COMPOSITE ELECTRETS: MATERIALS COMBINATIONS WITH ENHANCED PROPERT

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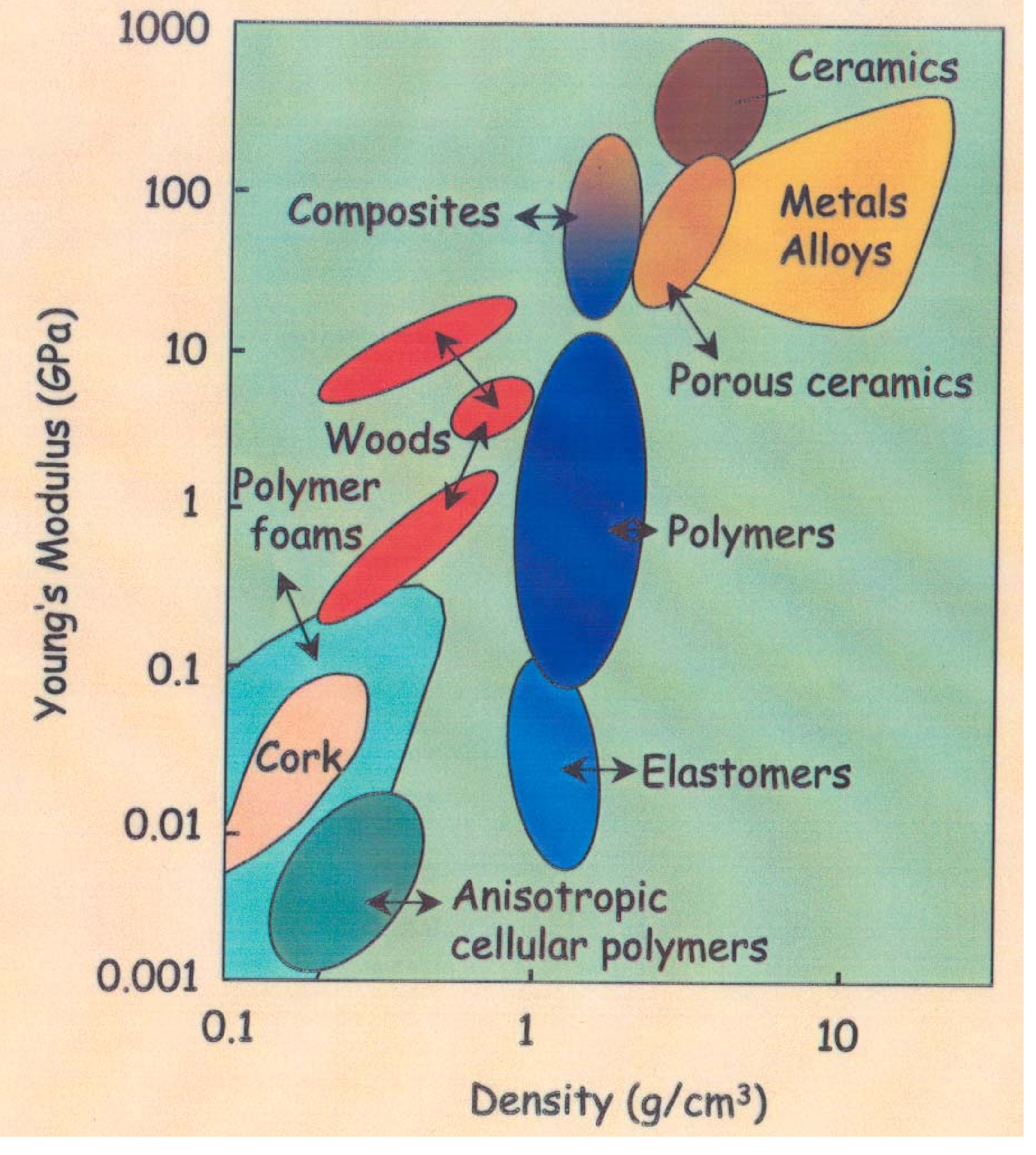
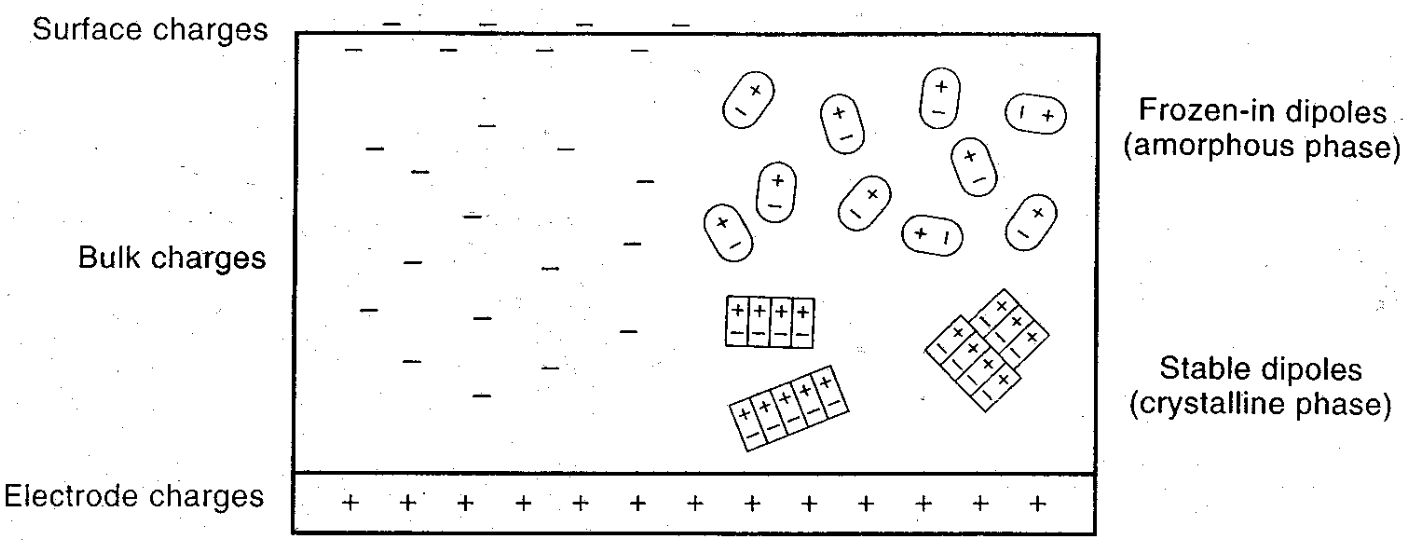
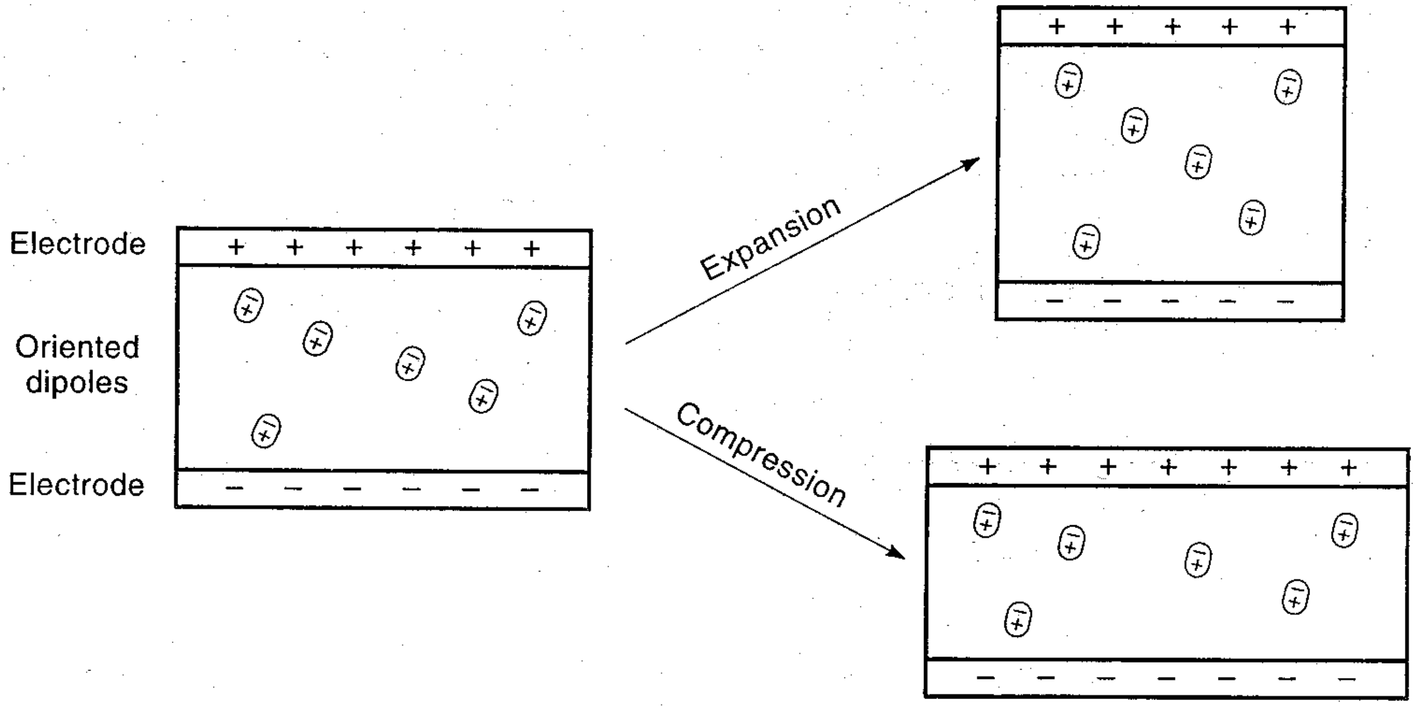
1. Polymer-matrix micro- and nano-composites: Combining advantages, avoiding shortcoming
2. Composite materials: The connectivity conce
3. Composite electrets: New multi-functionalitie
   - Piezo-, pyro- and ferroelectric particles in piezo-, pyro- and ferroelectric polymer
   - Magnetostrictive particles in piezoelectric polymer (inverse effect)
   - Liquid-crystalline electro-optic particles in space-charge electret polymer
4. Conclusions and outlook


