# Breve Introducción a la Física de los Materiales Poliméricos

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Nuevos usos para viejos Materiales y nuevos Materiales para viejos usos
( 16-19 de Abril 2007) , Universidad Complutense de Madrid

## Esquema

- Introducción histórica
- Nociones de termodinámica
- Nanoestructura de los Materiales Poliméricos
- Dinámica de Polímeros
- Propiedades Eléctricas
- Propiedades Mecánicas

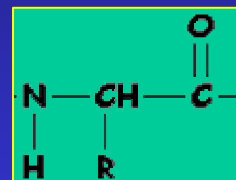
http:/www.iem.cfmac.csic.es/fmacro/downloading.htm

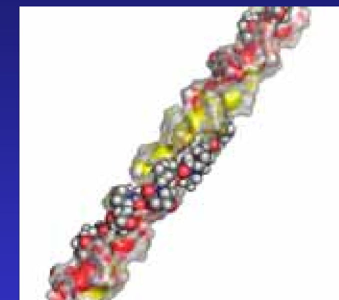
imte155@iem.cfmac.csic.es

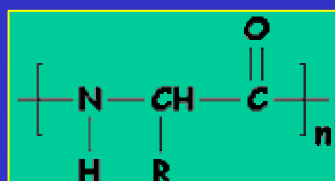
# Historia de los Materiales Poliméricos: El origen

Proteinas

Colágeno

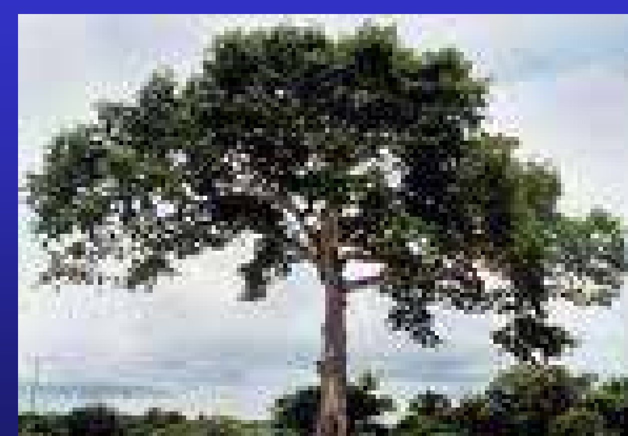


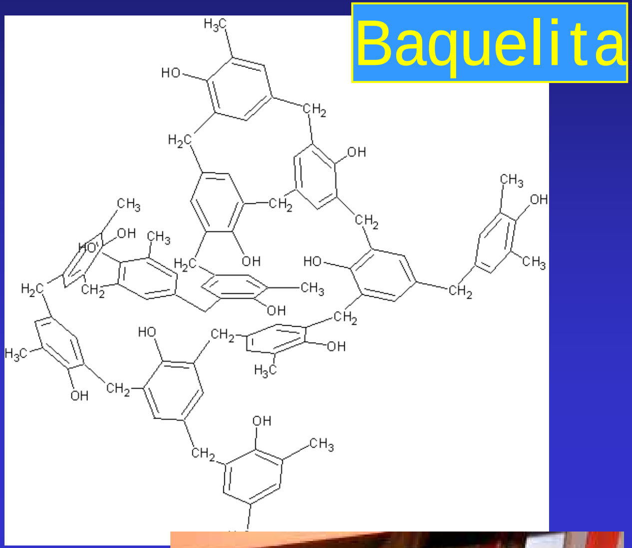



Seda

Celulosa



# Historia de los Materiales Poliméricos: Nacimiento




1862
Primer plástico
hecho por el hombre

1866
Celuloide

1891
Rayón
(viscosa)

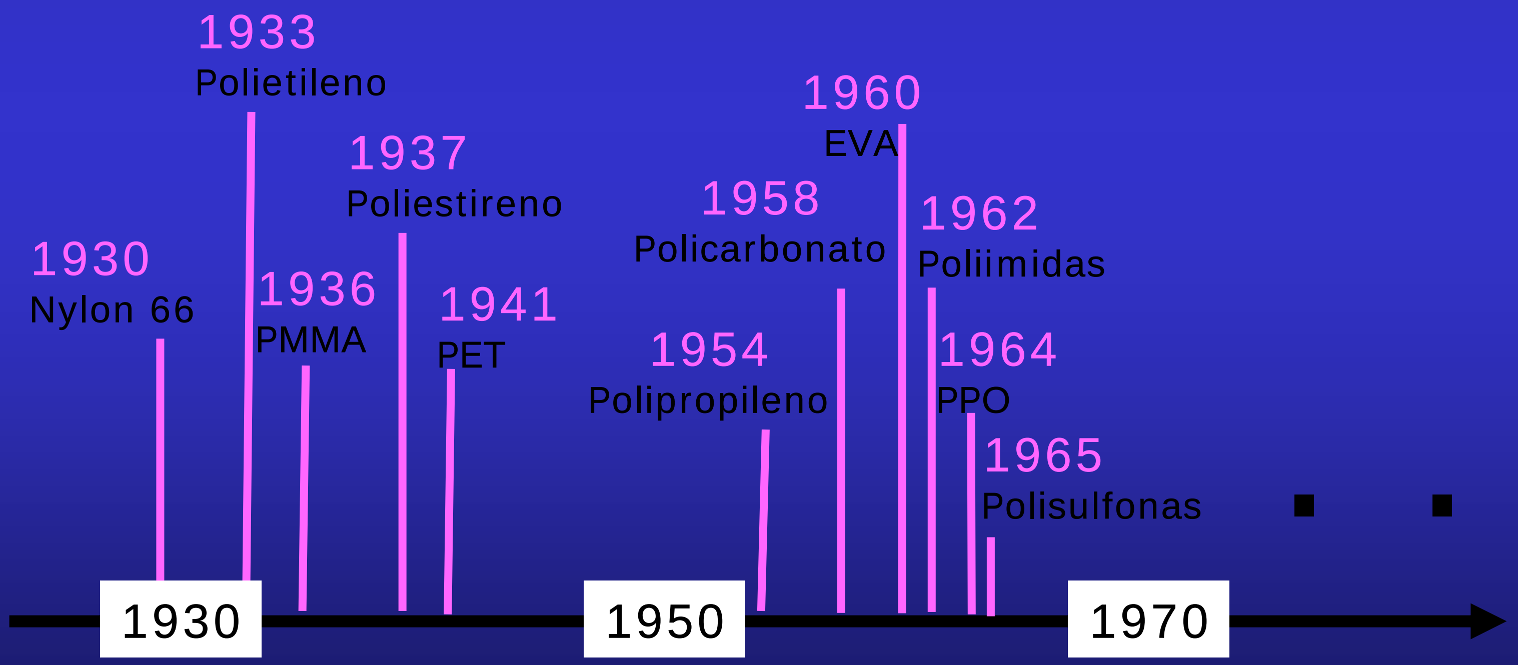
1907
Baquelita

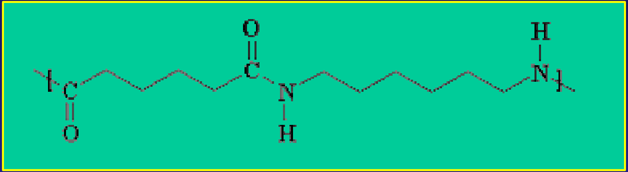
1913
Celofán

1880 1900 1920

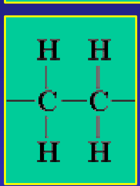
# Historia de los Materiales Poliméricos: La explosión

Sintéticos

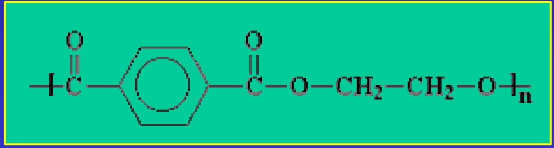




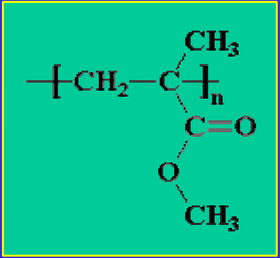
PA 6-6: Nylon 6-6



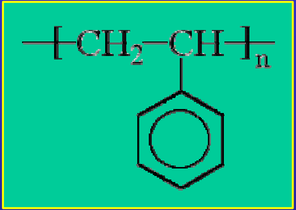
PE: Polietileno



PET: Polietilentereftalato



PMMA: Polimetilmetacrilato



PS: Poliestireno

$$(A)\text{-}(A)\text{-}(A)\cdots\cdots\cdots(A)\text{-}(A) \qquad (A)_{n-1} \Rightarrow (A)_n$$

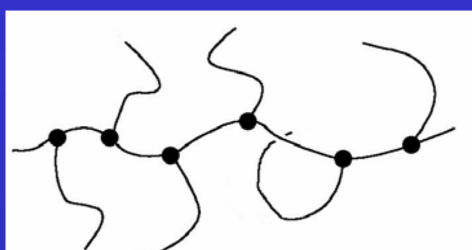
# Tipos de Materiales Poliméricos

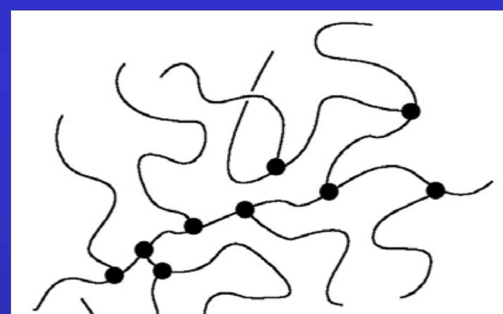
**Homopolímeros:** Todas los monómeros son iguales

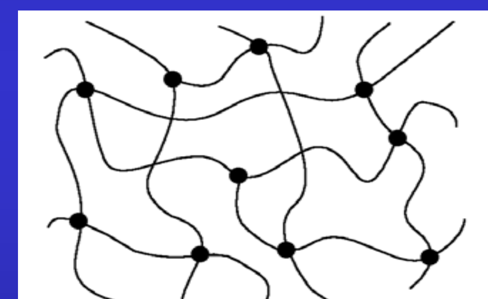
**Copolímeros :** Unidades monoméricas de diferente tipo

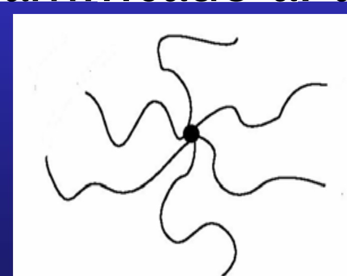
proteinas (20 tipos diferentes de unidades)
ADN (cuatro tipos diferentes de unidades)

