INDUCED REVERSAL OF ELECTRETS

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The reversal of electret polarity can be accelerated by temporarily unshielding the electret immediately after formation. As a result, the electret attains stable charge in a comparatively short time. Data on carnauba wax electrets with accelerated, or "induced", polarity reversal are presented and discussed.

In recent years there has been increasing interest in the utilization of electrets for practical applications.[1–4] The most useful electrets for such applications are electrets with strong and stable effective surface charge. As is well known,[5] the effective surface charge of a newly made thermoelectret usually decreases to zero, reverses polarity, and eventually builds up to a large and stable value of opposite polarity (Fig. 1). The time required to reach the stable period is shorter for those electrets for which the polarity reversal occurs faster. The time required to reach the instant of the polarity reversal ("reversal time") normally ranges from several minutes to several years.[7] The reversal time depends upon such parameters as forming electric field, temperature, cooling rate, duration of exposure in the forming field, and the shielding conditions after formation. As the stable period commences only after the electret has reversed its polarity, with some electrets one may need to wait exceedingly long times before the electrets stabilize themselves. Hence, it is desirable to be able to make electrets which would reverse and become stable in very short times. Such electrets would be ready for practical applications almost immediately after formation.

In studying effects of various shielding conditions on electret charge we have found a very simple procedure for effecting an accelerated polarity reversal of thermoelectrets, which leads to a rapid attainment of stable conditions. This procedure may be called "induced" reversal.

The induced reversal is accomplished as follows: At the completion of electret formation, instead of immediately wrapping the electret in a storage shield, the electret is left in the open for a period of "unshielding" and is wrapped only at the end of this period, after which it is handled in the usual way.

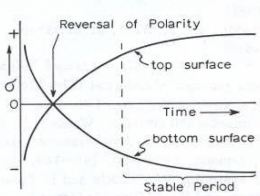

FIG. 1. Typical curves for electret effective surface charge (σ) as a function of time. The stable period begins at a time ranging from several days to several years after formation.

Our electrets were made from a mixture of 45% carnauba wax, 45% colophonium, and 10% white beeswax. The pulverized mixture was melted and heated for 1.5 h at 120–125 °C. The melt was then allowed to solidify into a disk 7 cm in diameter and 1.27 cm thick while in a forming electric field of 7900 V/cm. Aluminum foil was used as the electrode material and the wrapping shield. Typical results for four electrets are shown in Figs. 2–5.

In Fig. 2 the curve for the effective surface charge versus time is shown for a "regular" electret (i.e., an electret not subjected to induced reversal). This electret had a reversal time of 50 min and required about 24 h for attaining a stable charge.

The electrets whose characteristics are shown in Figs. 3–5 were made under conditions identical to those of the regular electret except that they were temporarily unshielded for 30 sec, 1 min, and 5 min, respectively. The unshielding took place immediately after formation, after which the electrets were tightly wrapped in foil shields just as the regular electret was. Electret No. 175 (Fig. 3) with 30 sec unshielding exhibited a reversal time of 7.5 min and attained a stable charge in about 12 h. Electret No. 176 (Fig. 4)

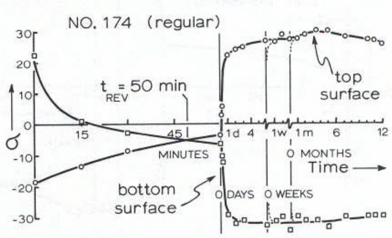

FIG. 2. Effective surface charge (in arbitrary units) versus time for a regular electret; stable charge is attained in about 1 day.

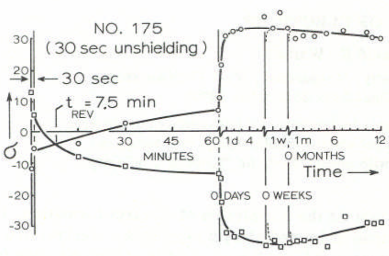

FIG. 3. Effective surface charge (in arbitrary units) versus time for an electret with induced reversal. Duration of unshielding is 30 sec; stable charge is attained in about ½ day.

with 1 min unshielding exhibited a reversal time of about 1 min and attained a stable charge in about 8 h. Finally, Electret No. 177 (Fig. 5) with 5 min unshielding exhibited a reversal time of less than 1 min and attained a stable charge in about 2 h.

