Enhancement of the Long-Lived Positronium Annihilation Rate by a Static Electric Field

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The annihilation rate of the long-lived component of positronium in solid dielectrics was investigated as a function of an applied static electric field. It was found that in some materials like paraffin, polyethylene, and Teflon the triplet positronium decays, in the presence of the field, at a rate greater than the usual "pick-off" annihilation rate. Within the experimental accuracy the lifetimes τ in the three materials display the same trend with the field, which is expressed by the equation $\tau_E=\tau_0(1-\alpha E)$, where $\alpha=(9.3\pm1.3)\times10^{-4}$ cm/kv. No effect was found in some typical polar polymers, for instance, Lucite, Nylon, and polyvinyl chloride.

INTRODUCTION

It is well known that in some materials positrons annihilate with a complex decay curve having two lifetime components, strongly favoring the positronium formation hypothesis. The long lifetime (the so-called "τ_2 component") is due, as is generally accepted, to the formation of orthopositronium which in solid insulators decays only by "pick-off" annihilation.[1,2] Some factors have been found, in the last few years, to affect the τ_2 component and its intensity, among which are magnetic fields, temperature, pressure, and phase.[2]

A strong influence of an electrostatic field on positronium formation in some polymers was found recently by us[3]; this work will be referred to as (I). As a further development, the present research was intended to investigate the influence of the field on the lifetime of the τ_2 component in the same materials.

EXPERIMENTAL

The same experimental method used in (I) was adopted; its basic features are summarized here. The time-distribution spectra of the annihilation quanta with respect to 1.28-Mev γ rays from Na^{22} were analyzed using a fast time-to-height converter[4,5] and a 200-channel pulse analyzer.

The γ rays were detected by means of two plastic scintillators (Pamelon) ($1\frac{1}{2}$-in. diam, 1-in. thick) optically coupled to RCA 6342 photomultipliers. The counters were biased to accept only the pulses belonging to the two Compton edges. The prompt resolution curve fit a Gaussian curve with full width at half-height of 8.0×10^{-10} sec.

The same active specimens as used in (I) were employed; they were placed between the parallel plates of a capacitor whose envelope had been grounded.

Several recording runs were made for every specimen, alternately with and without electric field, the runs being stored, every 10 min, respectively, in the first and in the second hundred channels.

RESULTS AND CONCLUSIONS

A typical time spectrum of the τ_2 component in Teflon is reported in Fig. 1 with and without electric

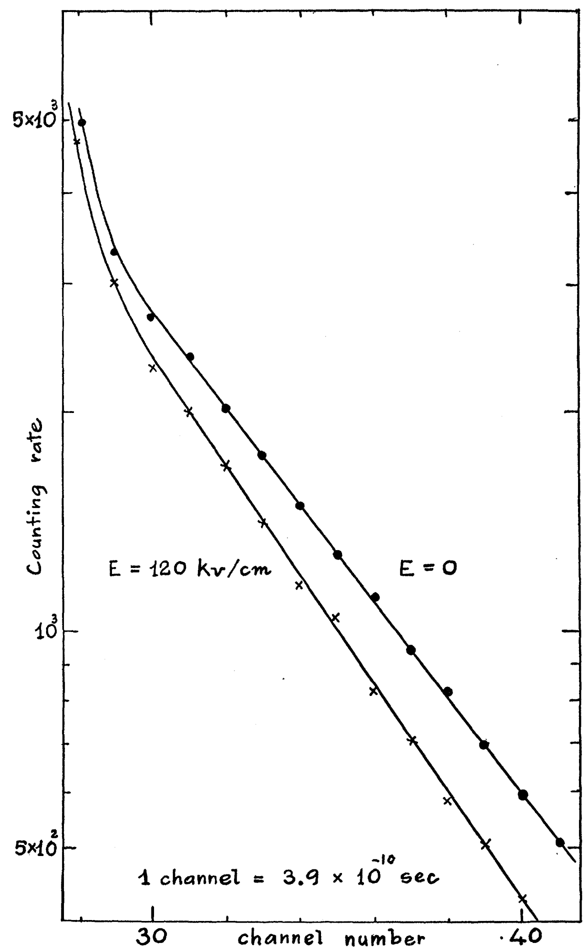

FIG. 1. Electric field dependence of the long lifetime in Teflon.

