Pinturas piezoeléctricas.

Nuevas perspectivas y aplicaciones

Ismael Payo Gutiérrez

III Semana de Iniciación a la Investigación Nebrija (del 7 al 11 de junio de 2021)

¿Para qué sirve una pintura?

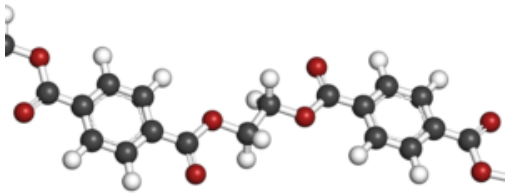
¿Para qué sirve una pintura?

¿Para qué sirve una pintura?


¿Y si …?

Hagamos magia…

Aditivos

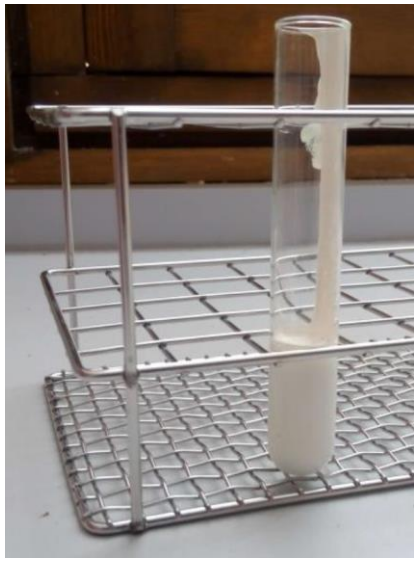


Polímero
(resina)

+

solvente

Pintura
piezoeléctrica



Material activo
(polvo piezoeléctrico)

Piezoelectricidad

David Brewster (1824)

Piezoelectricidad

Familia Curie, Pierre, Jacques, Marie. (1881)