1000
100
10
1
0.1
0.01
0.001
0.1
1
10
Young's Modulus (GPa)
Density (g/cm³)
Ceramics
Composites
Metals
Alloys
Porous ceramics
Woods
Polymer
foams
Polymers
Cork
Elastomers
Anisotropic
cellular polymers

Surface and bulk charges (left), frozen-in and ordered dipoles (right) in a polymer electret

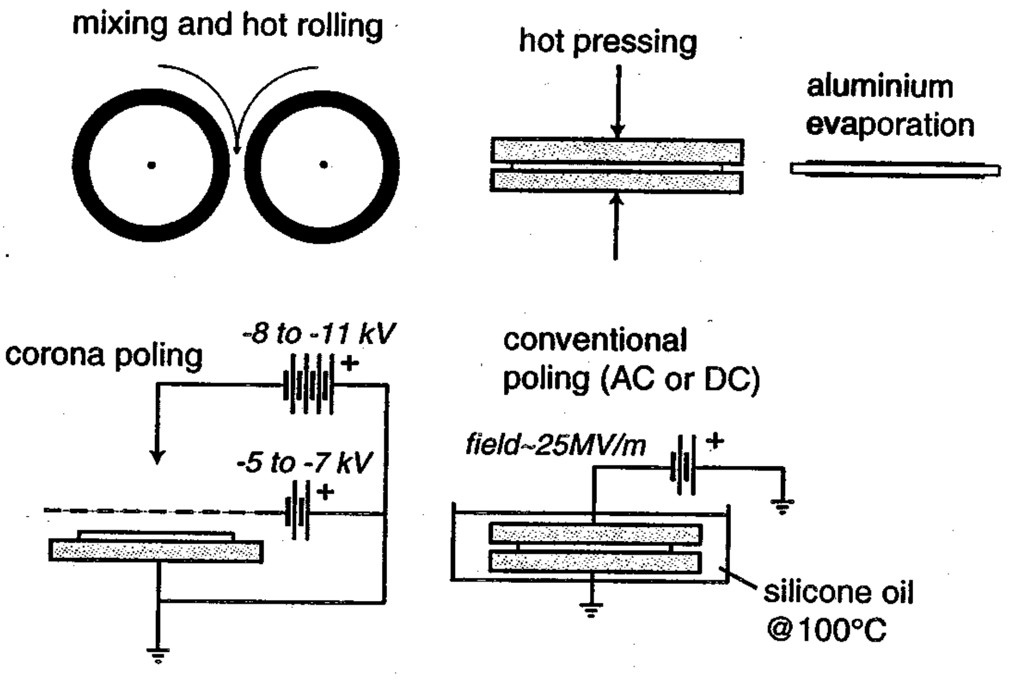


Dipole-density effect as basic mechanism for piezo- & pyroelectricity in polymer electrets