## ARQUITECTURA DE POLÍMEROS

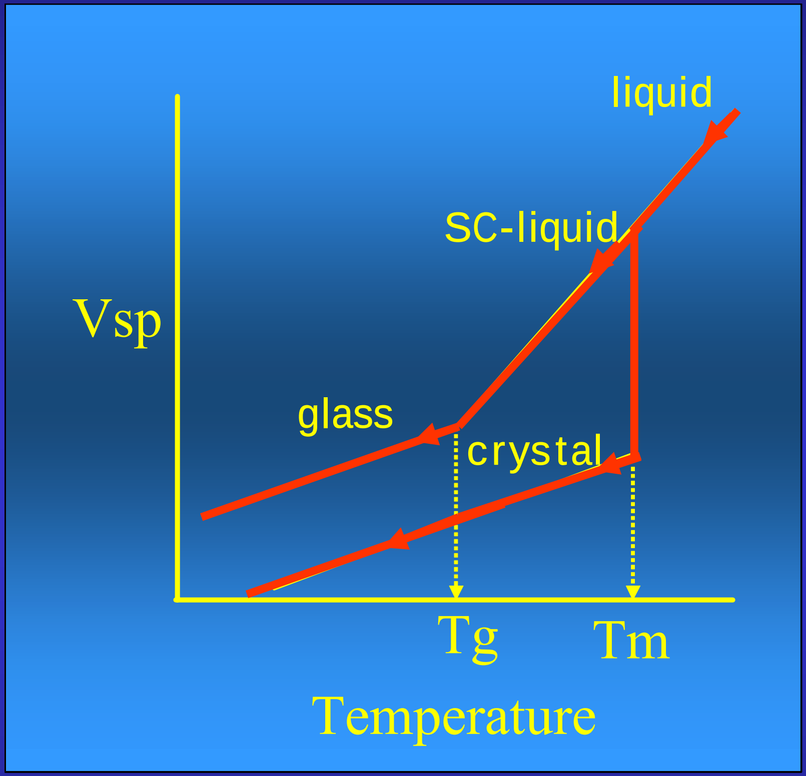

Tipo peine


Ramificado al azar

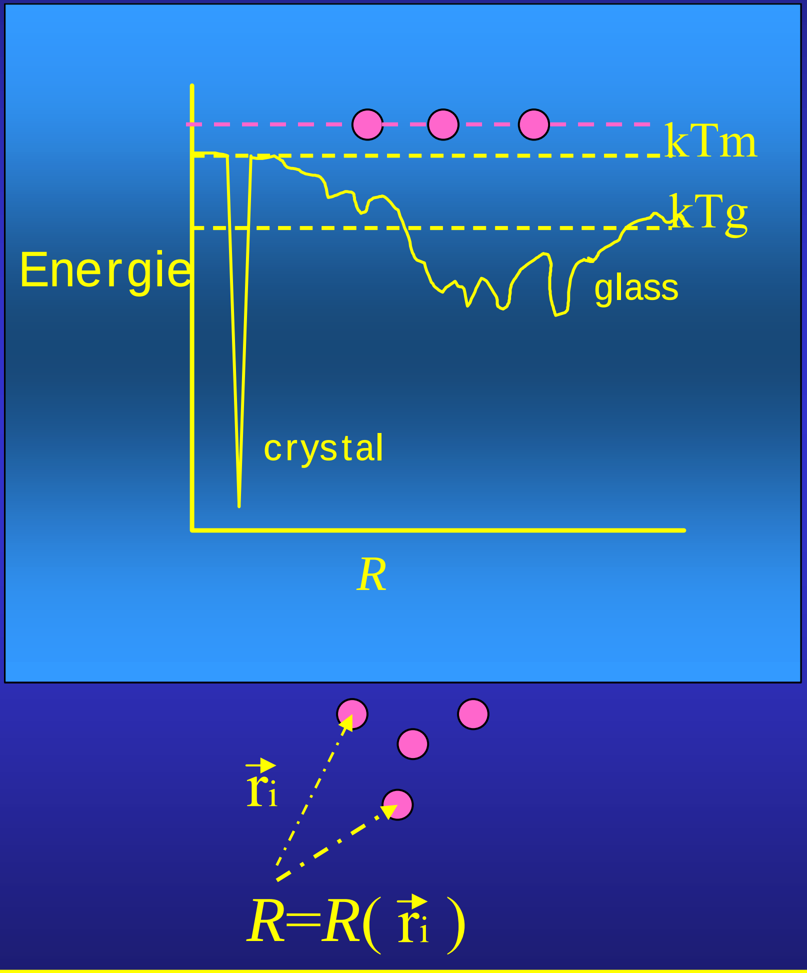

Red polimérica


Tipo Estrella

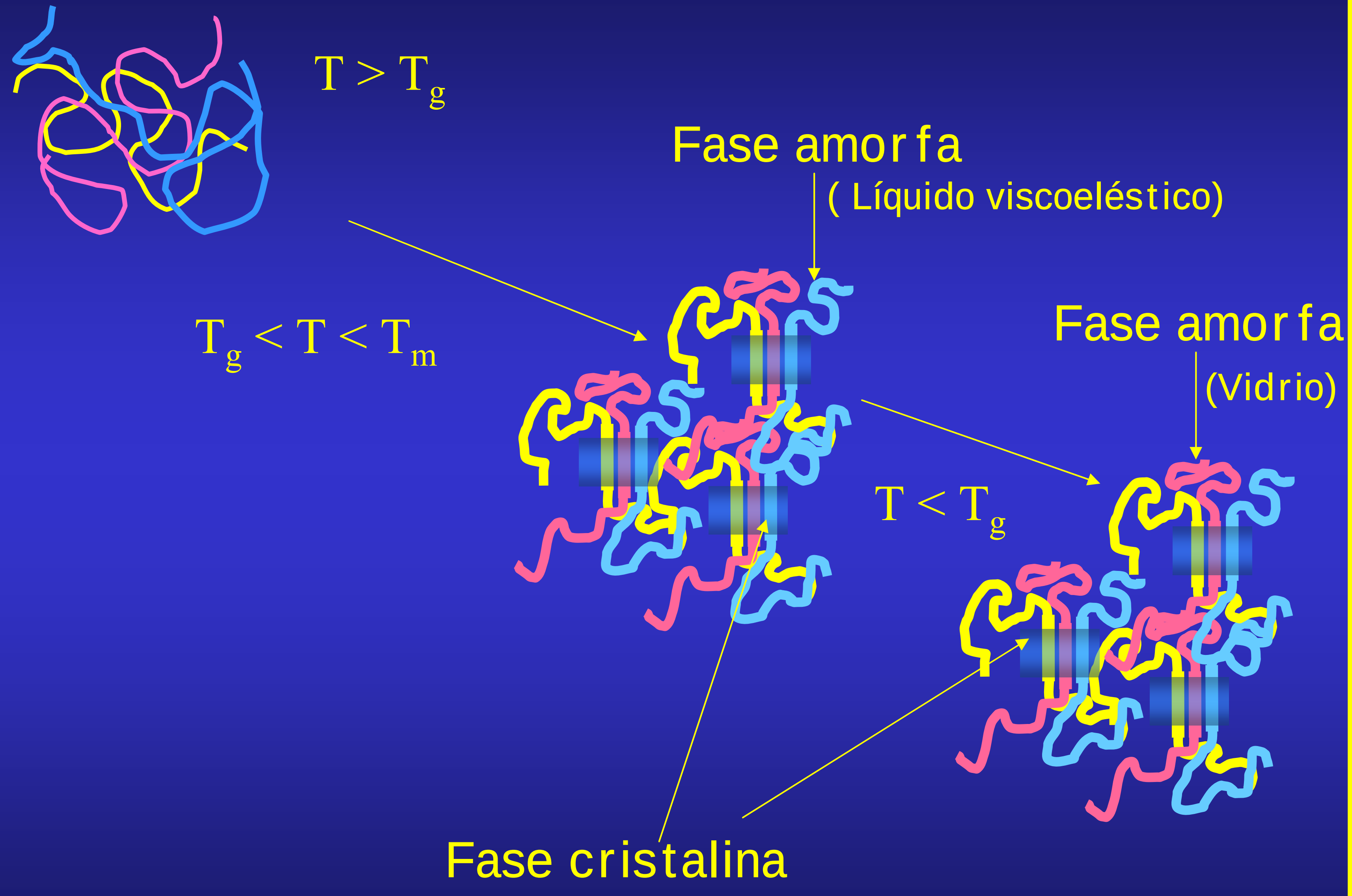
# Termodinámica



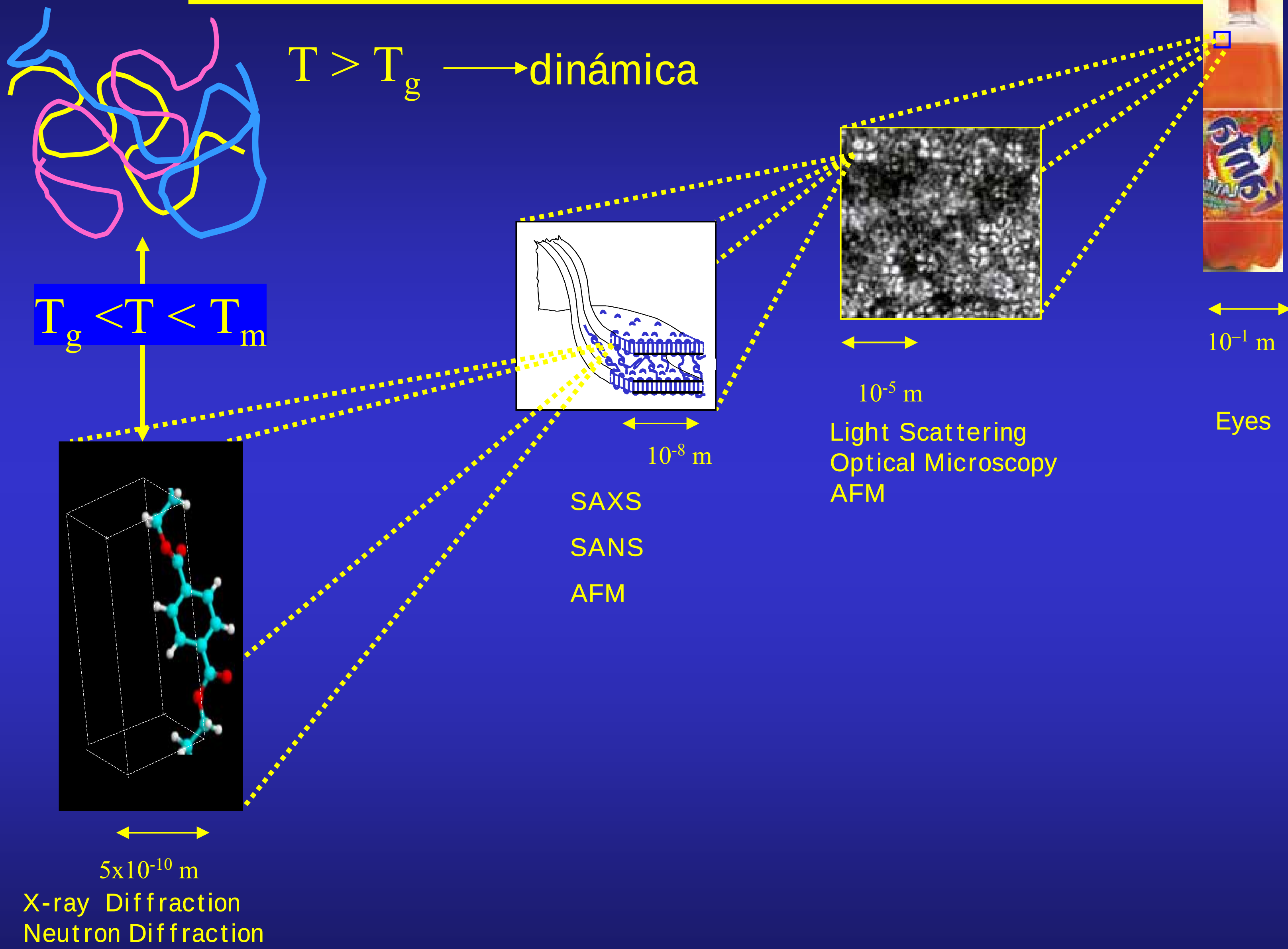

M.D. Ediger,C.A. Angell, S.R. Nagel,
J.Phys.Chem. 100,13200 (1996)



