INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

H4-SMR 471/14

COLLEGE ON MEDICAL PHYSICS

10 - 28 SEPTEMBER 1990

<u>REFERENCES ON ELECTRETS</u>

S. Mascarenhas

Universidade de Sao Paulo
Sao Carlos
Brazil

MAIN BUILDING STRADA COSTIERA, 11 TEL. 22401 TELEFAX 224163 TELEX 460392 ADRIATICO GUEST HOUSE VIA GRIGNANO, 9 TEL. 224241 TELEFAX 224531 TELEX 460449

References on Electrets (XII)

1 – Electrets, Topics in Applied Physics, Vol 33, ed. G.M. Sessler, Springer-Verlag, 1980

2 – Bauser, H and Runge W., Health Physics 34 (1978) 97

3 – Mascarenhas S. and R.L. Zimmerman, in Xth Ann. Conference of the Ass. Med. Phys. Brazil S. Paulo, ed. S. Watanabe 1979, p. 488-491

4 – CAMERON J. & Mascarenhas S., Nucl. Instr. and Methods 175 (1980) 117

5 – Cruvinel P. and Mascarenhas S., Physica Medica, 3 (1988) 207

6 – Cruvinel P, Mascarenhas S. and CAMERON J., Nucl. Instr. and Methods A287 (1990) 580

7 – Several PH.D. and Ma. Sci. Thesis from the Institute of Phys. & Chemistry, USP, S CARLOS, SP, Brazil, 13560 under orientation of S. Mascarenhas.

DOSIMETRY with electrets I

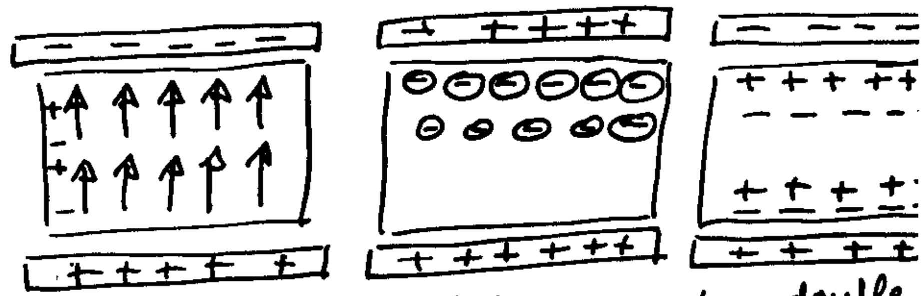
1 – WHAT IS AN ELECTRET?

AN INSULATOR (DIELECTRIC) WITH A LONG TERM POLARIZATION $\vec{P}$ (FROM MINUTES TO CENTURIES).

2 – SOURCES OF $\vec{P}$:

- dipoles (OH^-, OH_2, dipolar molecu…
- ions (H^+, Na^+, K^+ etc)
- electrons or holes (e^- or e^+)
- defects (M center, vacancies, interstiti…

3 – Distribution of sources for $\vec{P}$



Dipoles — injected space charge — ion-double layer

4- CHARGING METHODS

(II)

- THERMOELECTRET
- CORONA ELECTRET
- e^- injection ELECTRET
- FOTO ELECTRET
- RADIO-ELECTRET
- TRIBO ELECTRET
- ELECTROLYSIS - ELECTRET
- NATURAL ELECTRETS (PHASE-TRANSITION OR COSTA RIBEIRO effect)

5- MATERIALS

- POLYMERS (TEFLON, P.E., PVC etc)
- IONIC CRYSTALS (LiF, NaCl, $CaSO_4$ etc)
- glasses
- ice
- CERAMICS
- HIGH-INSULATION SEMICONDUCTORS (SiO_2 and others)