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[1] R. A. Ferrell, Revs. Modern Phys. **28**, 308 (1956).

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[4] C. Cottini, E. Gatti, V. Svelto, and F. Vaghi; *Proceedings of the Second Symposium on Advances in Fast Pulse Techniques for Nuclear Counting*, Lawrence Radiation Laboratory, Berkeley, California, February, 1959 (unpublished), p. 49.

[5] E. Gatti and V. Svelto, Nuclear Instr. **4**, 189 (1959).

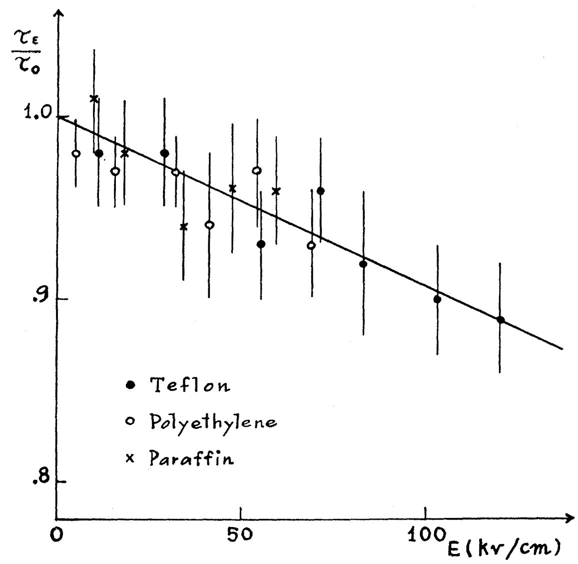

FIG. 2. Ratio between the long lifetime τ_E with field, and τ_0 without field as a function of electric field E.

field E. It can be remarked that the two curves have different slope, the lower one showing an enhancement of the annihilation rate in the presence of the field. For each time spectrum, the lifetime τ_2 was deduced by fitting an exponential curve to the set of experimental data by means of a least-squares adjustment. The ratio τ_E/τ_0 between the lifetime with and without field is plotted in Fig. 2 as a function of E, for three dielectrics, namely, Teflon, polyethylene, and paraffin. In the figure we included a few points obtained from the set of time spectra which were recorded in the previous research (I). Within the present experimental accuracy the three dielectrics behave in the same way, so that no distinction was made among them in fitting the points to a curve which schematically represents the effect of the electric field enhancement of the annihilation rate. By adopting the simple equation:

$$\tau_E = \tau_0(1 - \alpha E), \tag{1}$$

we have

$$\alpha = (9.3 \pm 1.3) \times 10^{-4} \text{ cm/kv}.$$

It is interesting to note that the three quoted materials which display the electric enhancement of the annihilation rate are the same materials that show a strong dependence of intensity of the τ_2 component on the electric field, observed in (I). The results reported in (I) were obtained without taking into account the lifetime variation, so that, strictly speaking, they should be corrected by using Eq. (1). As the relative amount of the two effects are quite different, the correction to be applied is slight; for instance the data plotted in Fig. 1 of (I) at $E = 50$ kv/cm should be increased by 4% and 7%, respectively, for Teflon and polyethylene.

As far as concerns the behavior of those polar polymers that did not show any electric effect on the long-lived component intensity, no influence of the electric field on the τ_2 component lifetime was found in the present investigation. In particular, the investigated materials were Lucite, nylon, and polyvinyl chloride.

The nature of the electric enhancement on the positronium decay rate seems at present to be obscure. Any attempt to interpret this effect as a consequence of a mixing of ortho- and parapositronium, due to a magnetic field in the positronium Lorentz frame, with the aid of existing theories, is to be ruled out. In fact, the positronium should move across such a strong electric field that the existence of a bound system is prevented. An analogous situation was described by Ferrell, in discussing the two-photon angular correlation in fused quartz.[1]