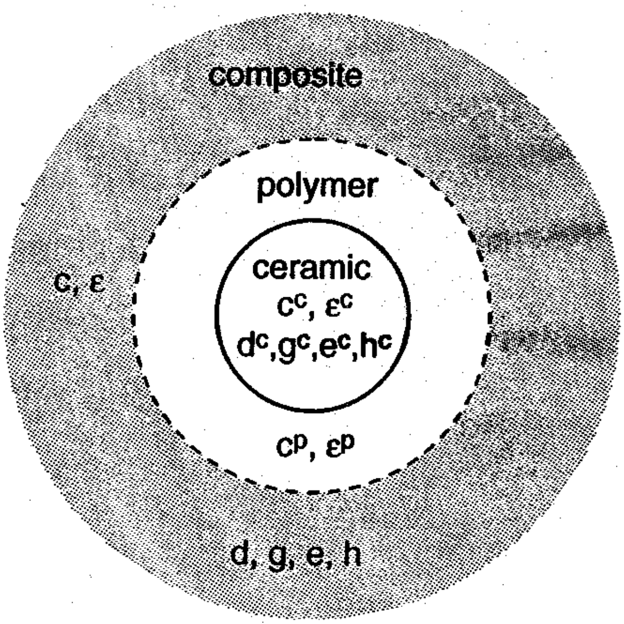
Preparation of 0-3 ceramic-polymer composites with ferroelectric or dielectric properties

(after Dias and Das-Gupta 1999)

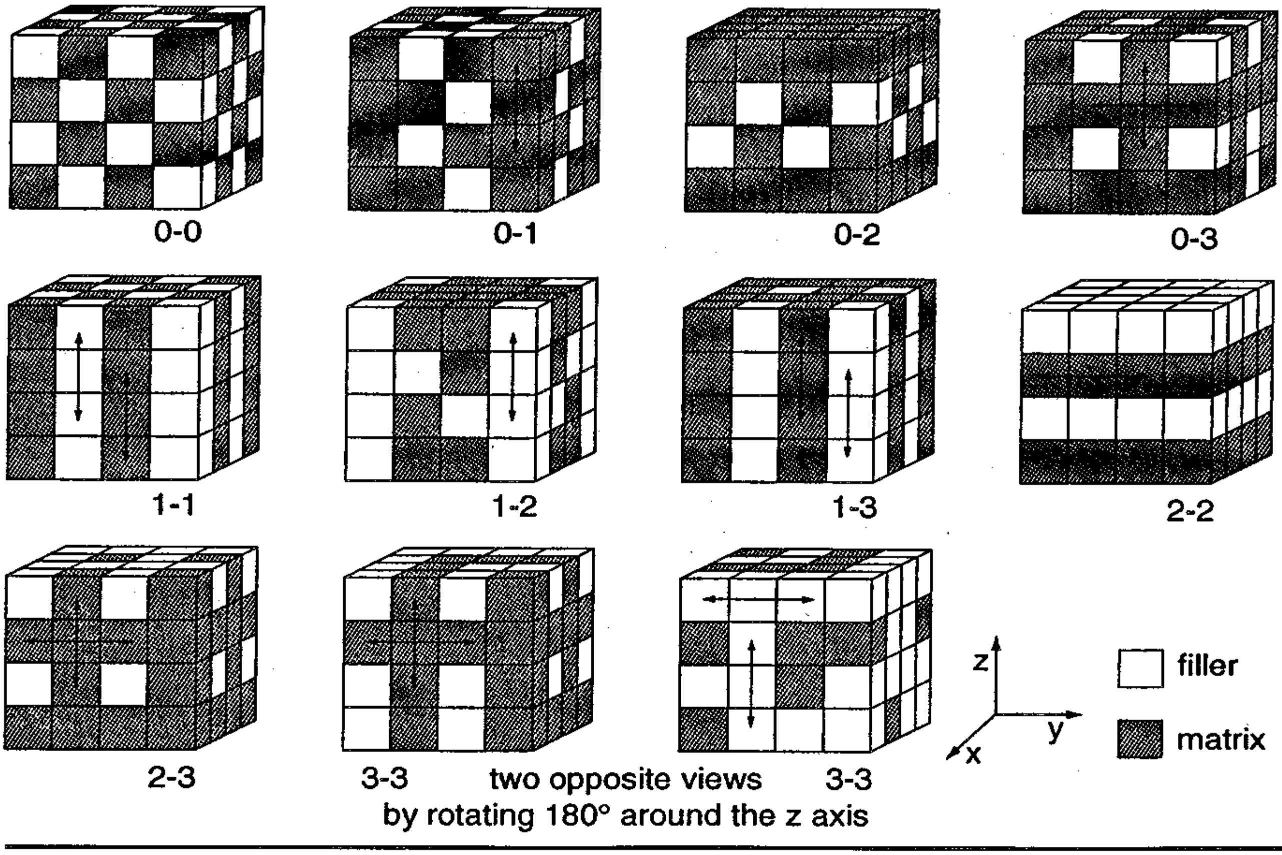


Model of a composite with spherical ceramic inclusions embedded in a polymer matrix

(after Furukawa and Fukada 1976 as well as Dias and Das-Gupta 1999)