6 - BIOELECTRETS

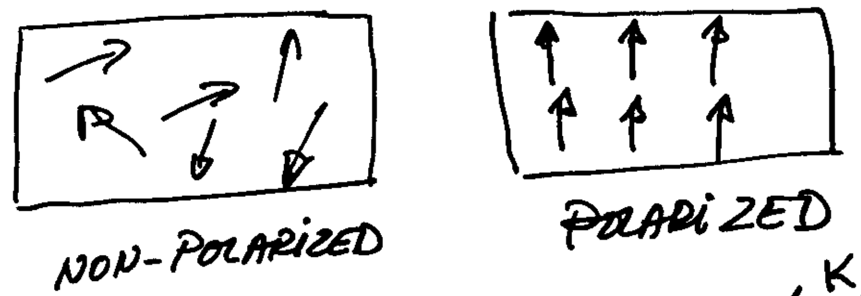
- BIOPOLYMERS (PROTEINS, DNA, RNA, POLYSACHARIDES)
- TISSUES (BONES, TEETH, HAIR etc)
- BOUND-WATER + AMINO ACIDS

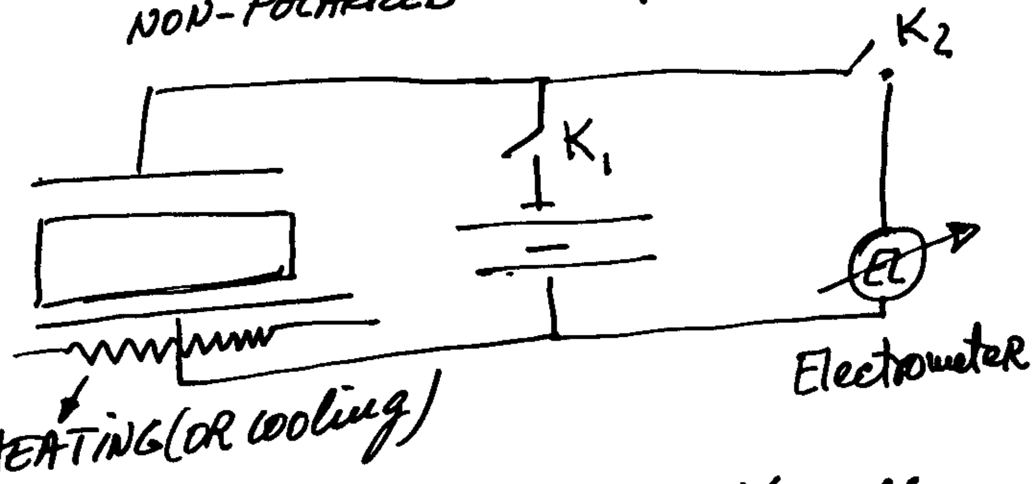
(III)

7- EXPERIMENTAL TECHNIQUES FOR MEASUREMENTS

Thermal Stimulated Polarization (TSP)

Thermal Stimulated Depolarization (TSD)

