Life Time of Thermal Electrets of Carnauba Wax, Esters, Fatty Acids and Alcohols

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Abstract

Residual surface charge with time was observed for thermal electrets of carnauba wax, esters extracted from carnauba wax, fatty acids and alcohols derived by hydrolysis of esters. All the electrmts were prepared in A.D.1951-1953. The samples was poled by applying various electric field at temperature range between room temperature and 65°C. After poling, both surfaces of the electrets was shorted with tin foil and kept in a desiccator. Thirty six years have passed after the preparation of the electrets,a stable homocharge of (4.6 ~ 6.6) x I0 SC/m2 was observed for electrets of carnauba wax, esters and fatty acids, but no charge was observed for fatty alcohols.

].Introduction

About seventy years have passed since the electret was discovered by Eguchi{L~· He prepared the original electret from a mixture of equal volumes of carnauba wax and rosin, which was poled under a high static electric field above its melting point and cooled down to room temperature under the field. So far, the electret property of carnauba wax was fully

investigated~= ~)· However the electret property of esters, fatty acids and fatty alcohols extracted from carnauba wax were investigated very few. This paper presents some experimental results on life time of thermal electrets made from carnauba wax, esters, fatty acids and fatty alcohols. All the electrets were prepared in A.D.1951-1953.

2. Experimental

2-I. Samples

Commercial carnauba wax (denoted as sample A), esters extracted from carnauba wax (sample B), fatty acids (sample C) and fatty alcohols (sample D) derived by hydrolysis of esters were used in the experiments. The method of chemical separation and purification of their samples was reported on the other paper[C4]· 2-2. Thermoelectret preparation All the samples with a thichmss of 2.0 mm and diameter of 3.5 cm was poled by applying various electric field (Ep) for 30 minute at temperature range between room temperature and 65"C. After poling, both surfaces of the electrets was shorted with tin foil and kept in a desiccator at room temperature for thirty five years. Surface charge of all the electrets was measured by an induction method.

3. Results

Figure ~ shows the relation between surface charge density (~) and poling temperature (Tp) for sample A. The poling field (Ep) was 4 X 106

V/m. After poling the initial polarity of the o was heterocharge and the

o ,,,,tar° charge increased with the increase of Tp. The ~ hot.~o charge gradually decreased and changed to homocharge with the lapse of time.The homocharge increased with time and saturated at (4.5 ~ 8.0) ×]0-SC/m2.The homocharge did not decay after the storage of 35 years.

Figure 2 shows time dependence of o for sample B poled at various Ep at

65°C.After poling the heterocharge appeared and the charge changed to homocharge with the time. The time required for heterocharge transformation decreased by increasing poling field as shown in Fig.3.

Figure h shows the relation between Ep and a for sample B poled at Tp = 65°C. After poling the initial polarity of o was heterocharge and then the polarity changed to homocharge. The charge increased with the increase of Ep and saturated at a constant, After the storage time of

35 years, the homocharge was settled at 6 x]0 SC/m2.

Figure 5 shows the relation between o and Tp for sample which was poled at 3 x IORV/m. The amount of heterocharge was rather smaller when Tp was below 45°C. After the storage time of 35 years, the polarity of ~ changed from hetero- to homocharge and saturated at about (4 ~ 6) ×]0-~C/m=·

Figure 6 shows the relation between o and Ep for sample C poled at'Tp = 60°C. After poling the polarity of ~ was heterocharge" and then changed to homocharge with time. Figure 7 shows the relation between o and Tp for sample C poled at Ep = 3 ×]06V/m. The polarity of the ~ was heterncharge and transformed to homocharge. The amount of homocharge increased with the increase of Tp. In the case of sample D no surface charge was observed after poling.

4. Discussion

The main component of carnauba wax are esters (75 ~ 91%), fatty acids (5 ~ 7%) and fatty alcohols (]0 ~ 12%) as shown in Table]c~J Table 2 shows chemical formular of esters, acids and alcohols in carnauba wax. Table 3 showed the time dependence of o for all the thermoelectrets. Very stable homocharge were observed in poled carnauba wax, esters, and fatty acids. On the contrary, however, no residual surface charge was observed for fatty alcohols. According to the dielectric measurement, hindered rotation of -OH radical in fatty alcohol was observed under below melting point.Moreover the electric conductivity of fatty alcohols at room temperature was much larger than those of esters and fatty acids. Therefore the surface charge in poled fatty alcohols must be disappeared in a very short time.

Gross assumed that no homucharge-heterocharge recombination took place and provided the explanation of the heterocharge-homocharge transition; subsequent to electret formation, heterocharge decays in a relaxation way,

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while homocharge decays slowly due to electric conductivity. Consequently, with the storage of time homocharge began to increase in the thermoelectret.

Gubkin proposed the following expression for the electric field intensity inside a thermoelectret~S~:

$$\frac{(\sim RCI\ e\ A)\ \sim f_{,,}}{Oo\sim}$$
$$= \sim \quad + \sim \cdot \quad (\sim RC/\sim A) - I \qquad (e \sim - e \sim. \sim c\sim)$$
....

$$+ G \sim e^{I'A/Rc)t} \quad (1)$$

and A-]/(8+6.D/do) (2) where R,C and e are electric resistance,electric capacity and dielectric constant for the air. D and do are thickness of the sample and air gap between the electret and the metal plates and ~ o dielectric constant for the vacuum.

If the air gaps between the electret and the metal plates are very small, then Ah0. For a non-shorted electret, electric field strength inside the electret is given by formula

E= (~, + ~)/~°e~ (3) where ~, and ~ ~ denotes the effective density of charge on thermoelectret surface I and 2.

