transition in Ir^{192} (mean life 2.16 min., energy 58 kev), which shows a continuous γ-ray spectrum in addition to conversion electrons, we have computed the γ-ray energy spectrum and lifetimes for zero-zero transitions in which one electron and one quantum are emitted. For comparison, the lifetime for the transition $og\rightarrow og$ (or $ou\rightarrow ou$) is computed by direct emission of an electron. The analogous transition in the case $og\rightarrow ou$ is strictly forbidden.

The calculation is straightforward, and most of the necessary matrix elements are given by Sachs.[1] We consider the transition $og\rightarrow og$ and $og\rightarrow ou$ with a *single* intermediate state of total angular momentum one and parity either the same or different from the ground state. The energy of the intermediate state above the ground state is taken to be either very much less than E or very much

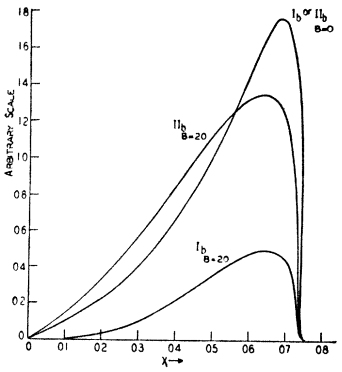

FIG. 1. Gamma-ray energy spectra; $I_b\cdots o_g\rightarrow 1_g\rightarrow o_g$; $II_b\cdots o_u\rightarrow o1_u\rightarrow o_g$.

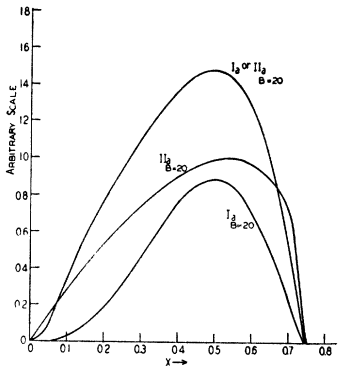

FIG. 2. Gamma-ray energy spectra; $I_a\cdots o_g\rightarrow 1_u\rightarrow o_g$; $II_a\cdots o_u\rightarrow 1_g\rightarrow o_g$.

greater than (~20 times) E where E is the total energy available for the transition, namely, 58 kev. It is to be noted that this energy is insufficient to remove a K electron in Ir and, consequently, we have only L conversion.[2]

It should be emphasized that the absolute values of the lifetimes are to be regarded as merely order of magnitude estimates. The shapes of the γ-ray spectra, on the other hand, should be fairly reliable. From Figs. 1 and 2, we see that one may have a rather peaked distribution which might be confused with a sharp line.

In Table I the lifetimes calculated for the various cases are summarized. The notation and numerical data are as follows: E is the energy of the transition, I is the ionization potential in units of E, x is the γ-ray energy in units of E, β is the energy of the intermediate state above the initial state in units of E, and τ is the mean life. For our lifetime estimates we take $E=58$ kev, and $I=0.25$. (A transition from an initial state with zero angular momentum and even parity to an intermediate state of angular momentum one and odd parity and then a transition from the intermediate to the final state of zero angular momentum and even parity is symbolized by $og\rightarrow 1u\rightarrow og$, etc.

TABLE I.

	Transition	β	(sec.)
Ia	$og\rightarrow 1u\rightarrow og$	~0	5.4×10^{-2}
		~20	1.18×10^{-2}
Ib	$og\rightarrow 1g\rightarrow og$	0	2.40×10^{2}
		20	7.45×10^{5}
IIa	$ou\rightarrow 1g\rightarrow og$	0	3.22×10^{-3}
IIb	$ou\rightarrow 1u\rightarrow og$	20	8.70×10^{-3}
	$og\rightarrow og$	—	4.26×10^{-8}

The experimental evidence at the present time is insufficient to draw any definite conclusions in the case of Ir.

This work is the result of interesting discussions of the Ir problem with Professors M. Goldhaber and R. G. Sachs.

* This work has been carried out under the auspieces of the Atomic Energy Commission. It was completed and submitted for declassification on August 1, 1947.
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[1] R. G. Sachs, Phys. Rev. **57**, 194 (1940).
[2] M. Goldhaber, C. O. Muehlhause, and S. H. Turkel, Phys. Rev. **71**, 372 (1947).