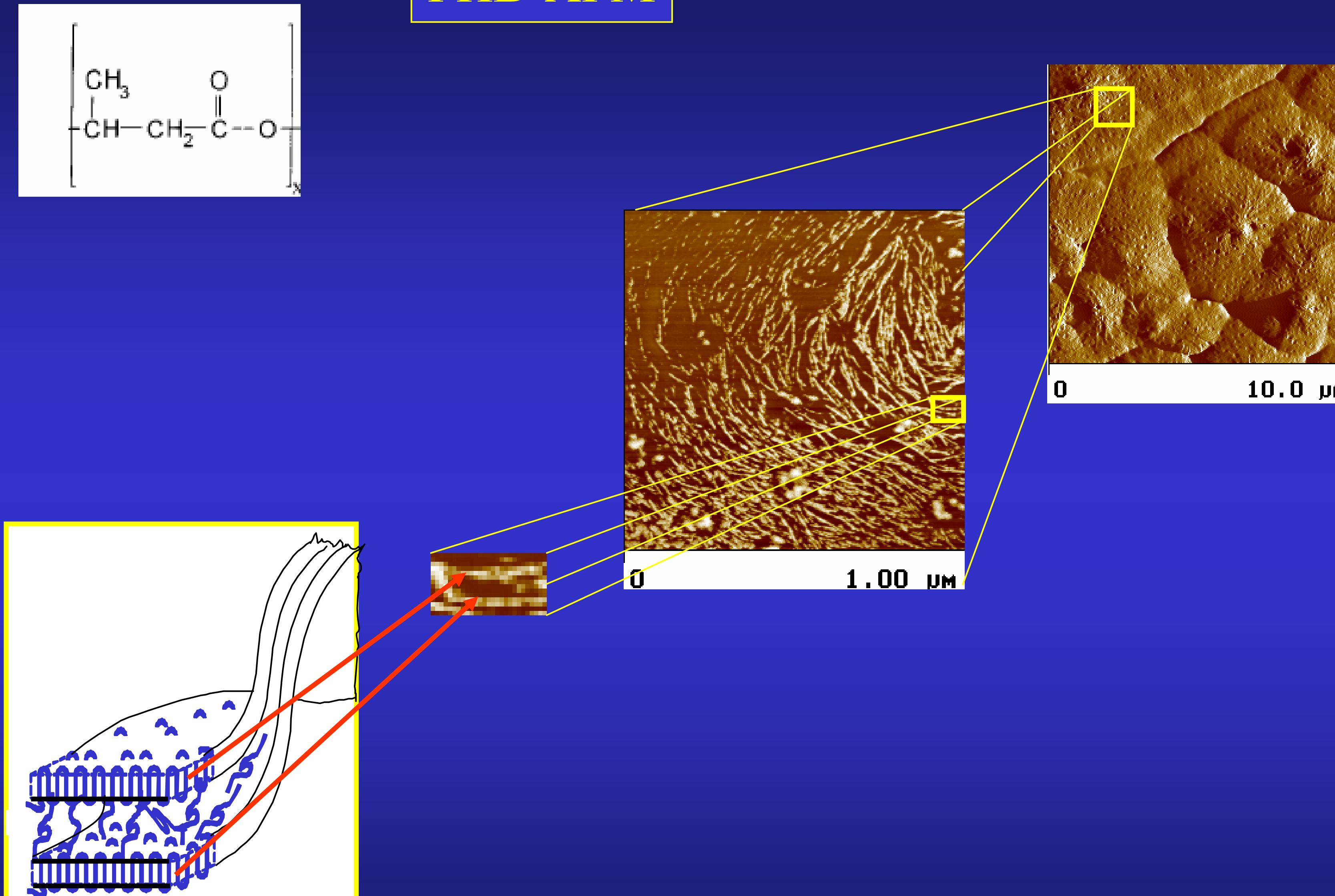
# Materiales Poliméricos : Termodinámica



# Materiales Poliméricos : Jerarquías Estructurales



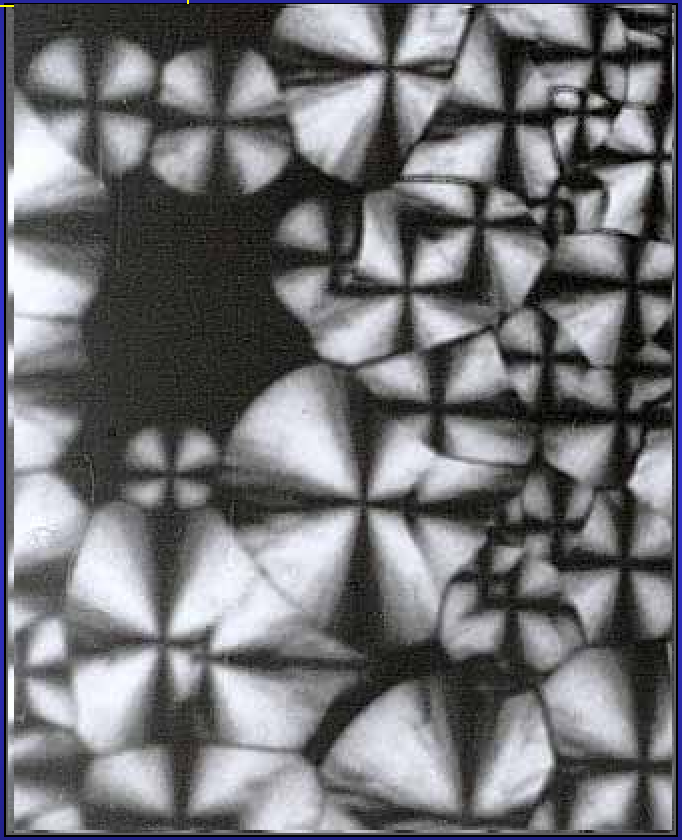
# PHB-AFM



# Cristalización de Materiales Poliméricos

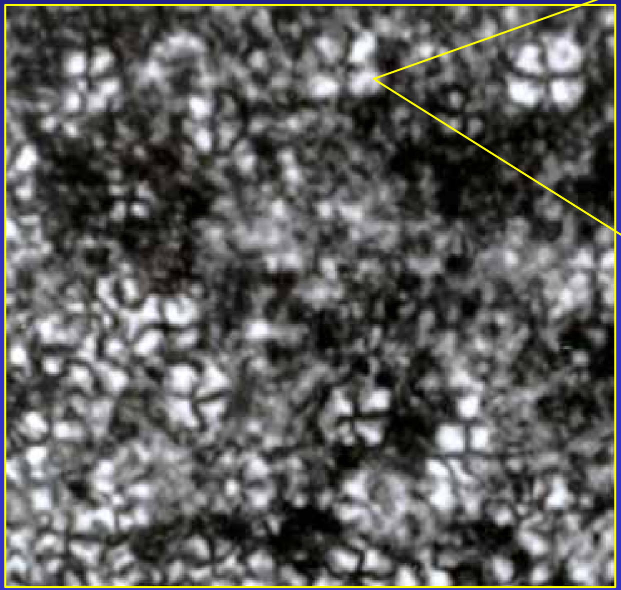
tiempo=30 s

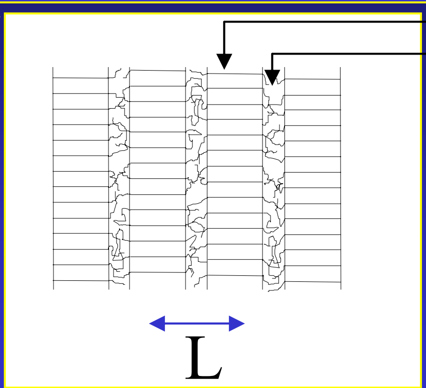
120 s



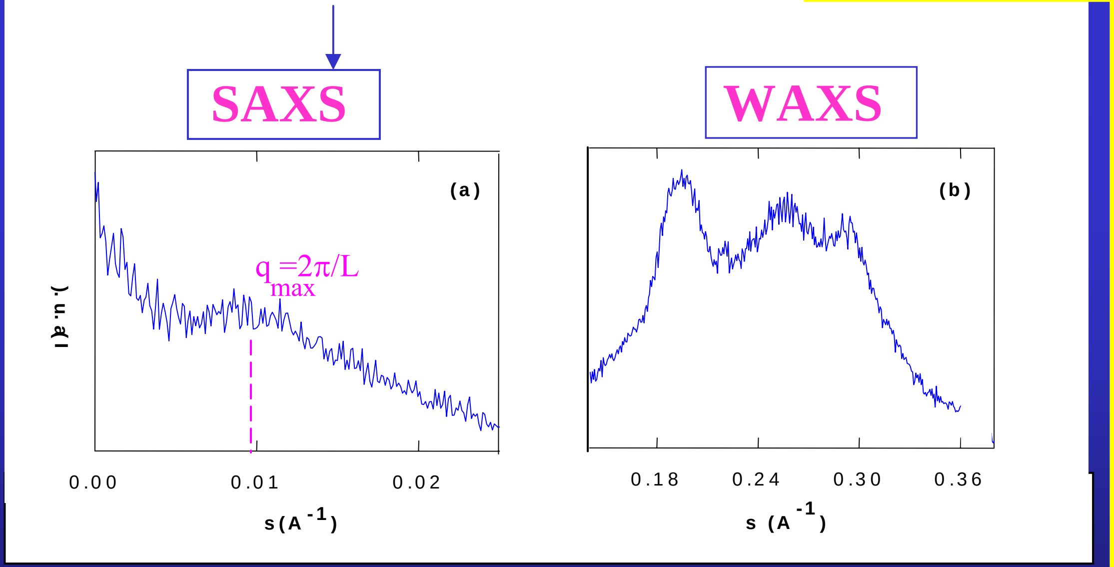
Tg < Tc < Tm

# Técnicas Experimentales : Estructura





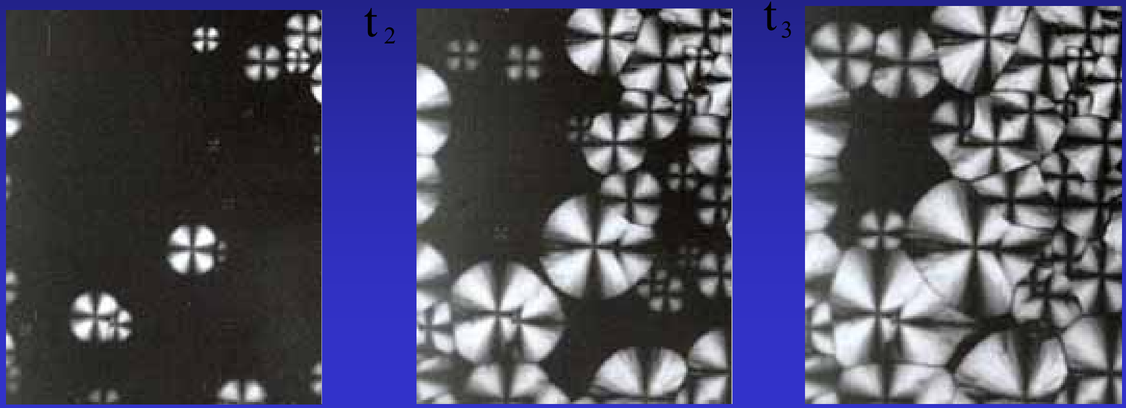

## Structure

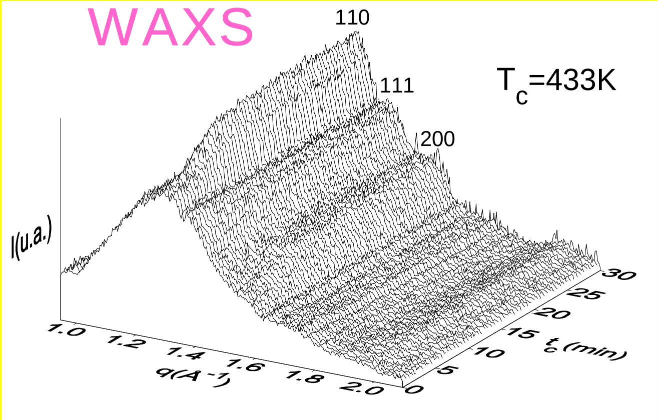


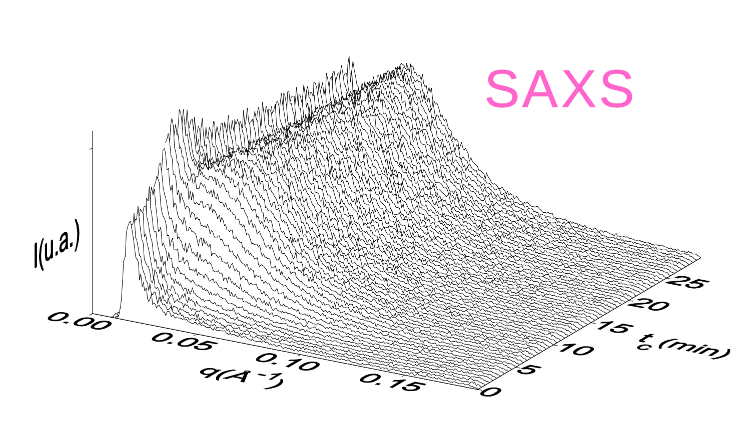
# Cristalización en tiempo real: luz Sincrotrón