Schematic views of connectivity patterns in two-phase composites



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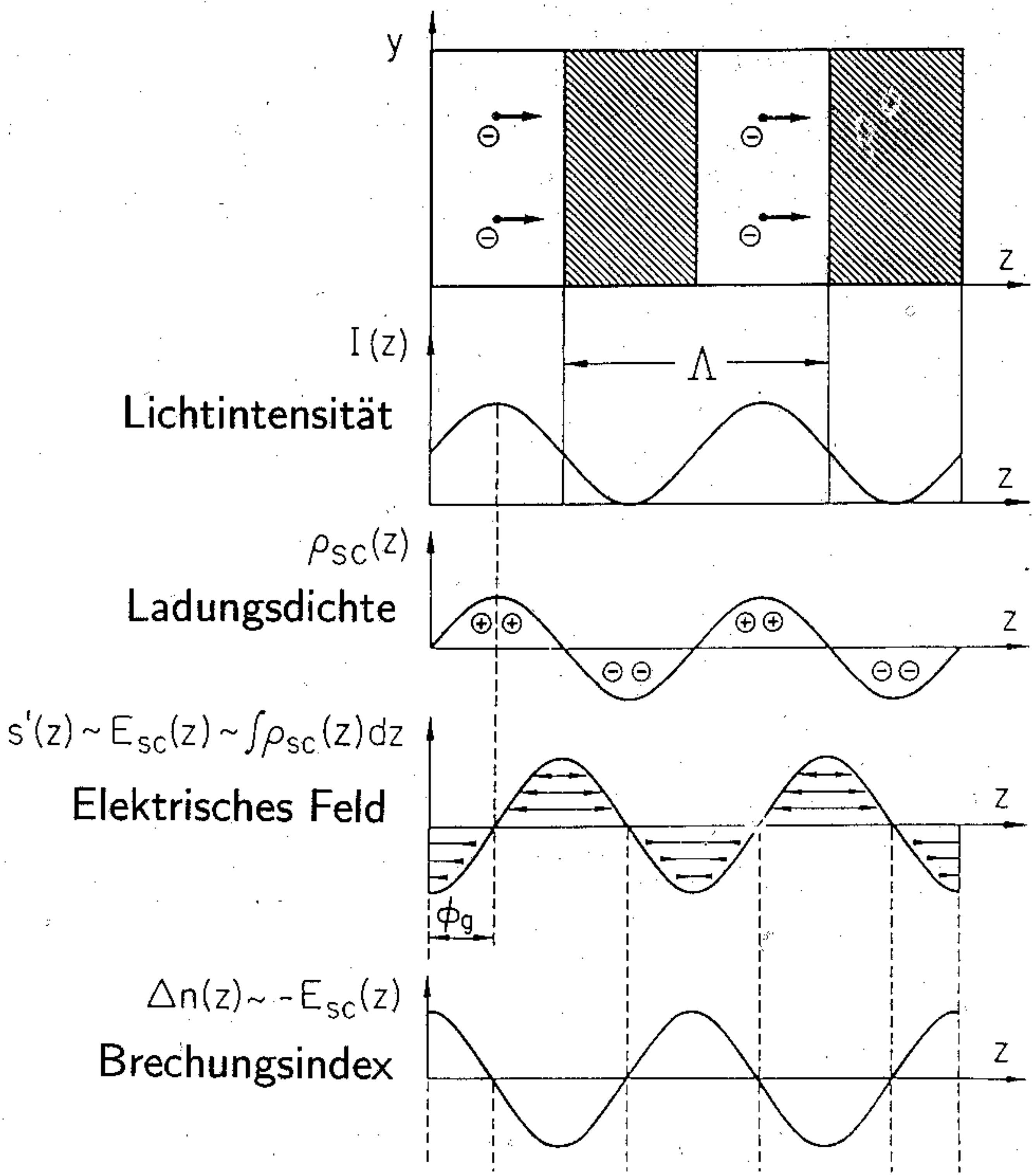
Connectivities and typical examples of practical composites (not all of them electrets)

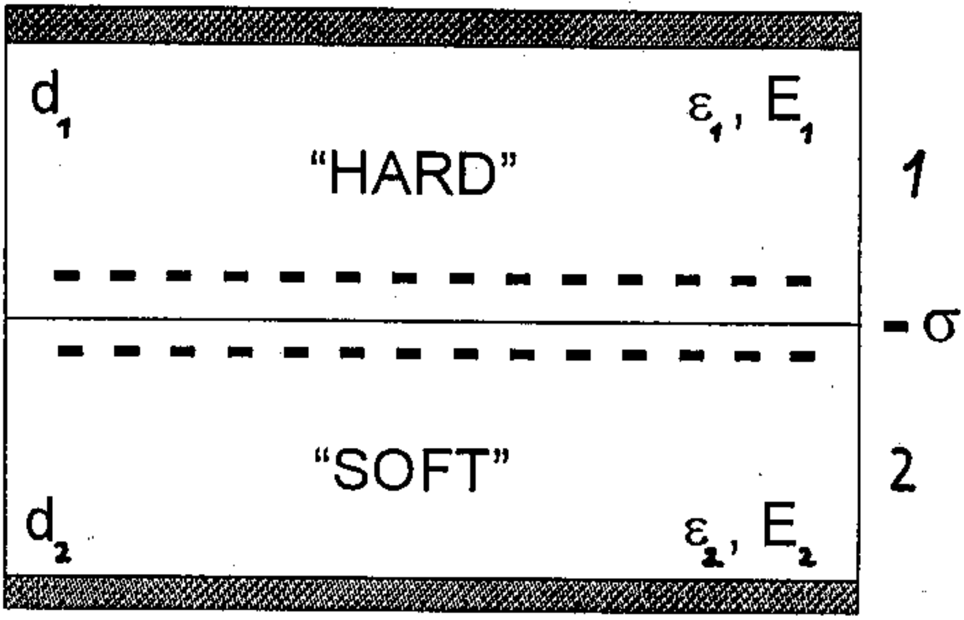
Index	Matrix	Filler	Examples	Comments
0-0	particles	particles	sintered powders	both phases only particles
0-3	continuous	particles	concrete, paint, etc.	particles in matrix
1-1	rod-like	rod-like	fibre bundle	e.g. two types of fibres
1-3	continuous	fibres/rods	fibre reinforcement	rod length $\approx$ thickness
2-2	layers	layers	sandwich panel	layers continuous
2-3	continuous	2-D grid	reinforced concrete	2-D tensional strength
3-3	continuous	continuous	"filled sponge"	interwoven networks

Photorefraktivität: Optische und elektrische Gitter



Model of a double-layer electret (soft + hard layer)

(after R. Kacprzyk *et al.*, *J. Electrostat.* **39** (1997))

