

X Band ESR Cavity for Studies of Paramagnetic Gases*

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A CAVITY for use in an X band, 100 kHz modulation ESR (electron spin resonance) spectrometer was specially constructed to measure atomic nitrogen densities for the determination of its volume recombination coefficient.¹ Such measurements are often made on gas flowing in a quartz flow tube which traverses a conventional cavity.^{2,3} The new cavity afforded a considerable improvement in the accuracy of the measurement of the recombination coefficient for several reasons: (1) There was less interference from surface recombination than in the usual flow tube arrangement; (2) the system was about 5 times more sensitive because the entire cavity was filled with gas and because the loaded Q (about 6000) was approximately 60% greater than with a flow tube arrangement; (3) the atom density could be monitored continuously (in the flow tube, time resolution is achieved by moving the

atom source toward the ESR cavity incrementally), (4) time intervals were measured directly and, hence, more accurately; and (5) the data for an entire decay curve took only about 3 min to accumulate, while it took about 3 h with the flow tube.

The cylindrical TM_{010} mode was chosen for several reasons: (1) The cavity resonant frequency is independent of axial dimension permitting construction of a cavity whose length nearly fills the magnet gap and hence has a large volume to surface ratio; (2) with its axis parallel to the polarizing magnetic field, the microwave magnetic field is azimuthal everywhere and therefore, perpendicular to the polarizing field so that resonance may occur throughout the volume (except on the axis, where the field is zero); and (3) the magnitude of the field rises rapidly from the axis and then varies slowly with radius, precluding the presence of "hot spots" at which saturation of the resonance is likely to occur.

Physical details of the cavity are shown in Fig. 1. The cavity was constructed of quartz tubing with quartz disks fused to the ends and was externally silvered with 11 layers of silver applied by the Brashear chemical process⁴ to a thickness of $8\ \mu$, which is approximately twelve skin depths for the X band radiation, but only one-thirtieth of a skin depth for radiation at the 100 kHz modulation frequency. It has walls approximately 1 mm thick, 24 mm o.d., and an over-all length 57 mm.

At a point on the cylinder wall, midway between the ends, a 6.35 mm diam spot of silver was removed for coupling to the spectrometer. A brass coupler with iris and matching screw fits tightly against the cavity at this point. At a similar point 90° around the wall a short length of 8 mm o.d. quartz tubing was fused on to permit entrance for the sample, and an 11 mm o.d. quartz tube around this extends up to make connection to the gas handling system. The free end of the short inner tube was fitted with a lapped Teflon seat for a Teflon plug which could be used to seal off the cavity from the atom source, which was a

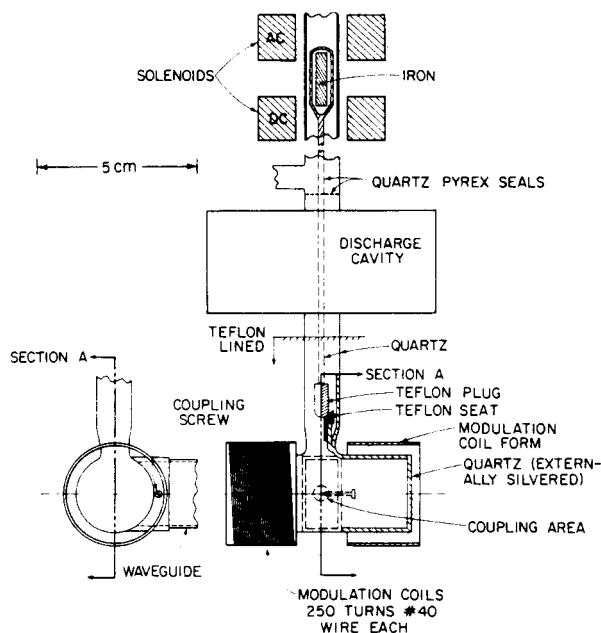


FIG. 1. X band ESR cavity for studies of paramagnetic gases.

discharge operated in the gas connection lead about 7 cm about the cavity. When a constant concentration of atomic nitrogen had diffused into the cavity, the valve was closed, and the decay of the atomic nitrogen was continuously monitored with the ESR spectrometer. The Teflon plug could be raised by activating an ac solenoid whose magnetic field reacted with a Pyrex encapsulated iron slug fastened to the Teflon plug by a quartz rod. The solenoid was located 60 cm above the cavity to prevent the interaction of the magnetic field of the solenoid with that of the ESR magnet. To close the valve, the ac solenoid was deactivated and to achieve a tight seal, the dc solenoid was used to create a downward force on the valve.

The inner surfaces of the cavity were coated with two thin coats of Teflon finish to minimize wall recombination.⁵ The modulation coils each consisted of 250 turns of No. 40 single enameled wire wound on composition forms slipped over each end of the cylindrical cavity as shown in the

drawing. The coils were connected in series and were coupled directly to the ESR modulation output.

The ESR spectrum of O₂ taken with this cavity revealed more than 110 lines between 1850 and 6100 Oe, while only 48 lines are reported in the literature.³ The signal-to-noise ratio was about 5 times better with this cavity than with the flow tube in the standard cavity, where about 48 lines could also be observed; thus, a considerable increase in over-all sensitivity was realized. Excellent results in the measurement of the atomic nitrogen recombination coefficient were obtained.¹

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