tiempo

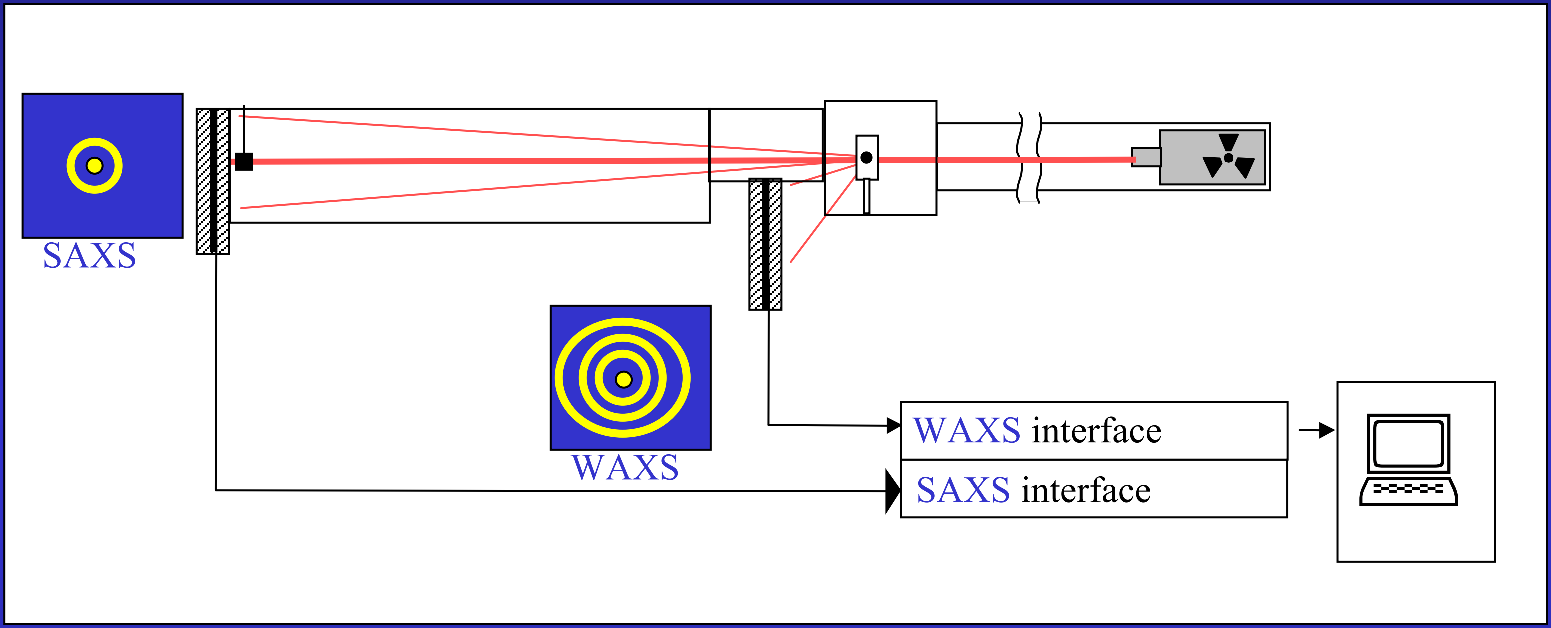
$t_1$ $t_2$ $t_3$





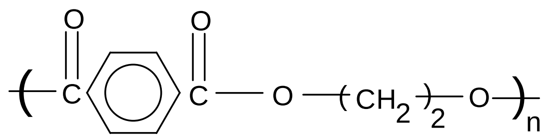
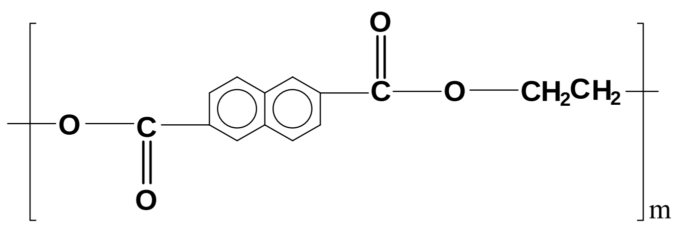
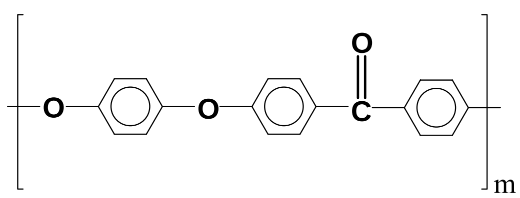