Thus, in the above examples the unshielding always resulted in a shorter reversal time and in an accelerated development of a stable charge.

The most effective duration of unshielding for our electrets was about 5 min. The 5-min unshielding yielded a strong and stable electret (Electret No. 177) after only 2 h, whereas a comparable regular electret required 24 h to attain stable conditions.

However, when periods of unshielding longer than 5 min were used, the electrets required a longer time to reach a stable charge and sometimes never achieved a final charge as large as that of a regular electret. Hence, there exists an optimal duration of unshielding, which, of course, is different for electrets made under different

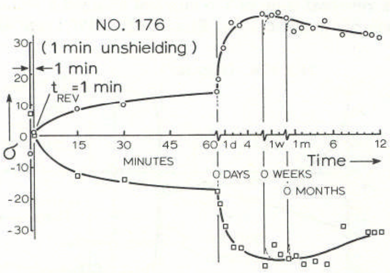

FIG. 4. Effective surface charge (in arbitrary units) versus time for an electret with induced reversal. Duration of unshielding is 1 min; stable charge is attained in about ⅓ day.

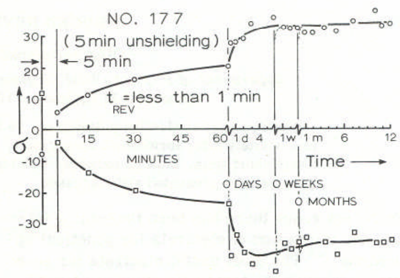

FIG. 5. Effective surface charge (in arbitrary units) versus time for an electret with induced reversal. Duration of unshielding is 5 min; stable field is attained in about 2 h. After 2 h this electret is essentially identical to the regular electret when the latter is 1 day old (Fig. 2).

forming conditions or otherwise possessing different characteristics.

The observed induced reversal effect is in qualitative agreement with the thermoelectret theories based on the assumption that at least two different processes of charge relaxation take place inside the electrets. In terms of the well-known Gubkin theory,[8] for example, this effect may be interpreted as a result of the accelerated relaxation of the "heterocharge" due to the presence of a strong internal electric field within the electrets that are not tightly shielded. Likewise, the fact that an excessively long duration of unshielding weakens the electrets may be interpreted, in terms of the same theory, as a result of the excessive decay of the "homocharge" due to the onset of electric conduction within the electret and in the surrounding air upon the removal of the shielding foil. The present electret theories[9] are, however, too incomplete to permit a quantitative interpretation of the above data.

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[1]A. N. Gubkin, *Electrets* (Academy of Sciences, Moscow, 1961).

[2]G. M. Sessler and J. West, J. Electrochem. Soc. 115, 836 (1968).

[3]Cornelius W. Reedyk, *Electrets and Related Electrostatic Charge Storage Phenomena* (The Electrochemical Society, New York, 1968), pp. 104–108.

[4]Oleg Jefimenko and David K. Walker, in *Conference on Dielectric Instruments, Measurements and Applications* (IEE, London, 1970), pp. 146–149.

[5]See, for example, V. Fridkin and I. Zheludev, *Photoelectrets and the Electrophotographic Process* (Consultants Bureau Enterprises, Inc., New York, 1961).

[6]The "stable period" may be defined as beginning at a time when the effective surface charge builds up to about 75% of its final value.

[7]David K. Walker, thesis, W. Va. University, 1968 (unpublished).
[8]A. N. Gubkin, Soviet Phys. Tech. Phys. 2, 1813 (1957).
[9]For a recent review, see Martin M. Perlman, *Electrets and Related Electrostatic Charge Storage Phenomena* (The Electrochemical Society, New York, 1968), pp. 3—5.