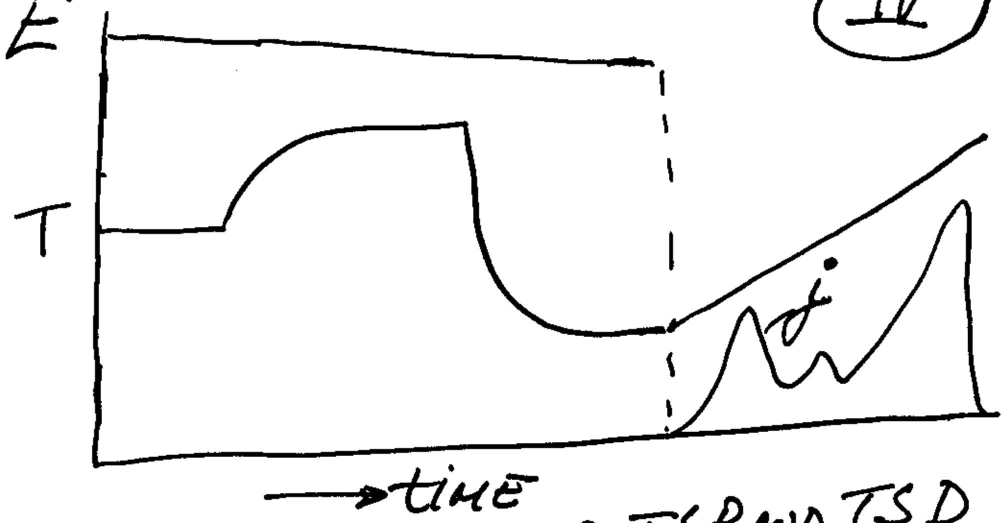




Polarization – K_1 ON K_2 off

Depolarization – K_1 off K_2 on

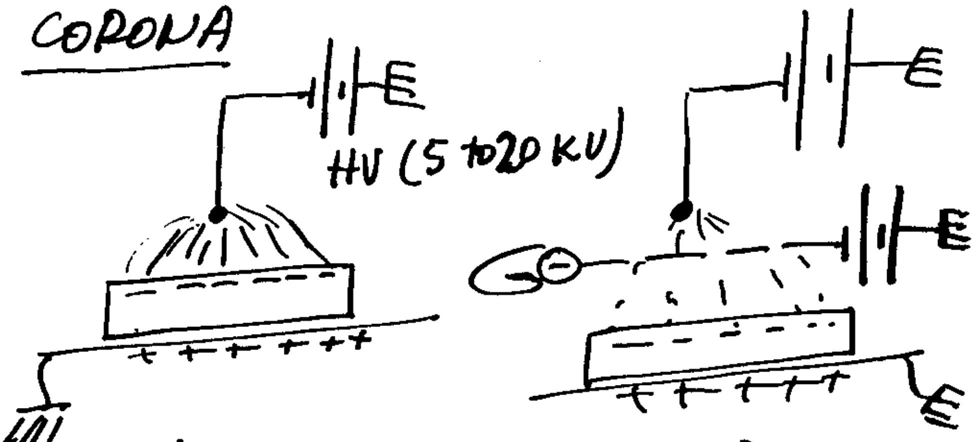
(IV)



TYPICAL CYCLE FOR TSP AND TSD

$j = -\frac{d\vec{P}}{dt}$ depolarization current-density

CORONA



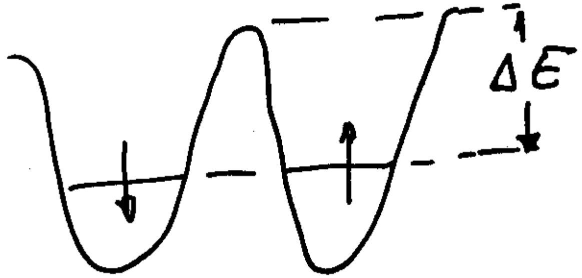
DIRECT CHARGING

CONTROLLED CHARGING WITH GRID

(V)

8- Relaxation Times for Electret Discharge

$\tau = \tau_0 \exp + \Delta E / kT$



$\tau_0 \sim 10^{13}$ sec

$\Delta E \sim 0.1$ to 2 eV

For teflon for ex. 10-20 years at R[oom temperature] depending on purity and environment.

9- Aplications:

condenser microphones
ion-chamber dosimeters
air and pollution filters
biophysics + medical physics
and others.

(VI)

9- Dosimetry with Electrets

a- using electret ionization-chambers

b- using TSD curves

c- using electret-transducers

10- Electret Radiation Dosimeter (ERD) ion-chamber

The electret is used as:

- electric field source
- charge detector

simultaneously.

Mascarenhas and coll. ~1972 introduced the cylindrical ERD.