# Esquema del Dispositivo Experimental



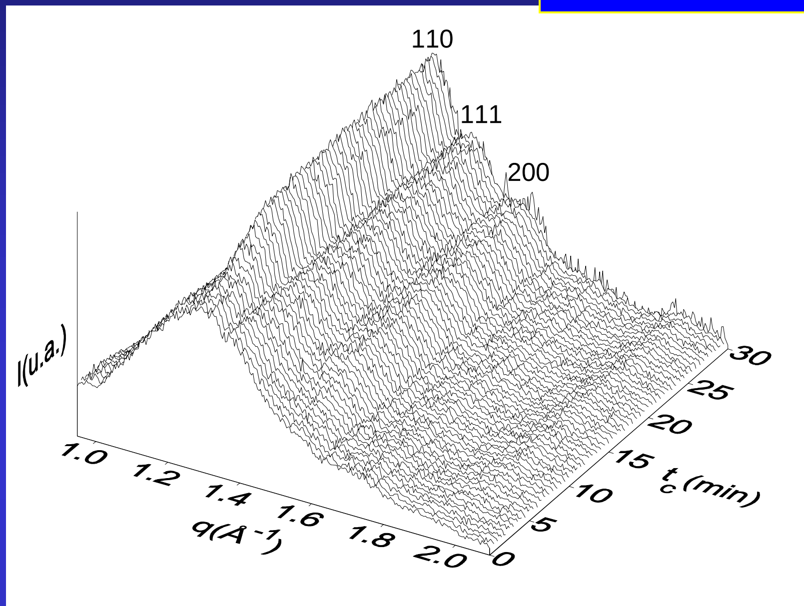

Ley de Bragg $d = \lambda/(2 \sin \theta)$

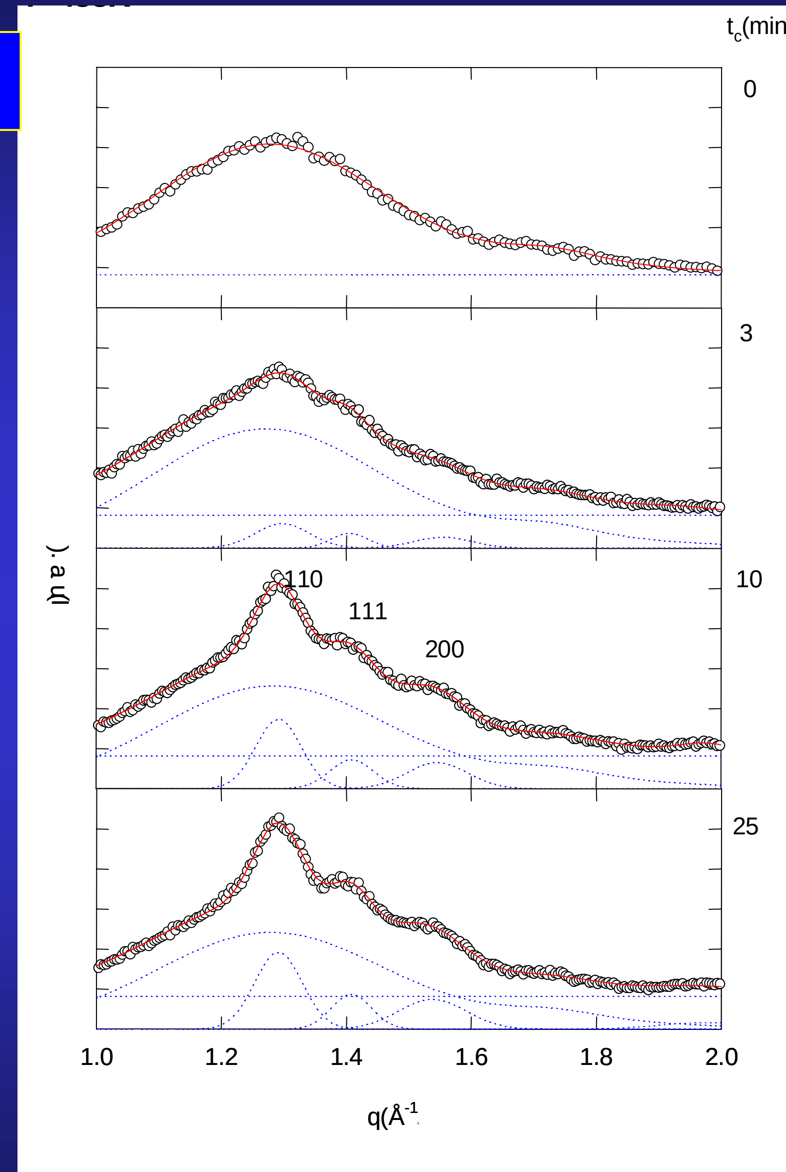
# Materiales Poliméricos de ingeniería

| | | Tg ($^{o}C$) |
|---|---|---|
|  | PET | 75 |
|  | PEN | 117 |
|  | PEEK | 145 |

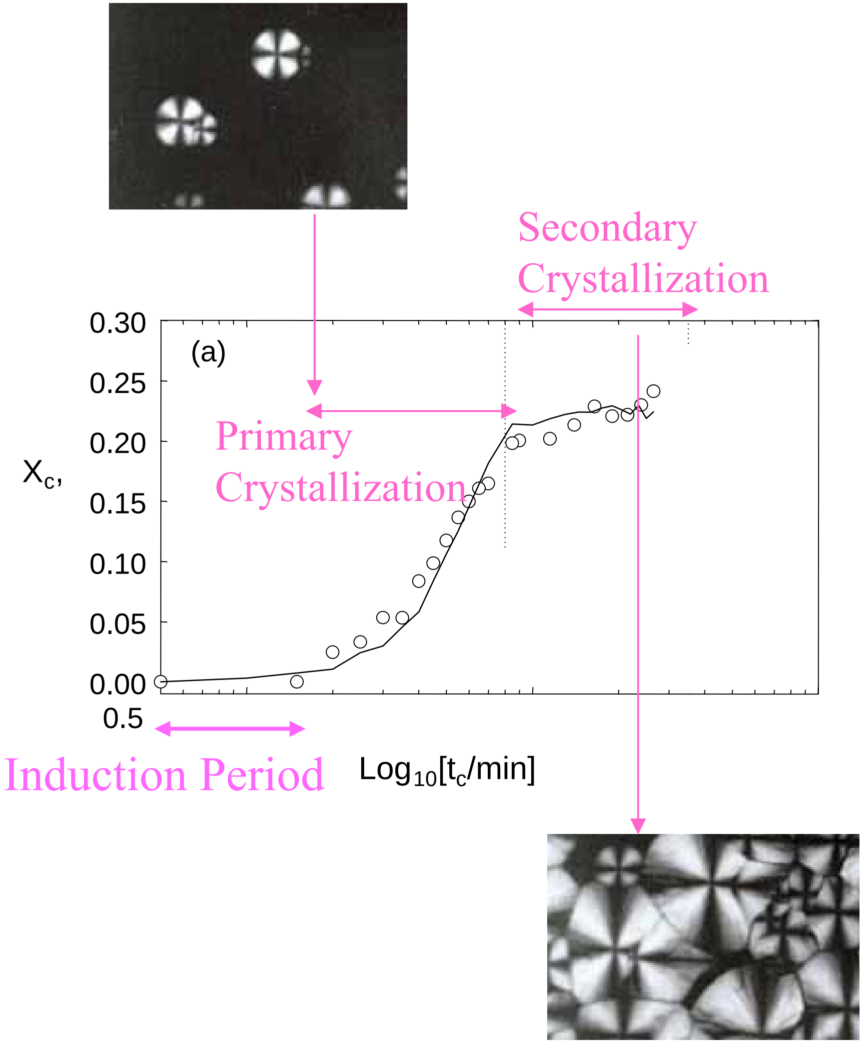
# Rayos-X : PEEK

Tc = 160 $^{o}$C



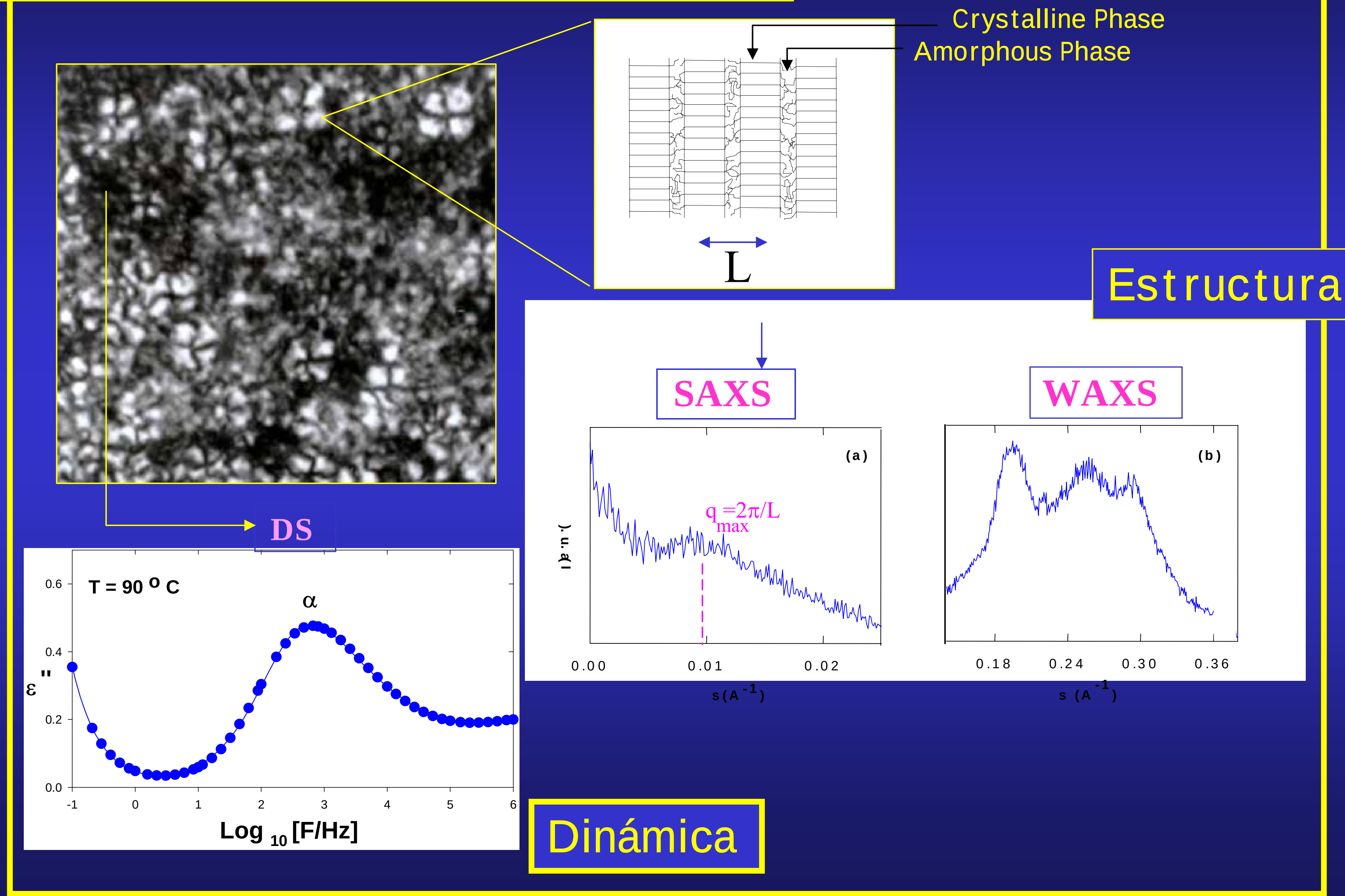




$$\text{Cristalinidad} = \frac{\text{Fracción de cristales}}{\text{Total}}$$



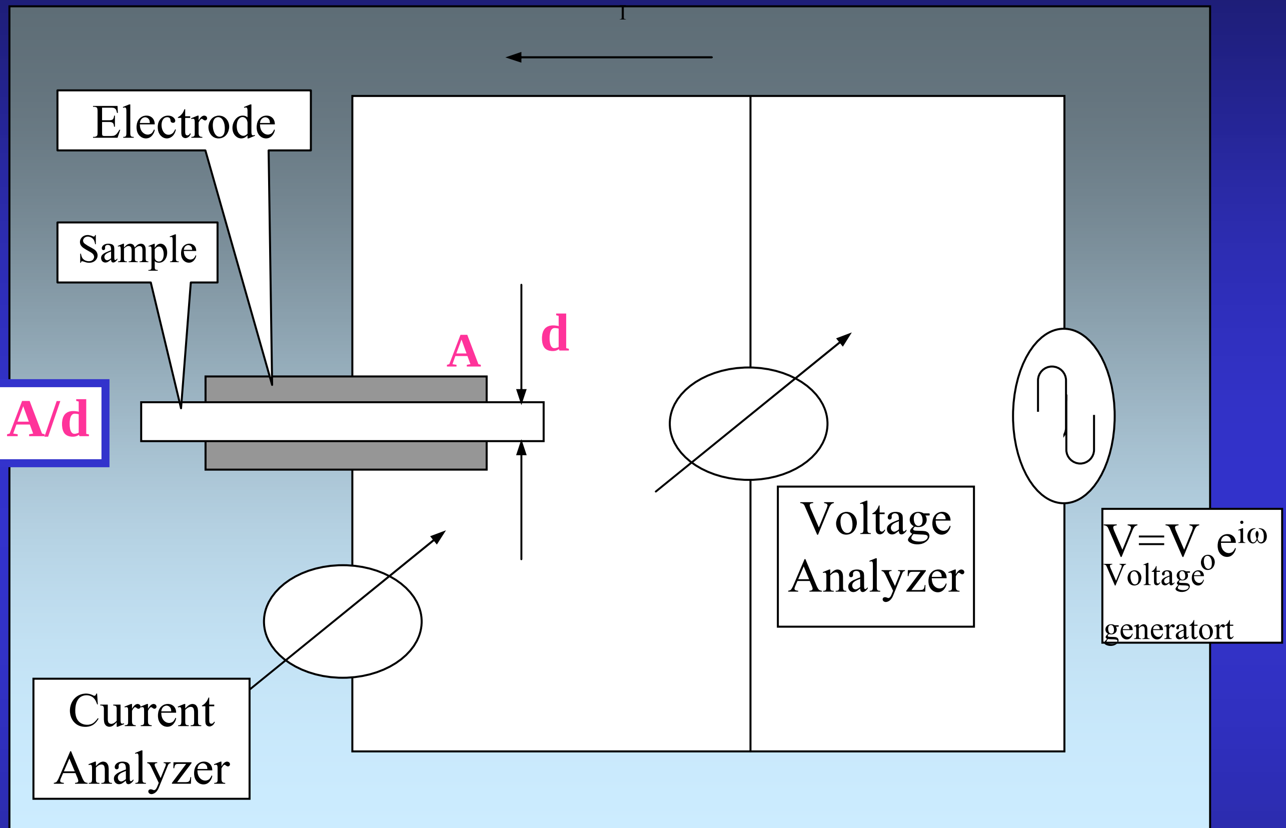
Secondary
Crystallization
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.5
(a)
Xc,
Primary
Crystallization
Induction Period
Log10[tc/min]