Turmalina

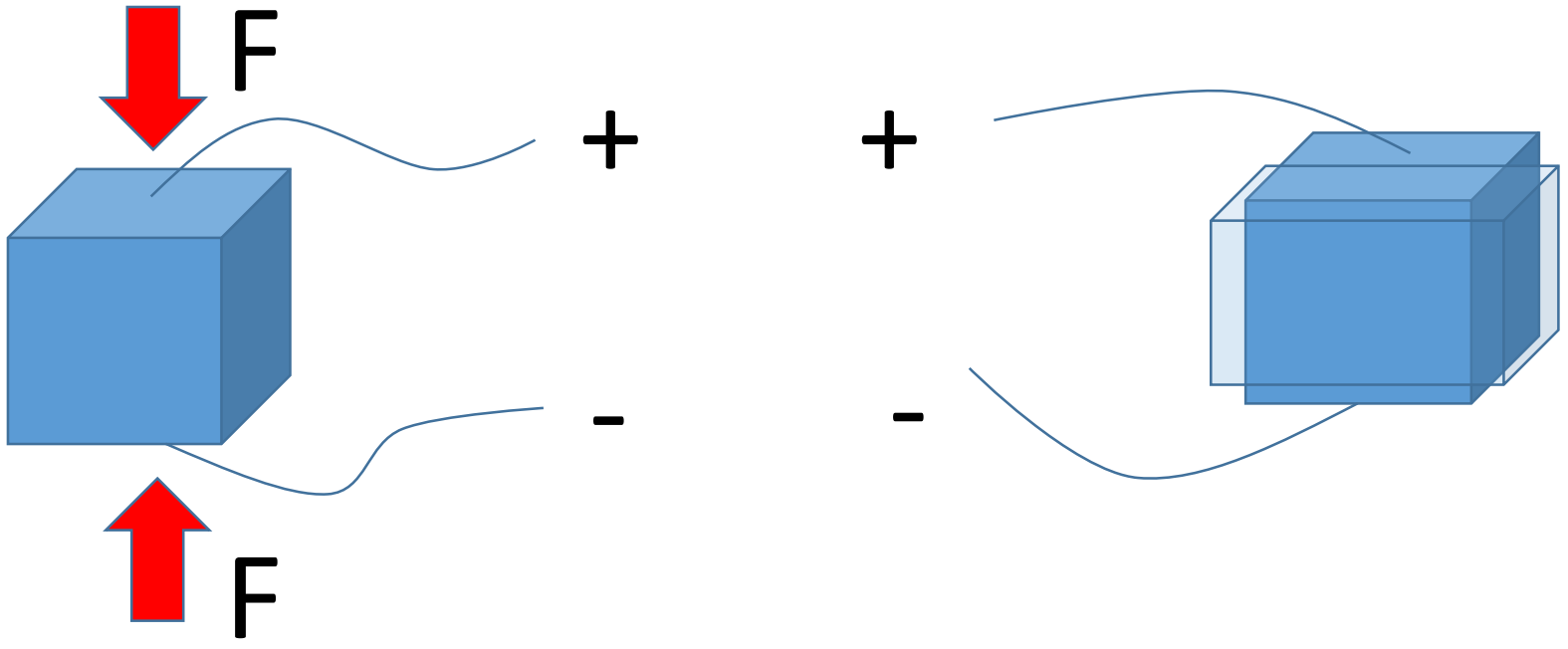
Piezoelectricidad

Efecto directo

$D = \mathbf{K} \cdot \sigma$

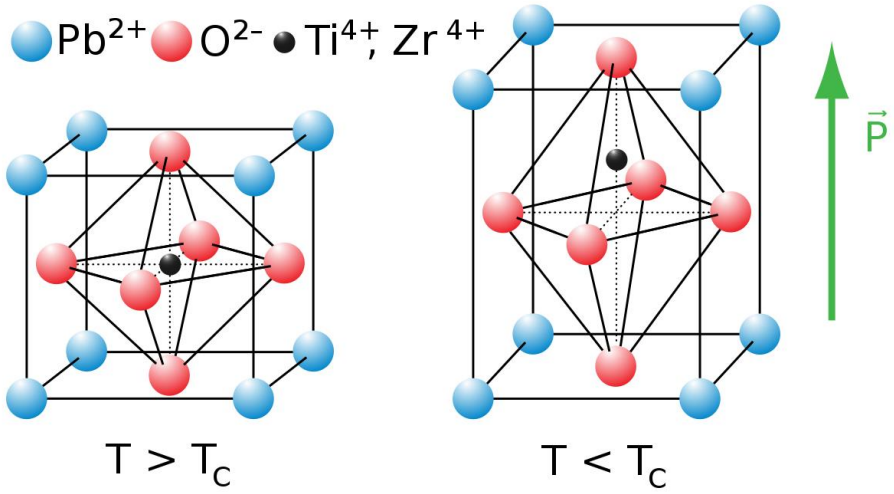
Efecto inverso

$S = \mathbf{G} \cdot V$

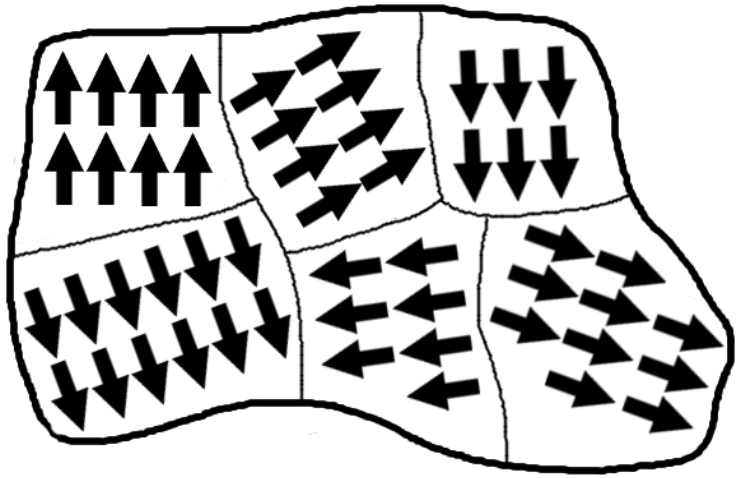


¿Cómo funciona la pintura?