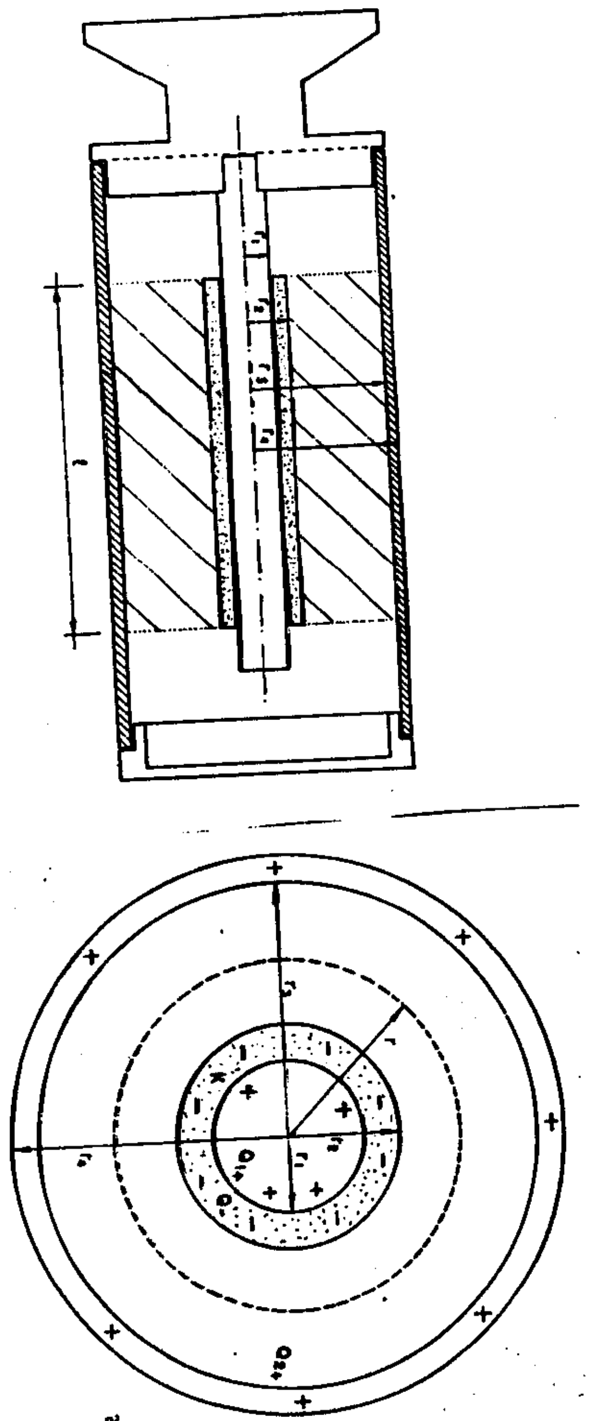
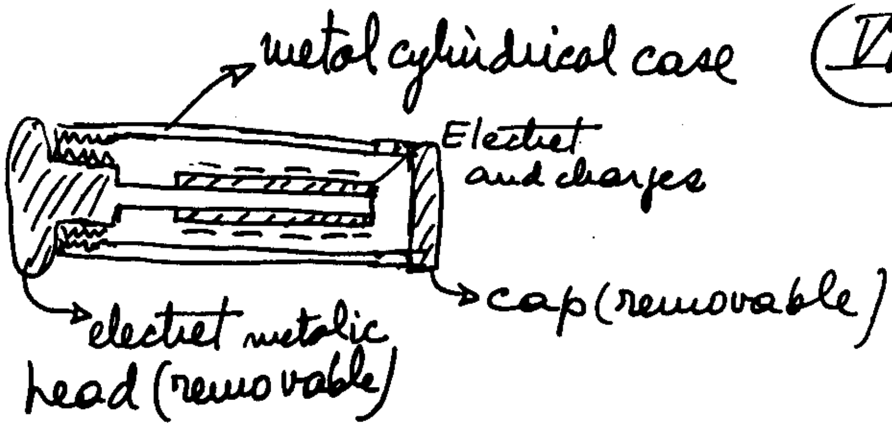
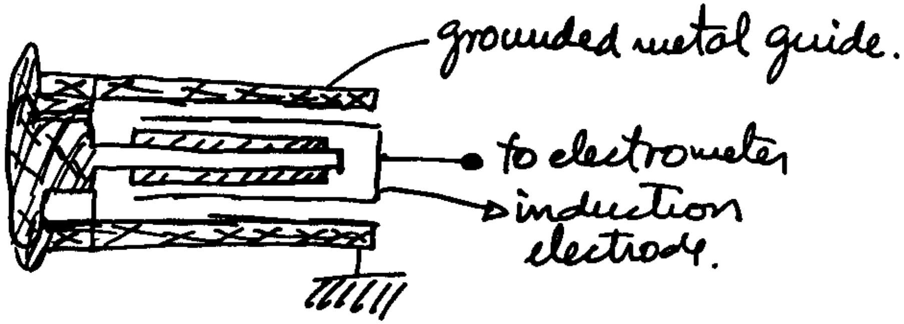