# Técnicas Experimentales : Dinámica



# Dinámica de Materiales Poliméricos Espectroscopía Dieléctrica

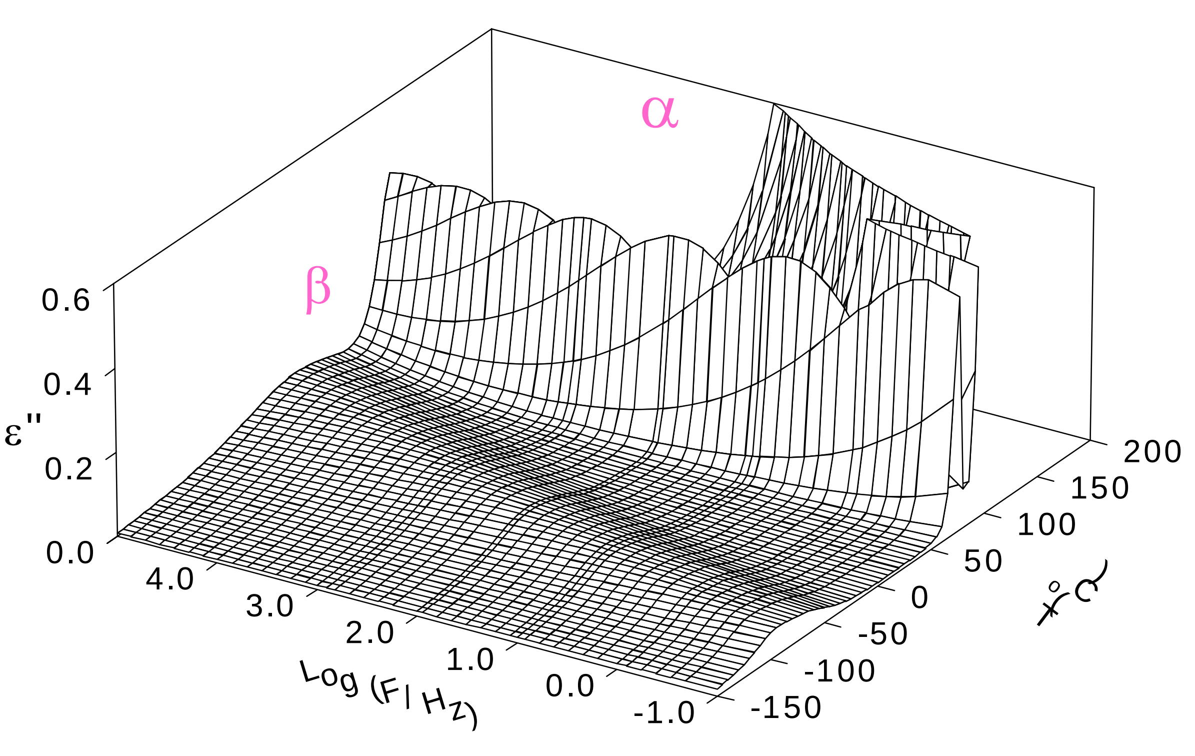
$Co = \varepsilon o\ A/d$



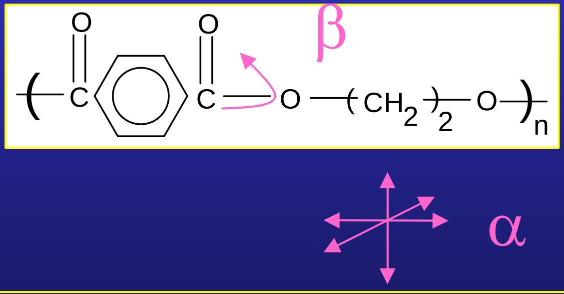

$Ic = i\ \omega\ Co\ \varepsilon'\ V$

$Ir = \omega\ Co\ \varepsilon''\ V$

# Dinámica de Materiales Poliméricos Espectroscopía Dieléctrica

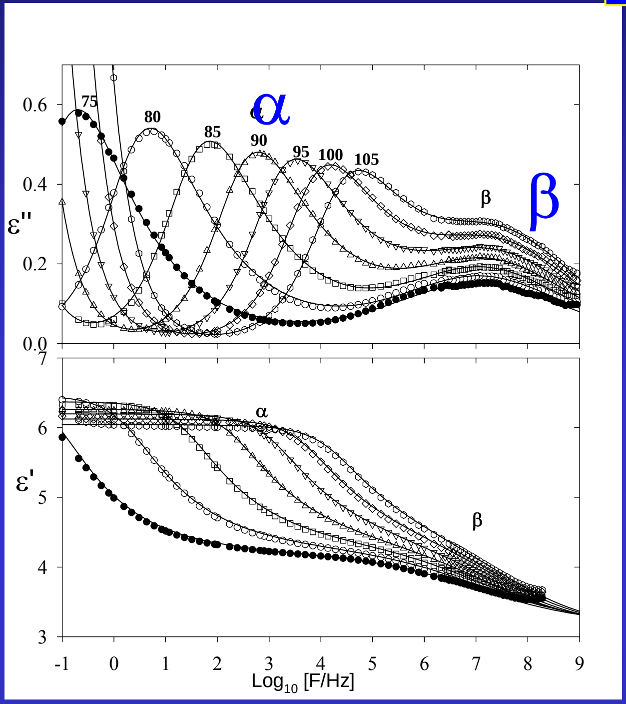


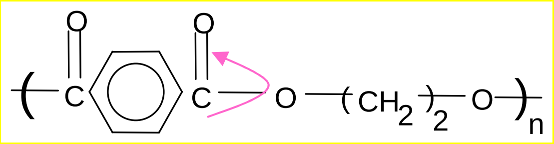

PET



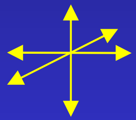
# Dinámica de Materiales Poliméricos Espectroscopía Dieléctrica

## PET



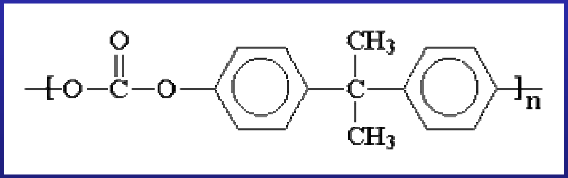
β



α

$$\varepsilon^* = (\varepsilon_\infty)_\beta + \sum_{x=\alpha,\beta} \frac{(\varepsilon_0 - \varepsilon_\infty)_x}{\left[1+(i\omega\tau_x)^{b_x}\right]^{c_x}}$$

## Policarbonato



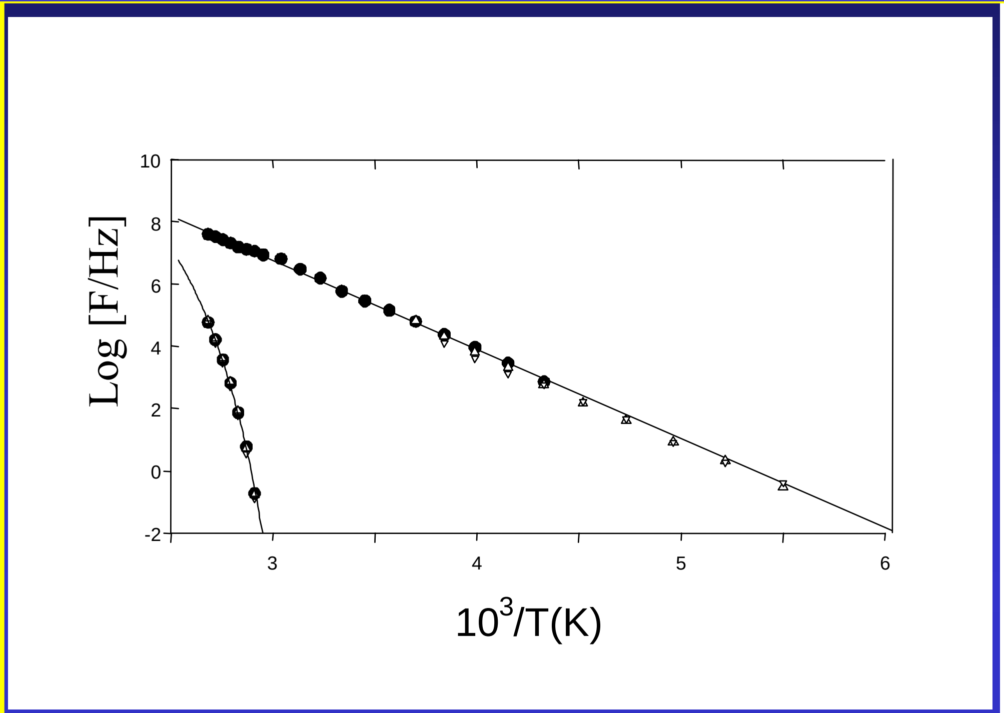
Alto resistencia al impacto mecánico

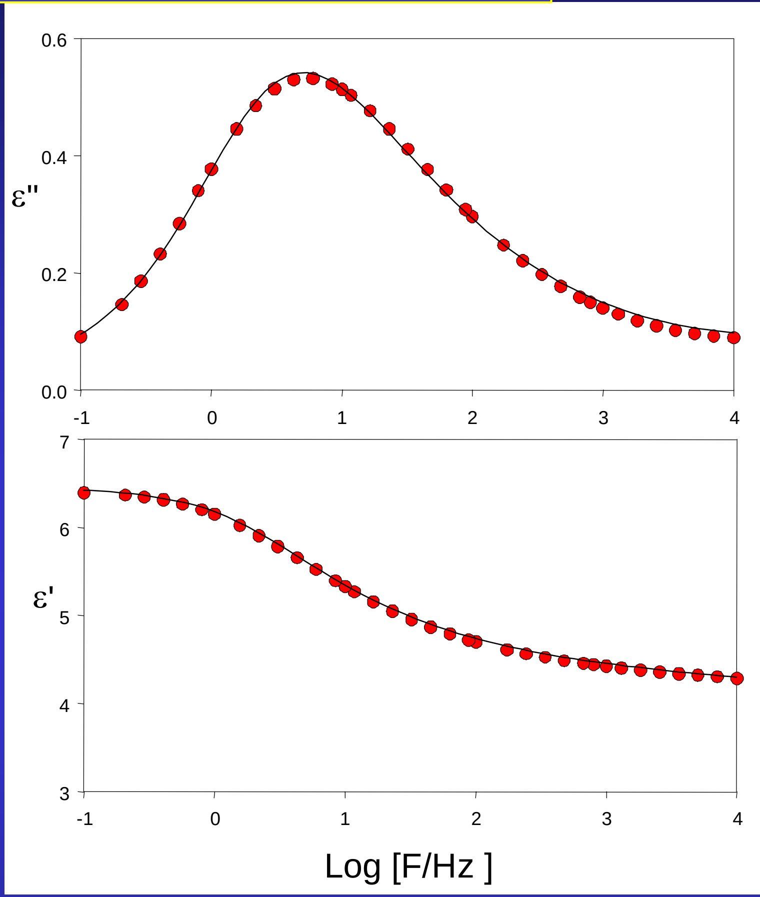
debido a la disipación de energia

por la relajación β

# Dinámica de Materiales Poliméricos Espectroscopía Dieléctrica

PET




VFT

$F_{max} = F_0 \exp(-DT_0 / (T - T_0))$

α

Arrehnius

$F_{max} = F_0 \exp(-E / T)$

β

HN

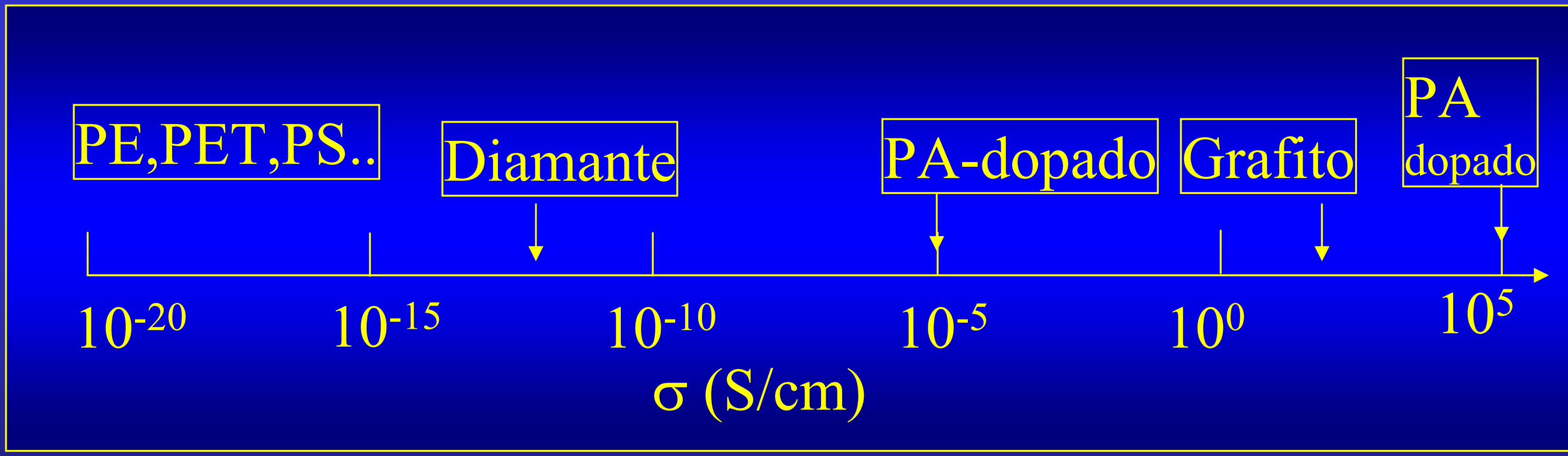
$$\varepsilon^*(\omega) = \frac{\varepsilon_o - \varepsilon_\infty}{\left(1 + (\iota\omega\tau_o)^b\right)^C} + \varepsilon_\infty$$