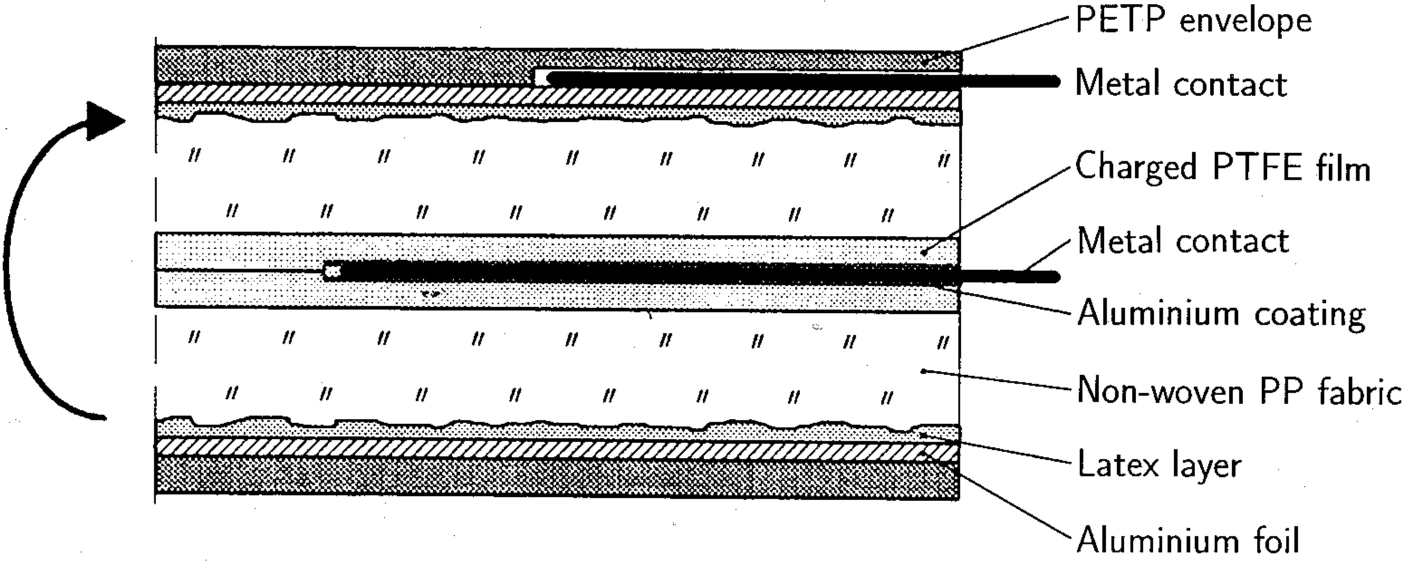


Response: $r_{33} = -\sigma \frac{\varepsilon_1 \varepsilon_2 d_1 d_2}{(\varepsilon_2 d_1 + \varepsilon_1 d_2)^2} \left(\frac{1}{E_2} - \frac{1}{E_1} \right)$

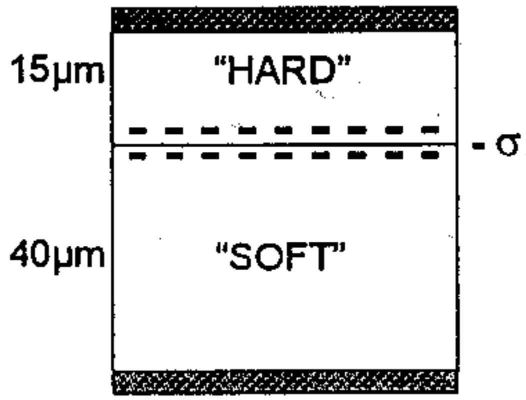
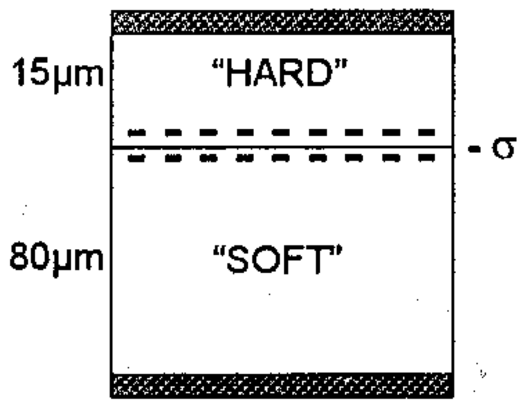
with the charge density σ and the thicknesses d_i, relative permittivities ε_i and elastic (Young's) moduli E_i of the hard (1) and soft (2) layers

Double-layer electret transducer with charged PTFE film and non-woven PP fabric

(after R. Kacprzyk, A. Dobrucki, and J. B. Gajewski, *J. Electrostatics* **39**, 33–40 (1997))



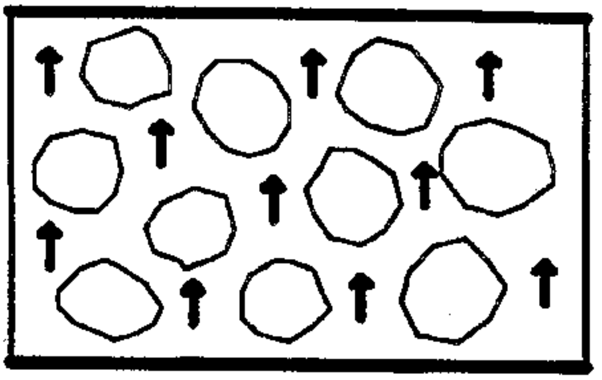
Two-layer arrangements with (D) 40 μm and (E) 80 μm thick porous PTFE films

<table>
<tr><th>Film sequence in stack</th><th>σ (mC/m^2)</th><th>r_{33} (pC/N)</th></tr>
<tr><td rowspan="3">D

</td><td>1.2</td><td>11</td></tr>
<tr><td>2.4</td><td>18</td></tr>
<tr><td>4.8</td><td>30</td></tr>
<tr><td rowspan="3">E

</td><td>1.2</td><td>5.2</td></tr>
<tr><td>2.4</td><td>7</td></tr>
<tr><td>4.8</td><td>15.5</td></tr>
</table>

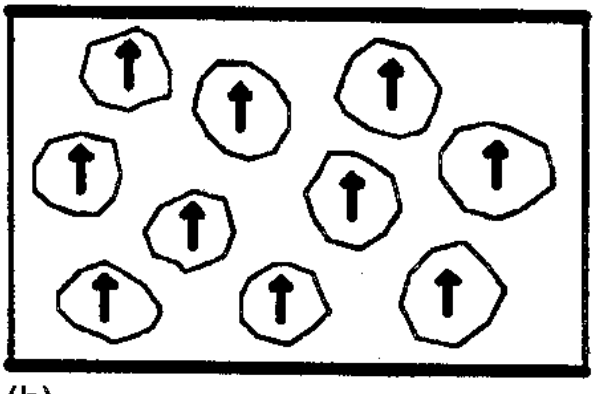
Twice the soft-layer thickness ⇒ Half the response