Figure 1 - Electret dosimeter with a cilindrical active volume

r_1 = 1,2 mm ; r_2 = 1,45 mm ; r_3 = 7,5 mm ;

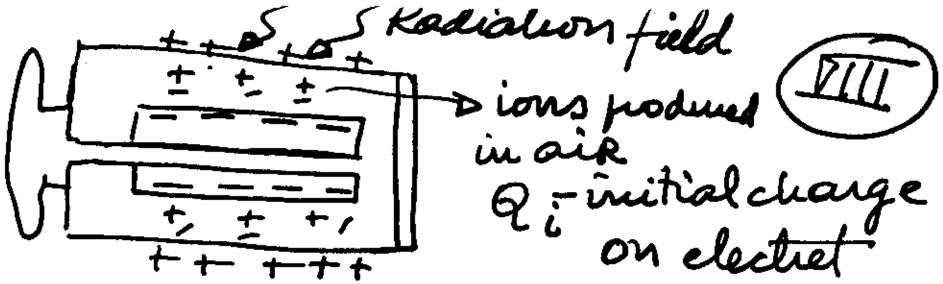
r_4 = 8,0 mm ; l = 30,0 mm

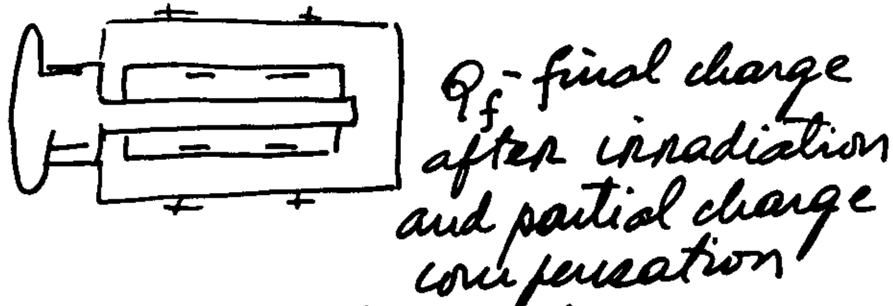




Typical quantities and dimensions

- electret thickness → 0.1 to 2 mm
- electret lenght → 4 to 10 cm
- internal radius → 2 – 4 mm
- external radius → 3 – 5 mm
- electret charging potential (teflon) → −100 V to −1000 V
- electret charge → $\sim 10^{-6} - 10^{-9}$ coul/cm^2
- ion chamber volume → ~10 – 100 cm^3
- typical range → 0.1 – 10 R





Fundamental equation:

$$\text{Dose} \sim Q_i - Q_f$$

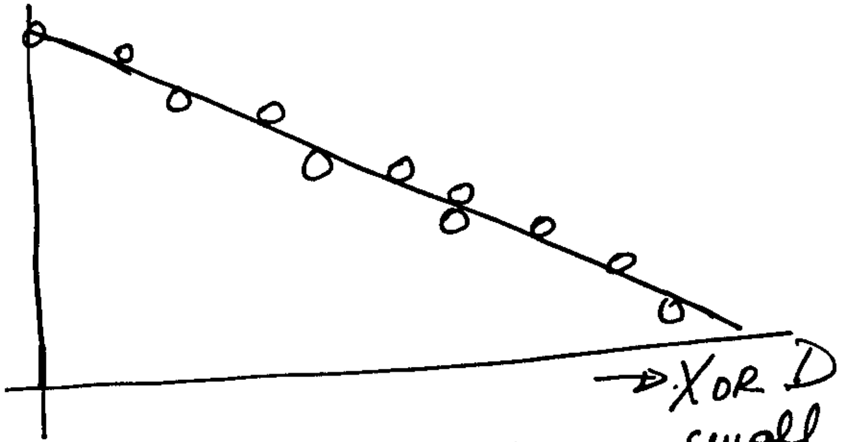
or

$$D = K(Q_i - Q_f)$$

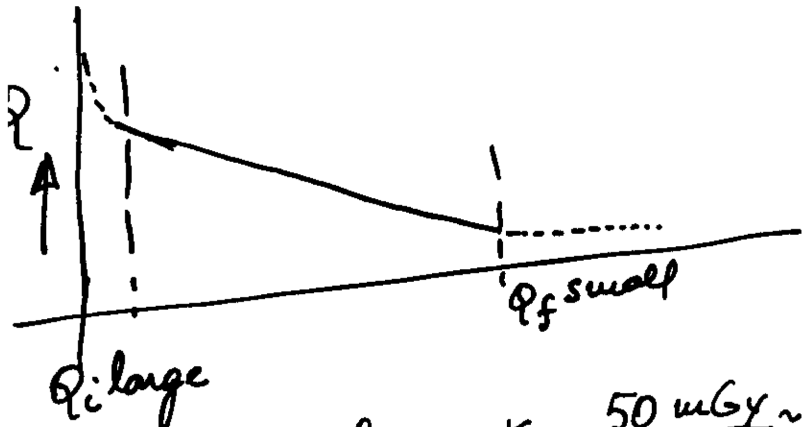
K → depends on material, geometry, radiation quality just like for any ion-chamber; also: If sufficient charges are maintained for chamber electric field to maintain proper value (no-recombination) and initial charge is not above critical field (ion multiplication).

Typical calibration curves for ERD

(IX)



If Q_i very large or Q_f very small

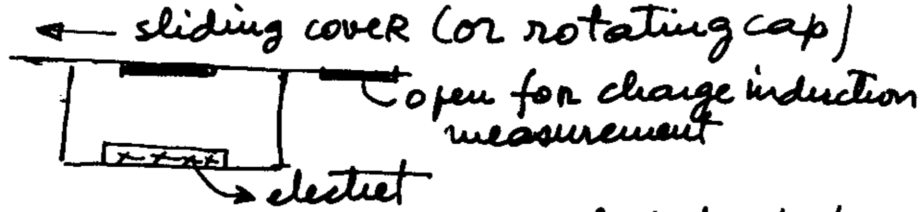


typical values $K = \frac{50\ mGy}{2 \cdot 10^{-9} C} \simeq 25$ mGy/nC

for typical pocket pen-dosimeter electret chamber minimum dose detectable of the order of $\pm 5 \times 10^{-5}$ GY (5 mRads)

(X)

FOR higher doses (.1 – 1 GY) a planar ERD was built with high mechanical precision and small volumes and special charge compensation measurement device.



guard-rings were used on electret detector for field homogeneity and precision of meas.

Other results found with ERD and other ideas:

- neutron ERD (fast and Thermal) using proper walls
- electron ERD using thin mylar walls
- α-ERD using source inside dosimeter
- X and γ-ray energy measurements using tandem ERD

MANY new ideas TO explore

Advantages of ERD (XI)

- Reading does not erases the dosimeter
- Re-usable
- simple to operate and read
- inexpensive
- good stability and small fading (< 1% in 30 days and < 0.1% in 30 days for special purposes)
- all the advantages of ion-chamber (well known theory, flexibility of design and use of wall materials)
- fast reading
- low cost reader
- portable or computerized reader

Disadvantages:

- Still needs to be tested intensively in personnel and ambient dosimetry
- has to compete with investments made in traditional techniques.