# Propiedades Eléctricas de Materiales poliméricos

## Conductividad eléctrica

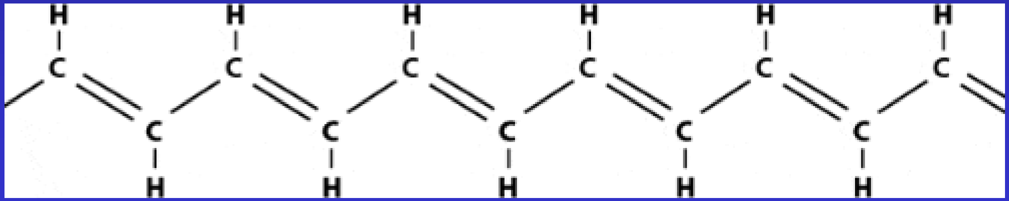
$$\sigma = n \, \mu \, q$$

- q → Carga
- μ → Movilidad
- n → Número de portadores

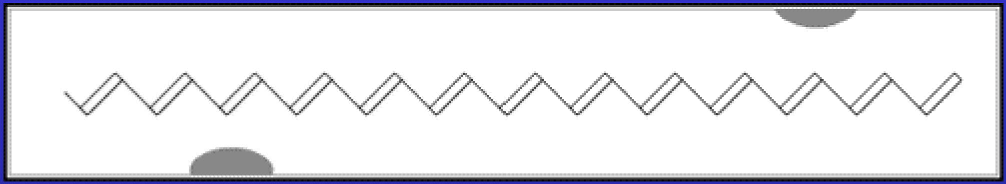


# Propiedades Eléctrica de Materiales poliméricos: Polímero Conductores

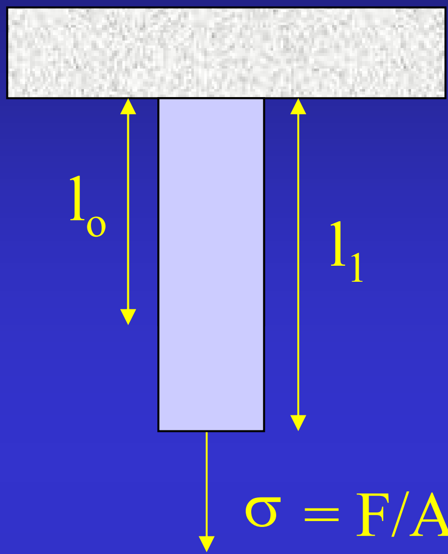
⇨ Premio Nóbel 2000




Poliacetileno



# Propiedades Mecánicas de Materiales poliméricos

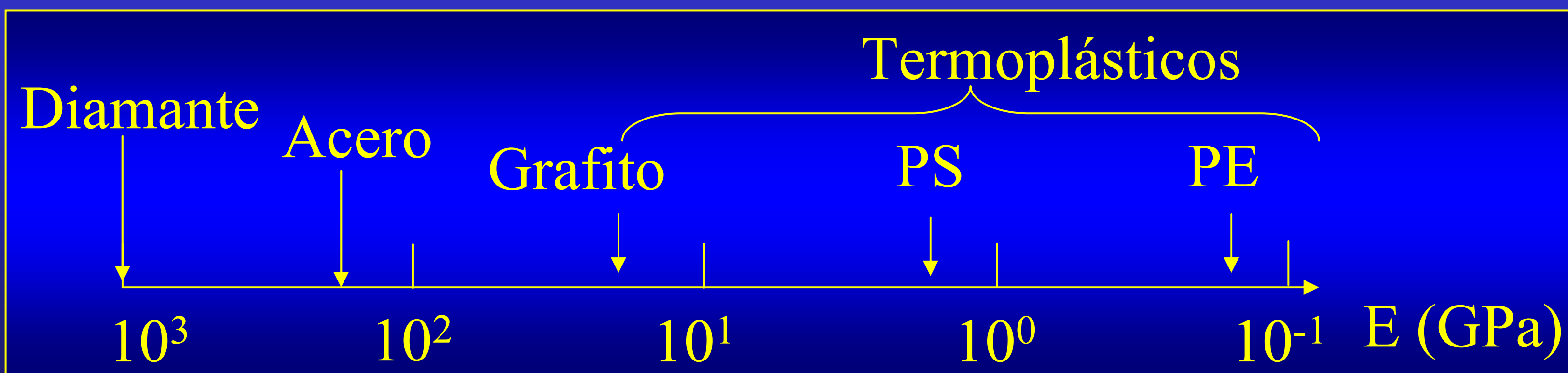



$\sigma = F/A$ esfuerzo

$\Delta l = l_1 - l_o$ deformación

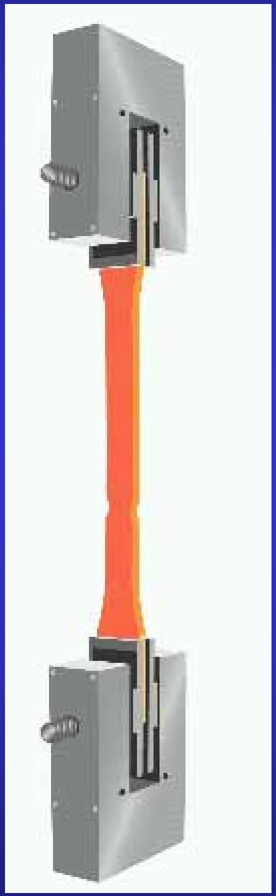
$\varepsilon = \Delta l / l_o$ Deformación unitaria

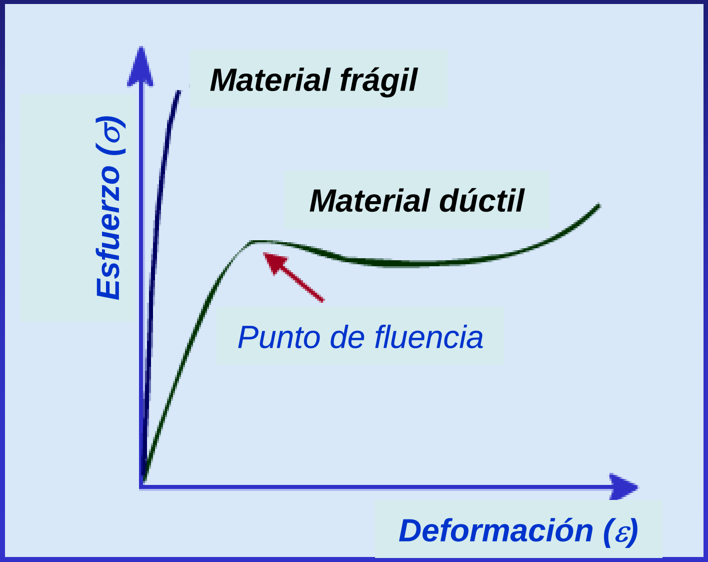
$E = \sigma / \varepsilon$ Módulo de Young

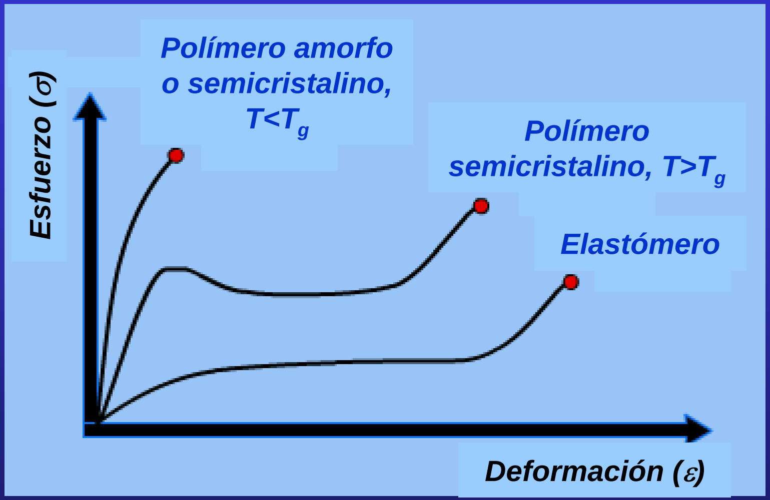


# Comportamiento mecánico

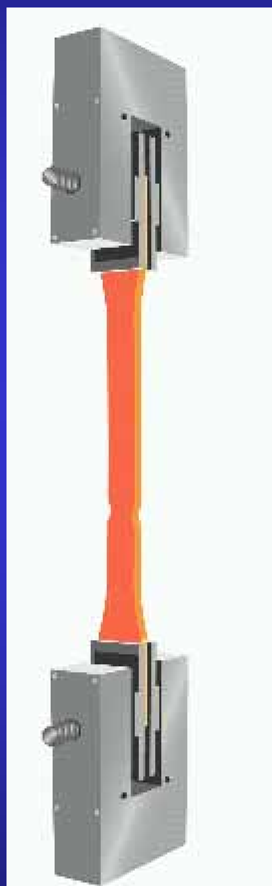
**Ensayo esfuerzo-deformación en tracción**

