TABLE I

EXPERIMENTAL RESULTS FOR ϵ_r OF A STANDARD FUSED SILICA SPECIMEN

First Method	Second Method	Value Assessed by Other Lab[a]
3.81_4 (1 ±1.3 percent)	3.81_6 (1 ±0.3 percent)	3.82_4 (1 ±0.1 percent

[a] Laboratory for Insulation Research, M.I.T.

pears more favorable and in close accordance (0.2 percent) with the value assessed by the laboratory which provided the standard material. The limiting factors here are the tolerance for the sample thickness due to machining, and the uncertainty of the stationary thickness inherent in the measuring method.

VI. CONCLUSIONS

Examining the performances obtained by the methods used in national laboratories [7], we are tempted to conclude that, for the determination of the permittivity of a low-loss material, our second method is practically comparable to the best methods in use. A study is presently in progress to extend the method to the determination of losses.

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Letters

Possible Mechanisms for the Biomolecular Absorption of Microwave Radiation with Functional Implications

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***Abstract*—A theoretical analysis of several possible modes of molecular absorption of microwave radiation suggests that interference with some stereospecific biomolecular processes may result from microwave irradiation.**

INTRODUCTION

A physical model on the molecular level of the absorption of microwave radiation, the structural changes that may result, and the relationship of these changes to biomolecular function are important for both analyzing the existing experimental information and designing new experiments that are likely to be informative. As a first step towards constructing such a model, the modes of molecular excitation in the microwave region and their possible effects on biological processes are considered here, using the insights of theoretical molecular physics.

At normal biological temperatures, the number of background photons in the microwave portion of the spectrum is very small, and in a nonirradiated system the only excitations in this energy range are induced by collision. Microwave irradiation is then unlikely to have any direct functional effect on molecules or parts of large molecules that in normal biological circumstances undergo a large number of collisions. In the interior of large molecules, essentially free from collisions, microwave irradiation can cause excitations that will occur only infrequently in nonirradiated systems [1].

The excitations that can result from the absorption of a microwave photon with an energy of 10^{-3}–10^{-6} eV may be divided into three general categories—excitations of: 1) magnetic and electric nuclei–electron coupling states; 2) molecular free rotational states; and 3) constrained motional states of molecular segments (both rotational and vibrational, although at these energies rotational states are much more likely to be important).

1) Magnetic and electric nuclei–electron coupling states are due to the interaction of unpaired electrons with magnetic nuclei, in the former case, and the interaction of nuclear quadrupole moments with the molecular charge distribution, in the latter case. Excitations of these modes do not cause changes in molecular structure, and if biomolecular functions are affected, the mechanism is obscure.

2) Molecular free rotational states are a function of the mass distribution of the molecule. These excitations leave molecular structure unchanged but increase the rotational kinetic energy of the absorber. A large amount of the microwave radiation incident on a biological system is absorbed in this way because water and other small biomolecules have rotational states in the microwave region of the spectrum. While these excitations are biologically important because the local kinetic energy and then the total kinetic energy of the system is increased by collision, their effect is likely to be a result only of the increase in kinetic energy.

3) Constrained motional states are rotational or vibrational states of part of a molecule that leave covalent molecular structure unchanged. For vibrational motion the states are only in the microwave region when tunneling is important. The ammonia molecule provides the classic example of this type of excitation [2]. The rotational states are much more important in the context of this letter because they are more generally in the microwave region.

Parts of molecules, from the size of OH groups up to a number of amino acids, are often free to rotate, constrained by existing covalent bonds. The relative orientation of these molecular segments to the remainder of the molecule is determined by the weak electrostatic interaction potential between the segment and its environment (generally the remainder of the molecule). Although the relative depths of the minima, heights of the barriers, and distances between minima are highly dependent on the segment we are considering and its chemical environment, the potentials are in general multiwell functions, and Fig. 1 is a characterization of such a potential. Depending on the number of constraints, the potential may be more than one dimensional. Similar potentials have been found for simple molecules and ions in solids [3], [4].

The absorption of a microwave photon by the molecular segment would increase its rotational energy. This increase in energy may have two effects that are significant. The segment may now be in a state that is localized in more than one potential well, like states C and D, and reemission of a photon may result in its rotation being localized in a well different from the initial well. Or the segment may be excited to a state like B, still confined to the same single potential

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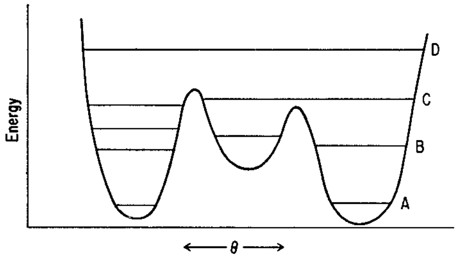

Fig. 1.

well, but with enough energy to greatly increase the possibility of tunneling to another well. This type of rotational tunneling has been demonstrated in a number of different circumstances for ionic defects in crystals [5]. Both of these effects lead to the same type of structural changes; covalent molecular structure remains unchanged, but the relative position of one segment of the molecule with respect to the remainder of the molecule is altered. Furthermore, in the interior of large molecules, the infrequency of collisions will increase the probability of multiple excitations and resultant structural changes.

There are many biological processes that depend on steric structure. The molecular absorption, with the resulting change in noncovalent chemical structure outlined above, provides a model for the direct interference of microwave radiation with biomolecular function, where the internal three-dimensional structure of the absorbing molecule is critical to its biological function. The effect of microwave radiation on these processes will depend on the details of the process itself. From our previous discussion we would expect any effect to be frequency dependent, and if allowed a long enough time, to be reversible. Biological considerations, however, may not allow enough time for reversibility to become apparent.

Conclusion

In this letter, a possible mechanism for the direct influence of microwave radiation on biomolecular processes has been elucidated. Intermolecular interactions that are dependent on steric conformation in regions essentially shielded from collisions are the processes one would expect to be influenced.

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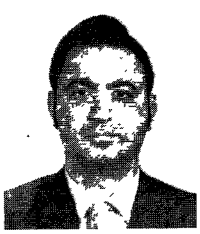

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