Composite with poled particles and/or poled matrix

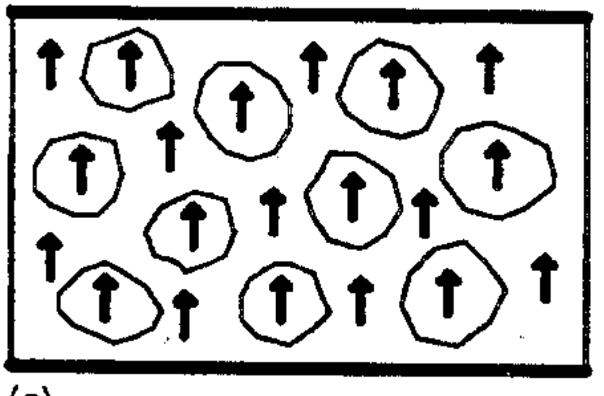
(after Ploss *et alii* 2000)



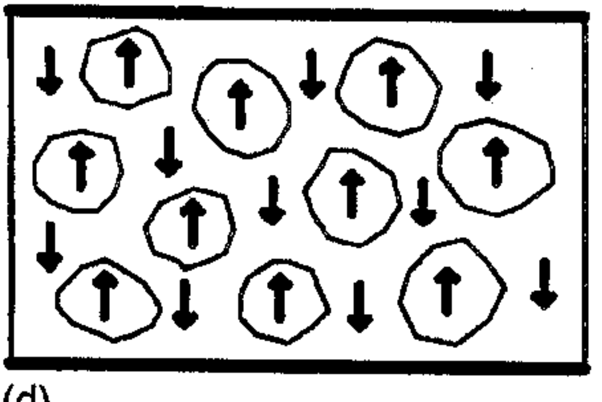
(a)



(b)



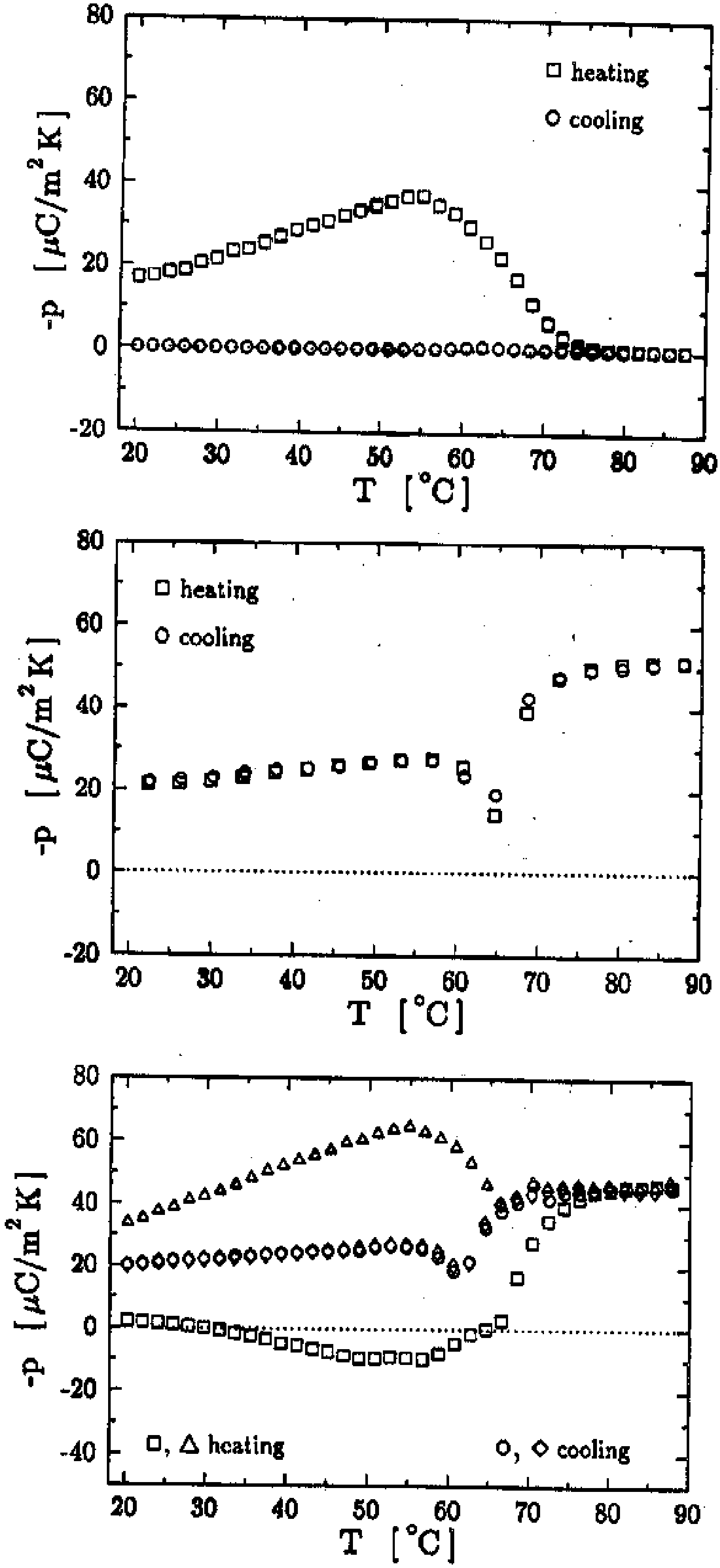
(c)



(d)