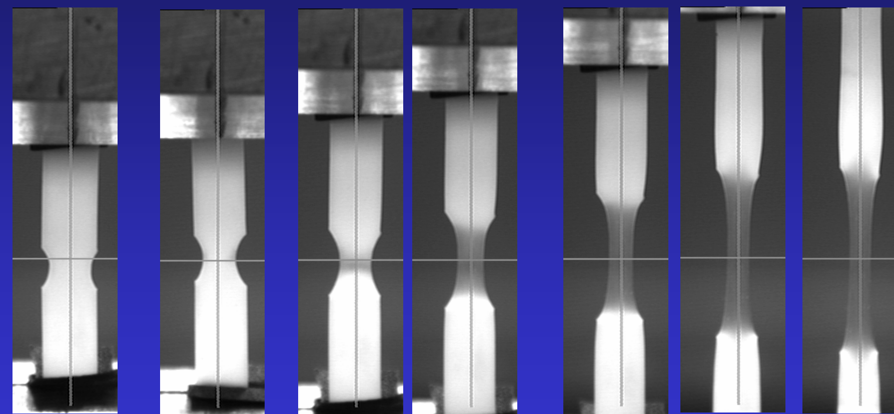


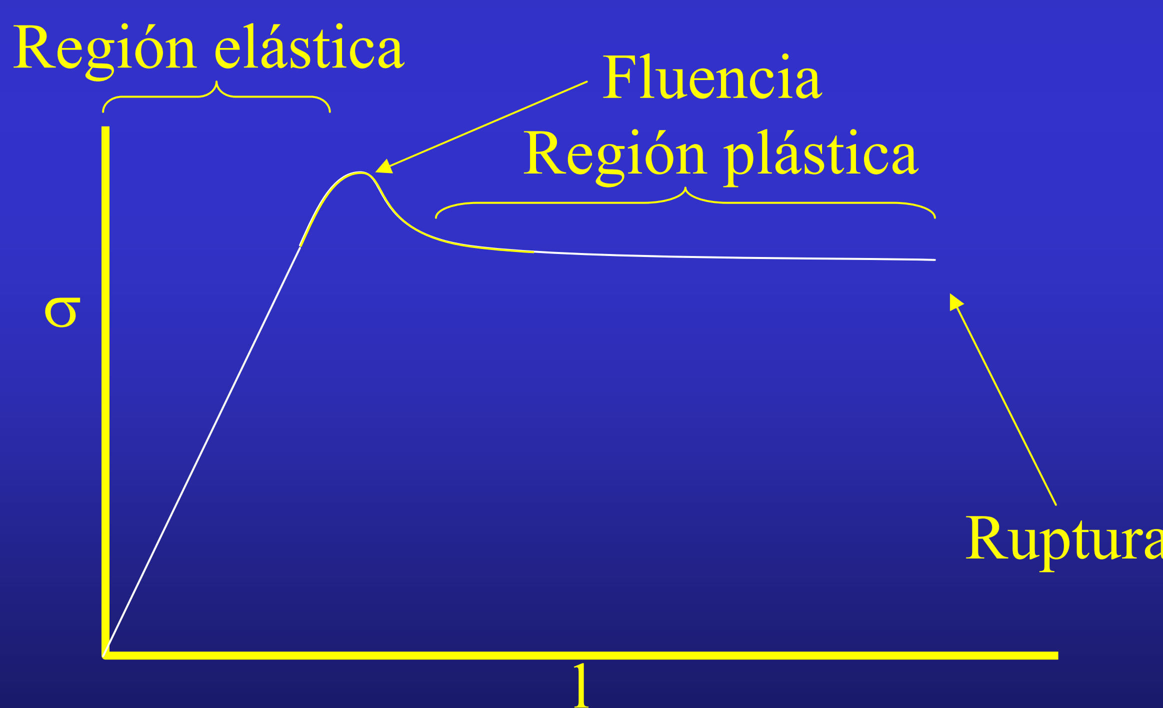


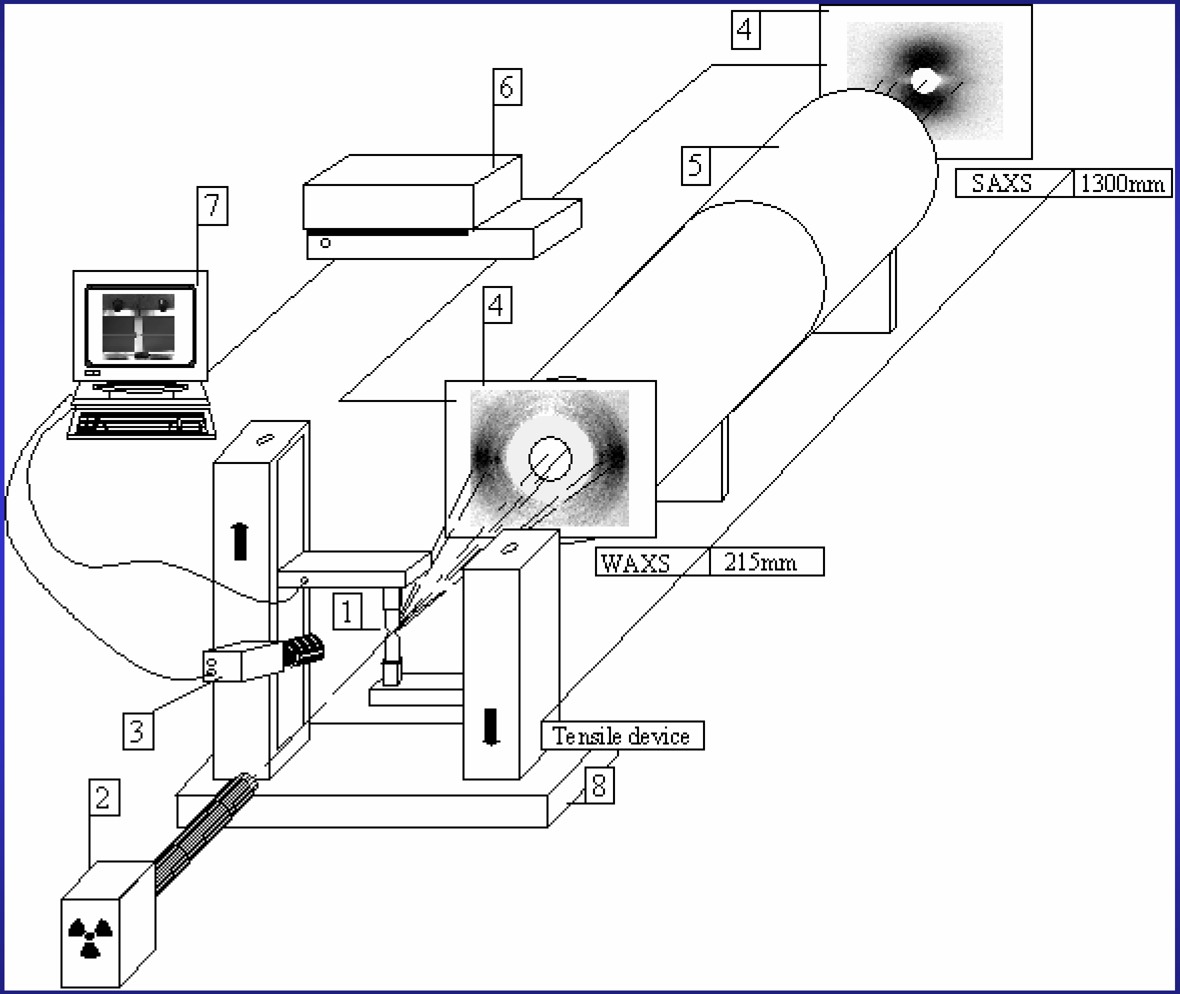
# Propiedades Mecánicas





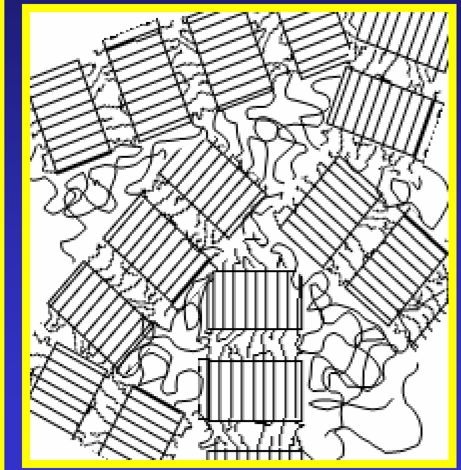


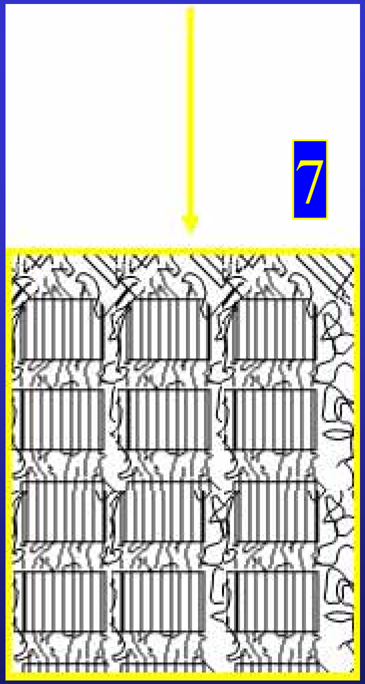
# Esfuerzo-Deformación

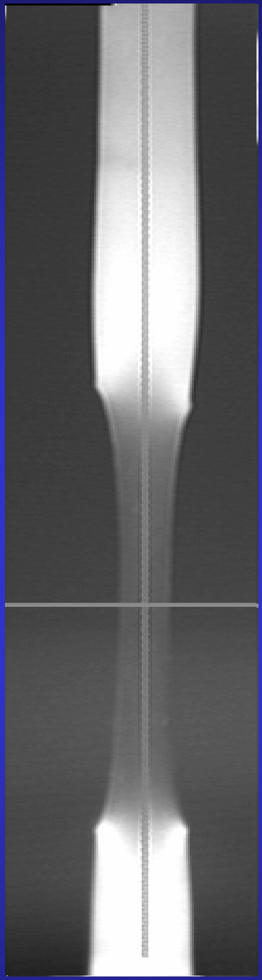


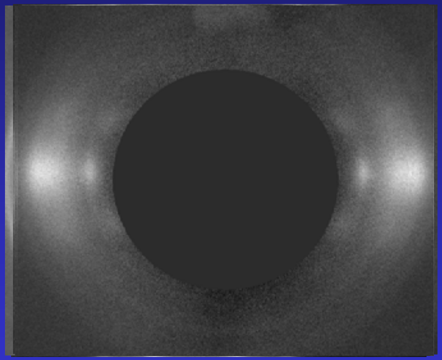
# Esfuerzo-Deformación : Arnitel (PBT-PO4)

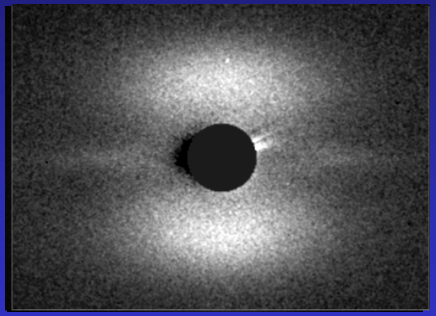
1

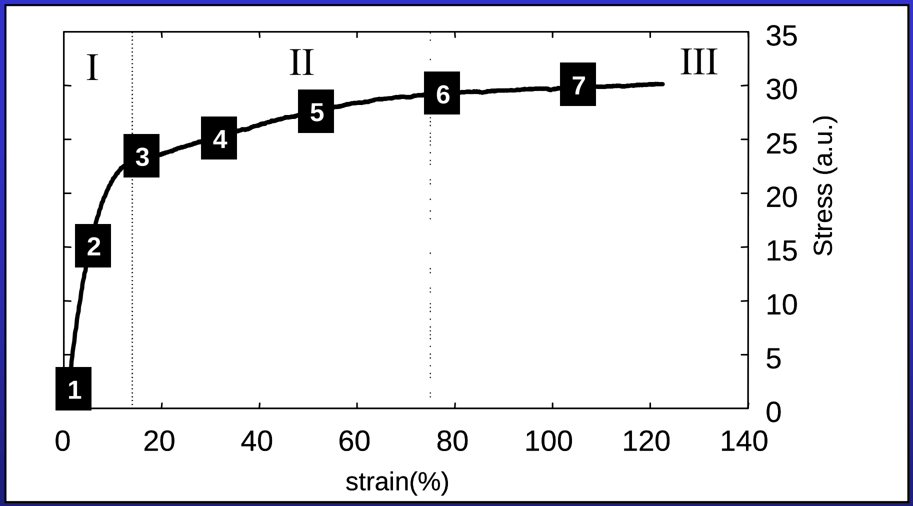










# Conclusiones

## Medicina

Seda
Quitoxano
Colágeno
Celulosa

- Mas biocompatible
- Mínima reacción a un cuerpo extraño
- Hidrofílicos
- Apropiados para química en la superficie
- Osteogénicos

Implantación In Vivo


Polímeros naturales

**Viejos Materiales** → **Nuevos usos**

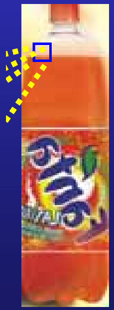
Diodos luminiscentes
Células fotovoltaicas
Sensores
Microelectrónica

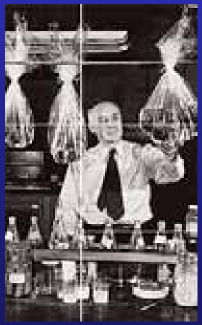
Poliésteres
Poliolefina
Pol. de ingeniería

**Nuevos Materiales** → **Viejos Usos**

Polímeros conductores

Contenedores
Biodegradables
Reciclables
Poco permeables





Materiales biodegradables

INSTITUTO DE ESTRUCTURA DE LA MATERIA

http://www.iem.cfmac.csic.es/fmacro/softmatpol/

# Soft and Polymeric Condensed Matter Group

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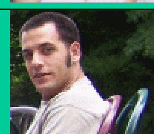
|  | **Jaime J. Hernández**<br>Predoctoral student *FPU*<br><br>web | imth001 at iem.cfmac.csic.es |
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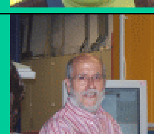
|  | **Daniel R. Rueda**<br>*Investigador científico*<br><br>web | emdaniel at iem.cfmac.csic.es |
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