Estructura cristalina asimétrica

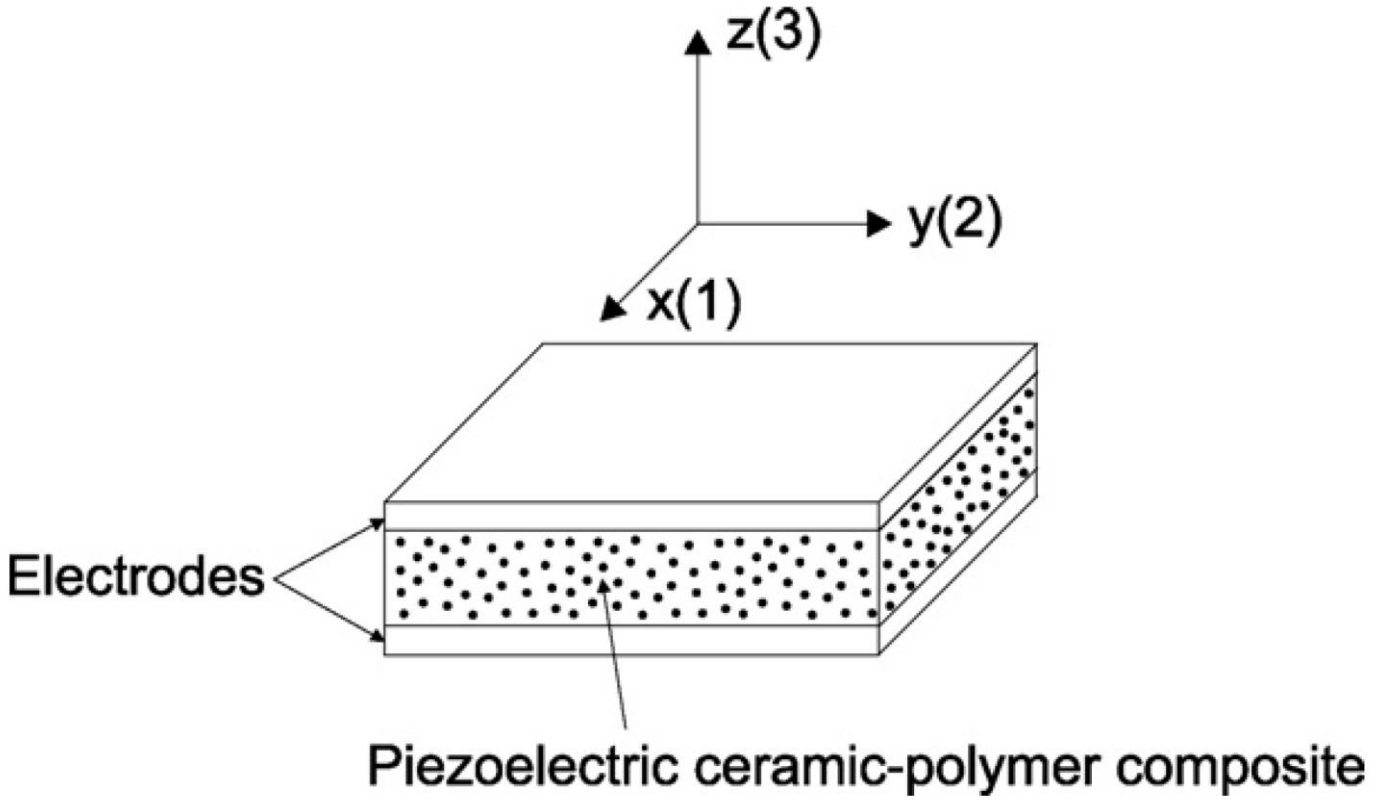


Dominios de Weiss

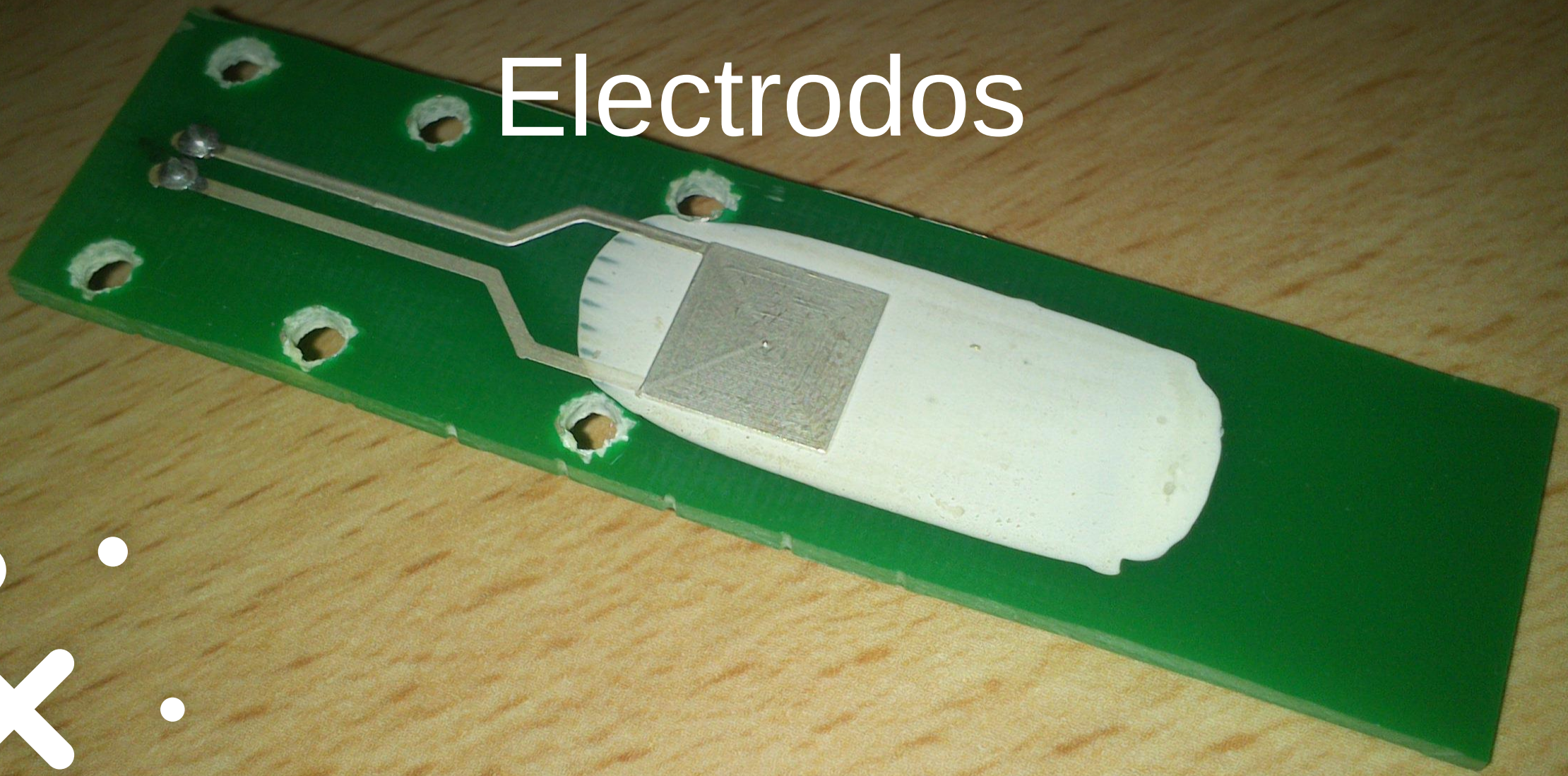


PZT (Zirconato titanato de plomo)

¿Cómo funciona la pintura?