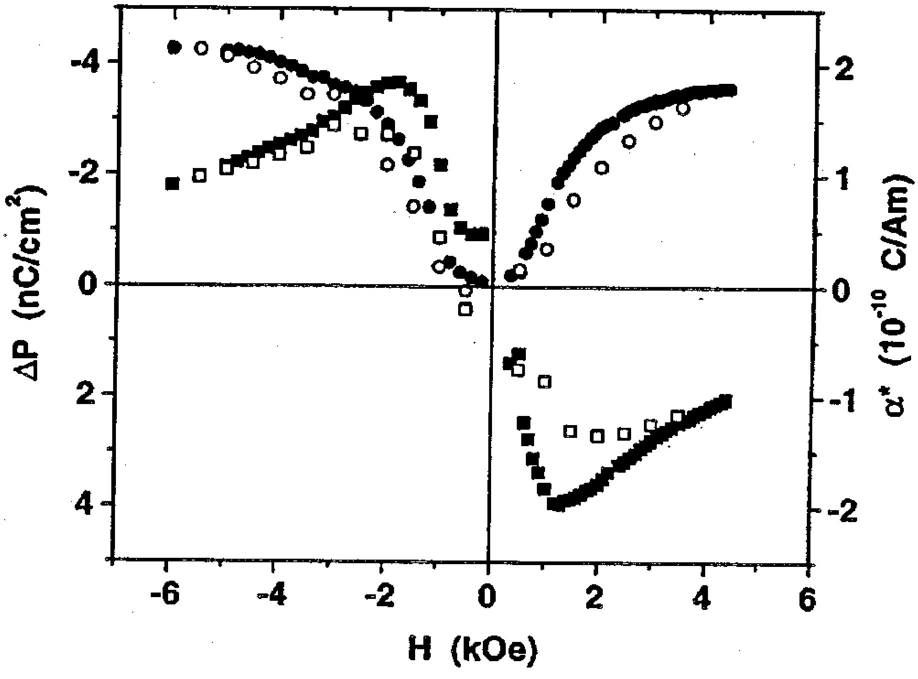
Pyroeletric coefficients of matrix, particles and both

(after Ploss *et alii* 2000)



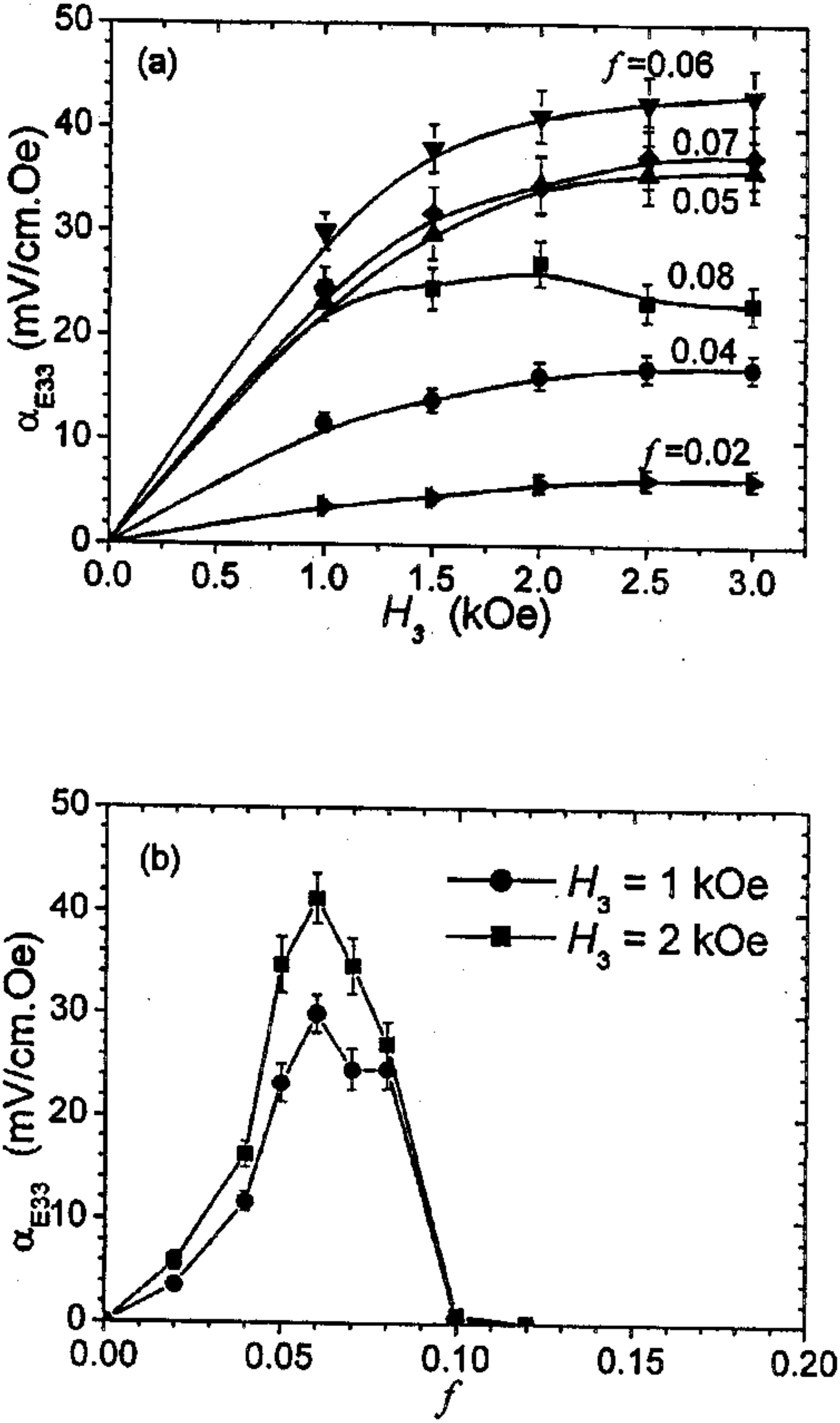
Electric polarization & magnetoelectric coefficient in a 2-layer Terfenol/PVDF composite

(after Mori and Wuttig 2002)