Piekara proposed the mechanism relating the hetermcharge homocharge transition with the change in the direction of dipole moment of molecular dipoles~ . In the electrets in which permanent polarization derives from frozen in ordered dipole moments of esters radical (-C(~3-) and carboxyi radicals (-COOl[), the mechanism is as follows. Application of a strong electric field Ep shifts the equilibrium toward conformation of a higher dipole moment value. An electret containing such radicals exhibits large heterocharge immediately after poling. Under such circumstances a homocharge appears in the electret. The heterocharge homocharge transitien in electret may be connected with the frozen-in of the arrangement of the dipole moment of esters and acids radicals. The analysis of the thermoelectret are now in progress.

According to Roos, maximm, nut[ace charge density of the electrets is calculated by the following equation

~.~ = 100e o[20 + (3e /D)'t=]' (4) where ~ o and a is dielectric constant of air and the sample, D is thickness of the sample.On the carnauba wax when a is 3, D = 2.0 mm, then u .... - 6.6 × IOSC/m~, The o .... for the esters and fatty acids is good agreed with the calculated value. The stability of surface charge on the thermoelectrets may be connected with freezing-in of the arrangement of the dipole moments of

esters and fatty acids.

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30 ~0 SO 60 7O Tp('C)

Fig, 2 "lime dependence of # Jor ester eleelrets as a funetlo,, of E~. 2'p=6fi+C.

..... ~° 1,, ...

~'1(10+ V/m) 0. _S 1 I ~ 2 3 3.~ 4 4.5

JCX

20O

., i m

Fig. 3 Rdationship between r,.* and El, fur e~lcr cieetret~. Tr =65'C.

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Relationship
IJetween a
al+d E,. h)r
ester

eleetrets.
Te=65*C.

Sign Time	Polarity
~: ~%fter poling (u.s.)	lleterochar~e
/~; Ahcr poling (I.s,)	Ilettroeharge
oi Alter 25 rt+ l~+~.~	I[omuehal'~
A; Alter 35 yr* (I s)	]lom#cher~e

Fig+

,/" ° , °

/

• ~-+~'-P~_ ~ •

~o -.7,:o s-An ~0 70 t'cl

Rc]ationship between a and 7'r Ior ester c]uctrels. Ev-3 $\times$ lO4 V/re.

O; Alter ~olln~ (u s ~ Ileterocharge

O; A~t~r 3~ ~r~ (u.~.~ llomochart:e

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• , ,-i o-l-" ,. ql]

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Fig. Re]atiu~shlp between a and
Ep tot acid

electrets. 7'P - 60°C.

Si~:~ Time Pot~r~ty

O;
After
polln~   liet~roctmrge
(u.s.)

,~:
After
pob.~r   Ilete~cl,a,ge
41.s.)

e;
~lter
35 yrs   IIQmoch~r~e
(u.s.)

A;
After
~5 yrs   Jlamocharge
(I.s./

Teble 1 Constitution of eernauba
wax*.

.....
i,0,~oo <u>**~jº**</u>

Ilydroea*bon	~. 3-1
Aliph~tl¢ ester5	**38 40**
Monollydllc alcuhols	15-12
~-hrdr~xy a1~phatic ~sl~r~	12-14
p.meth~xyclnnamlc allphar;c diesterl	5-7
pkhydro~ycinnami~ al~phatie dlest~rs	70-3O
Uneomblned tr~ter~ene type 0;oi	O4
Unco!,,b~ed a=ids and o~her unknown	5-7
cuns~1lue,,~s	

'Ref. Vande~burR el *al.:*l Am 0il
Chem. S~c., H, 659 (1970~

~'0~c'm^z} ~,~

F~g.

Relationship between ¢ ~nd
"~'r for ~cld elec,r~ts. El,= 3 x
10~ V/re.

O: A~t~r l=Otim: ~. ~.)
Heteroelaar¢~

e: A~t~r 35 yrs (u s)
ll~.locrla~ge

A; After ~5 yrs ~1 s)
H~t,l~char~e

"L'able ~ CIicmlcaL for~laular
of estees, acids and ~dc~hol~.

,O

l£~ler~ I~-C-(~   JR, R' :
         R'   a~ky]
                   radical~

~.hydro~lipl~atic e~t~r~

O

]IO C.Et:~ ~-O C~F12=rt (,,,,.
: 15. 25. 2~. 25)

Acids *R-C-OH* (R : alk~t
                radie~l~

Table 3 rri,tle deve,,de:lce ~f ~urf:lce charge ~n electrets. (A) C~r,loub~ W~x. Poling condition: £v=~×10~V/,n. T:=57.5~C.

S{olage llme (day)	I	It]	100	5O0	7295	8290	12775
Surface cl~arge, U(+)	4. I	,1 3	4 4	4.3	4.5	5.3	4.6
,, (1~ *~Clm')* L(-)	4. q	46	4 9	4.9	3.8	4.6	5.0

(B) Esters. /~=3xl0~V/m, "-¢'v-SO'C.

St~rz~e llme (day)	1	10	]~0	500	7665	86]5	12759

Surface chariJe, U(+)	1.5	4.0	,I.7	3.5	4,$	4,6	4.8
u (10 SC/m~) L(-)	L4	4.~	5,0	4.3	,L5	4.5	4.7

IC) Acids.
E~,=lxl0~V/m, 7"e=55'C.

Storage time (day)	1	10	100	550	7335	0~-14	12540
Sutlace charge. U(~)	05	F]3	.I.5	4.6	3.7	3.7	0.~
(IO-SClm:', L( )	+13	-0,8	4.9	4,6	4.;~	4.2	5.3

(he:erachatge) (hom~chnrge)

~h