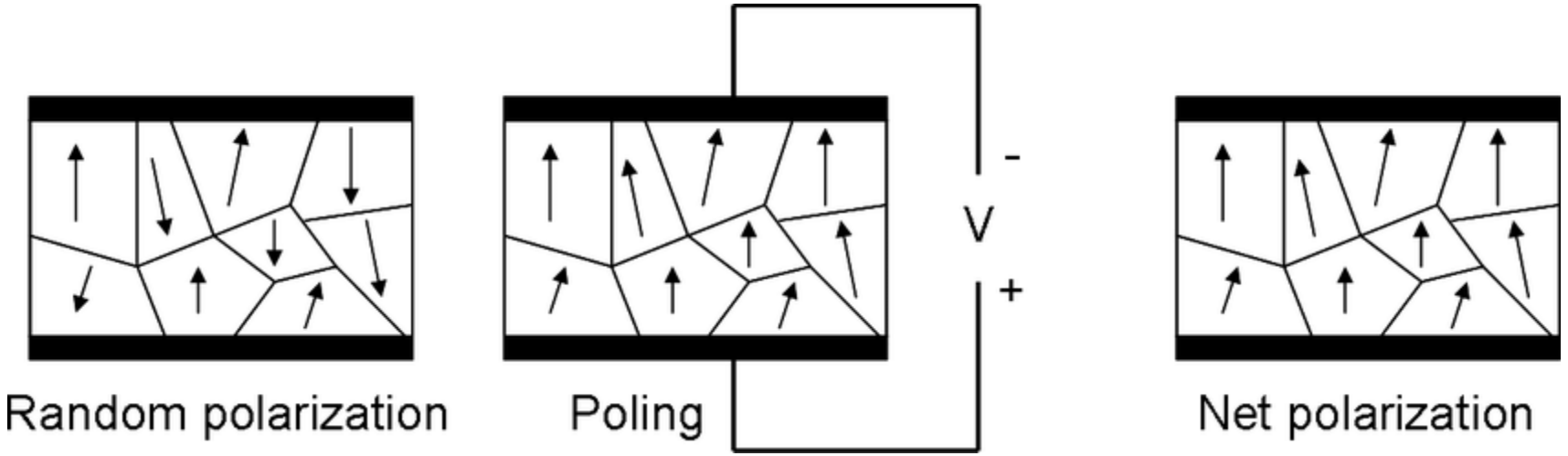


Electrodos



Electrodos

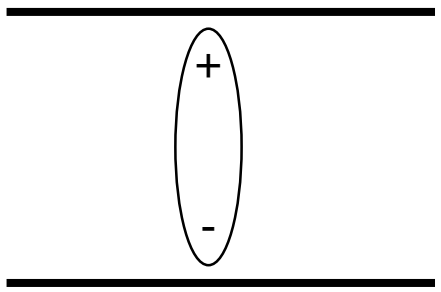
¿Cómo funciona la pintura?