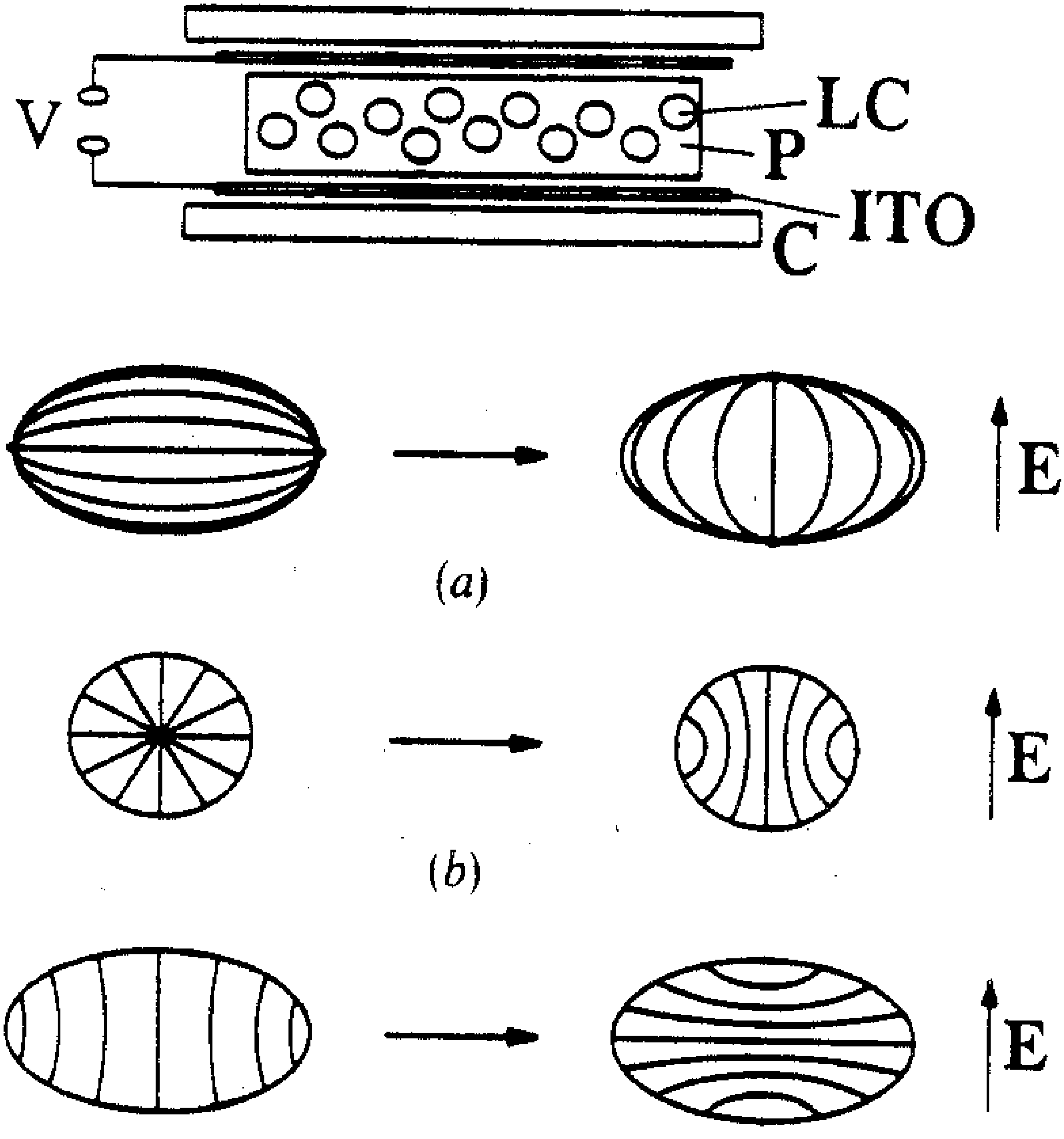
Field- and composition-dependent magnetoelectric coefficients of Terfenol/PZT/PVDF composites

(after Nan *et alii* 2002)



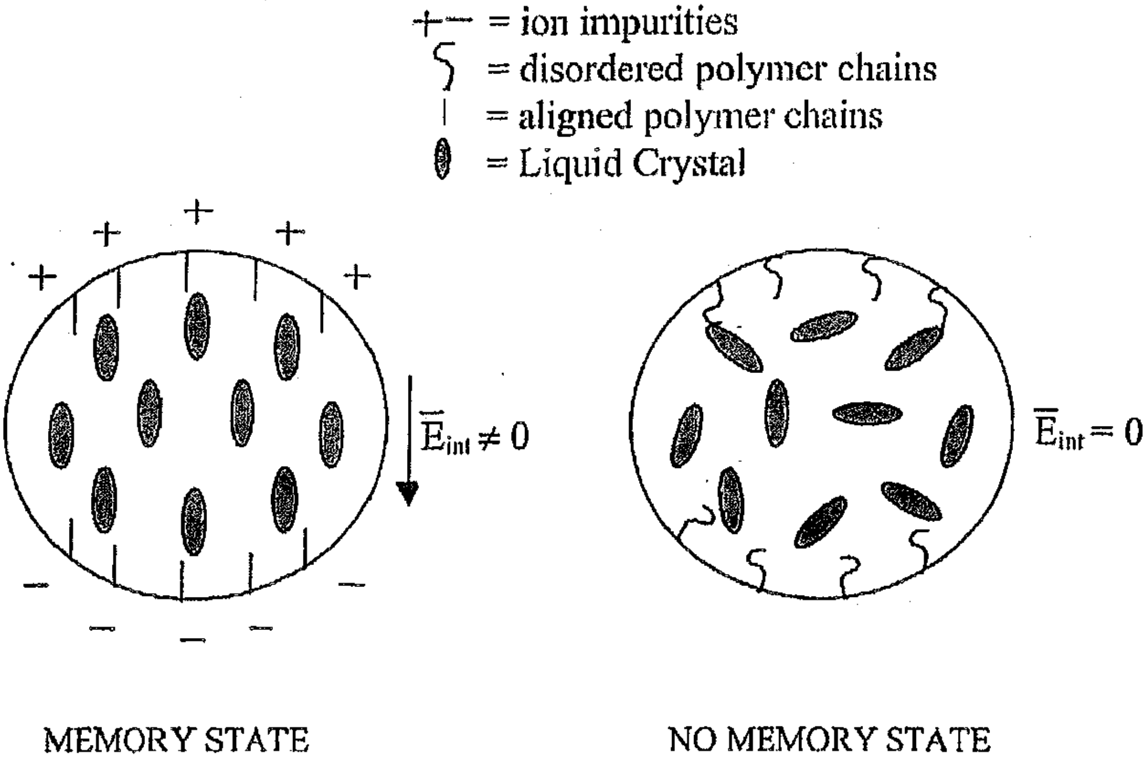
Schematic view of a polymer-dispersed liquid crystal

(after Kitzerow 1994)



Electret (memory) effect in the polymer matrix of polymer-dispersed liquid crystals

(after Cupelli, Nicoletta, de Filpo, and Chidichimo 2001)



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