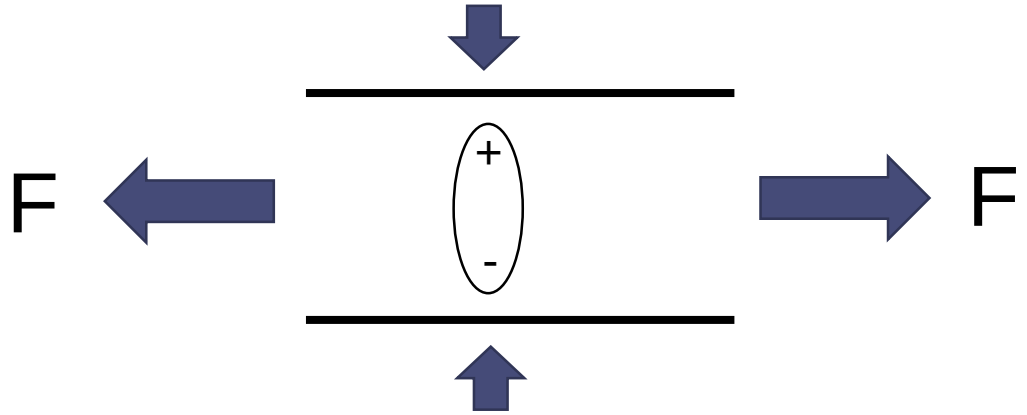


PZT material ferroeléctrico

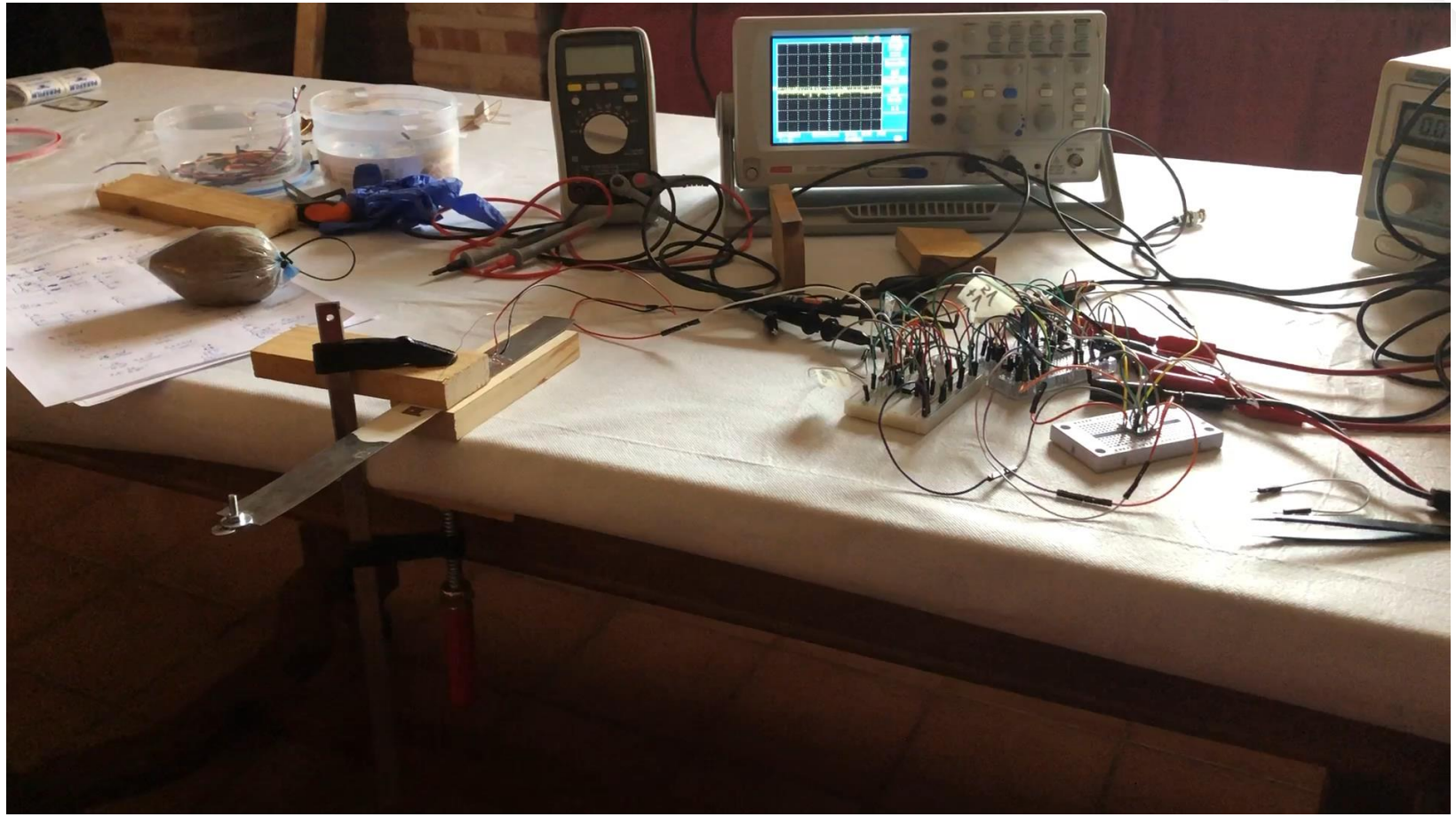
¿Cómo funciona la pintura?

Cambio en el momento dipolar → Generación campo eléctrico





¿Cómo funciona la pintura?



Aplicaciones

Vibraciones estructurales

Y

Salud estructural

Aplicaciones

Recuperación de energía

Aplicaciones

Recuperación de energía

Mutsuda et al. 2017

Pintura piezoeléctrica

Ventajas

Posibilidad de cubrir grandes superficies

Se puede aplicar a cualquier superficie

No hace falta adhesivo

Es flexible

No necesita fuente de energía externa

Diferentes propiedades

Desventajas

Baja sensibilidad

Sensibilidad depende de muchos parámetros

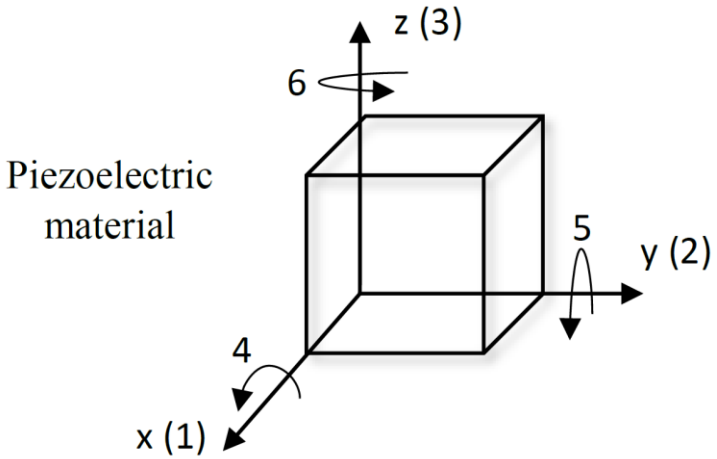
No distingue direcciones de deformación

No vale para medidas estáticas

Modelo electromecánico

$$D_i = d_{ik}\sigma_k + \varepsilon_{ij}^{\sigma} F_j$$

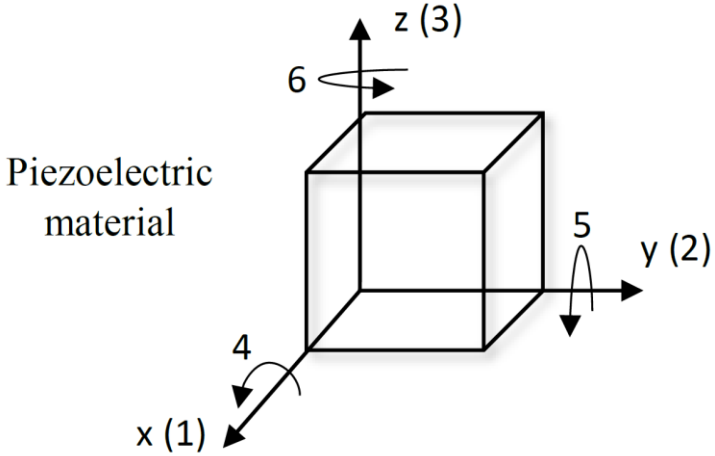
Asumiendo:
F = 0
$\sigma_3 = 0$
Dirección de polarización (eje z)



Modelo electromecánico

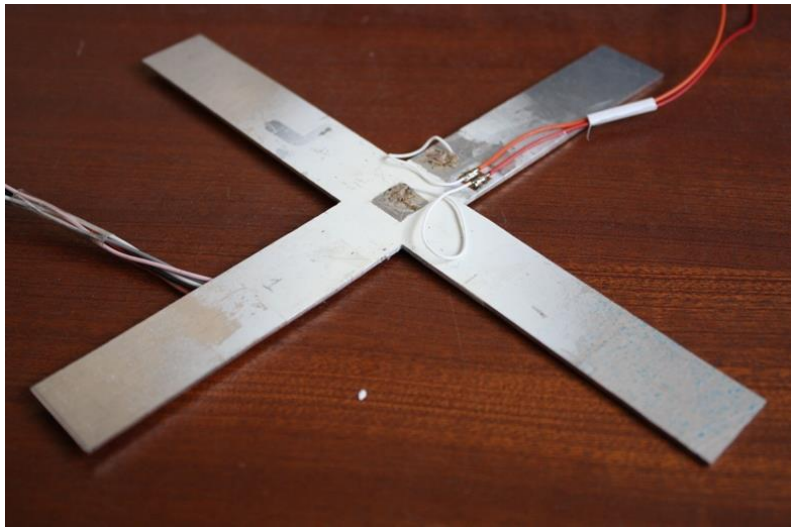
$$D_3 = d_{31}\frac{E}{1-\nu}(\varepsilon_1 + \varepsilon_2)$$

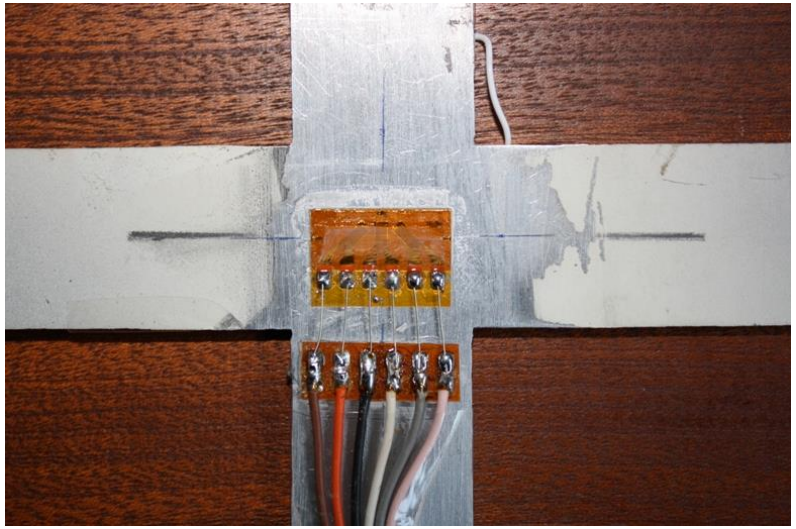
$$S = \frac{D_3}{(\varepsilon_1 + \varepsilon_2)}$$



Validación experimental

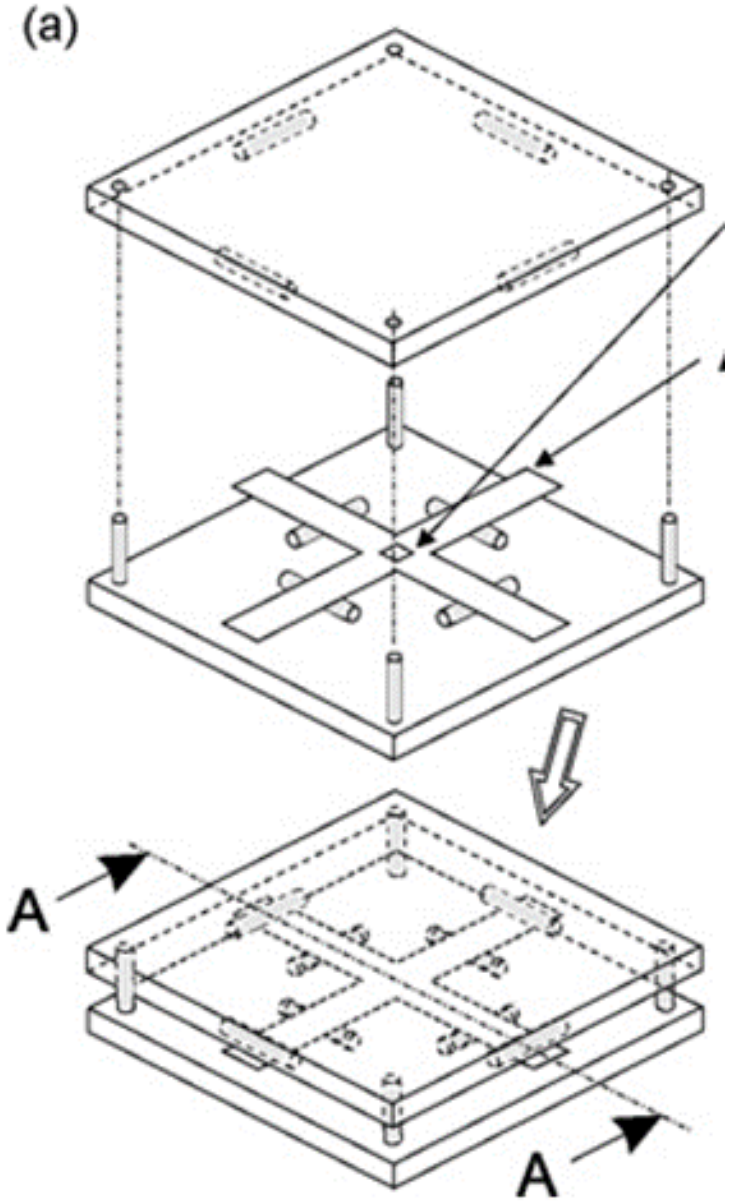
Prototipo experimental





Validación experimental

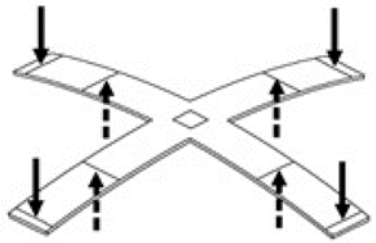
Prototipo experimental



Validación experimental

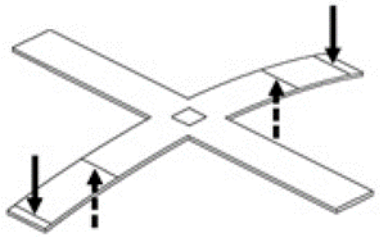
Experimentos

Experiment 1



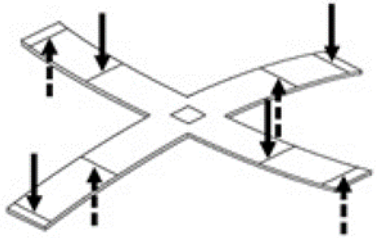
Biaxial positive bending moment

Experiment 2



Uniaxial positive bending moment

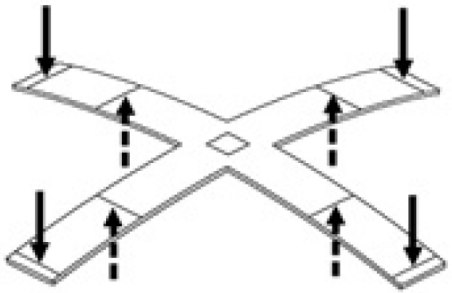
Experiment 3



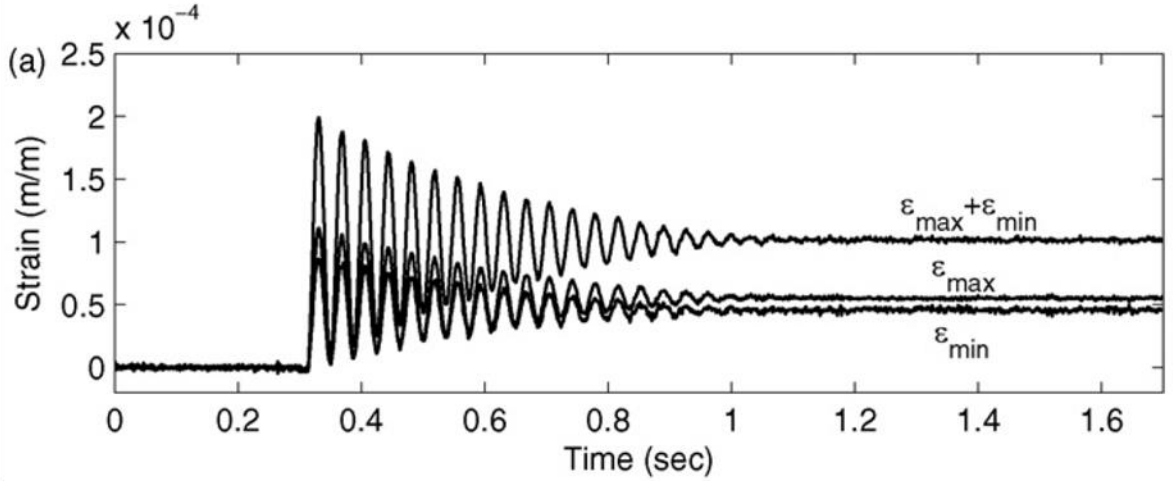
Biaxial opposite bending moment

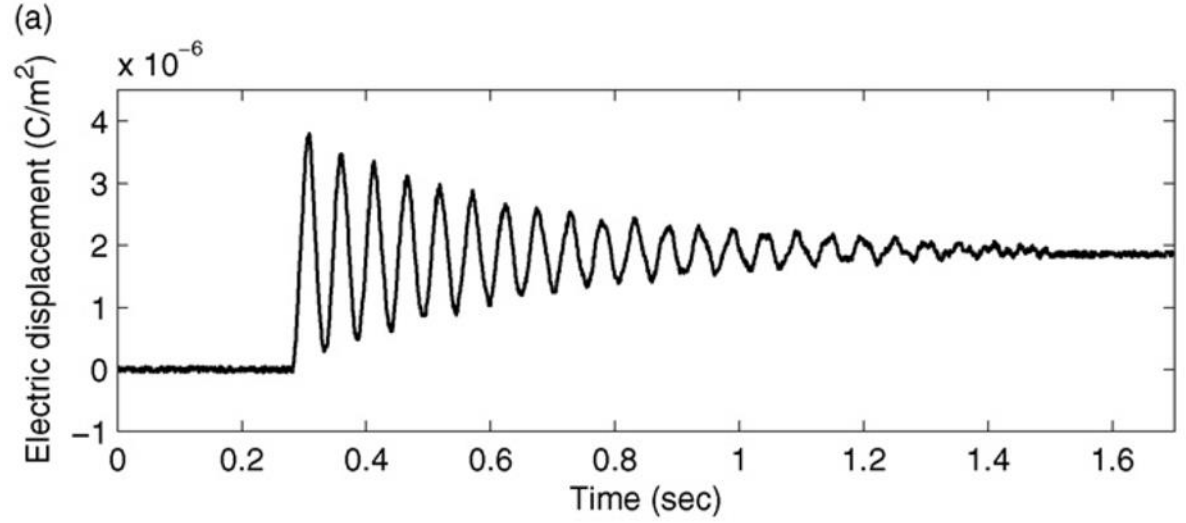
Validación experimental

Experiment 1



Biaxial positive bending moment

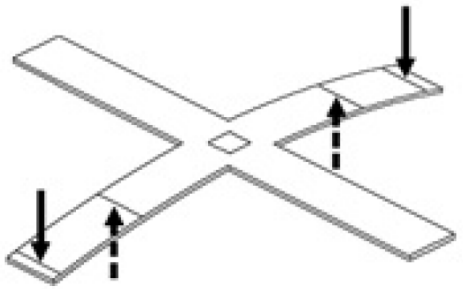




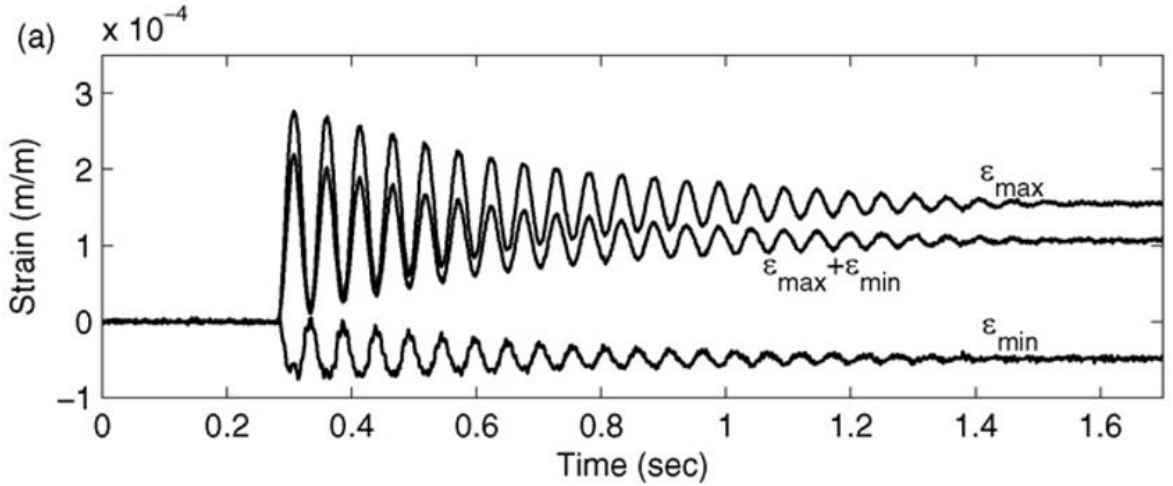
$$D_3 = d_{31}\frac{E}{1-\nu}(\varepsilon_1 + \varepsilon_2)$$

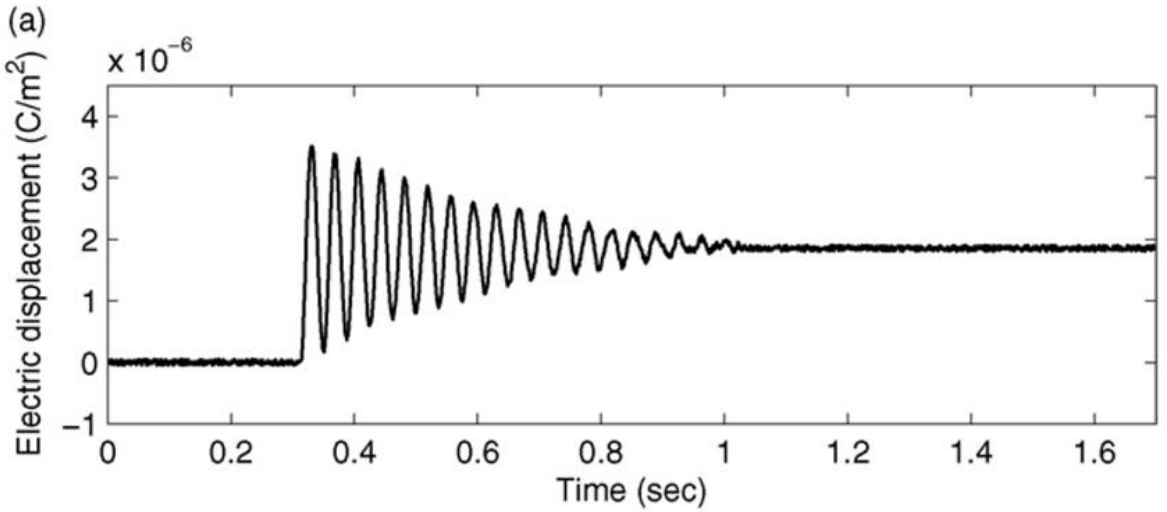
Validación experimental

Experiment 2



Uniaxial positive bending moment

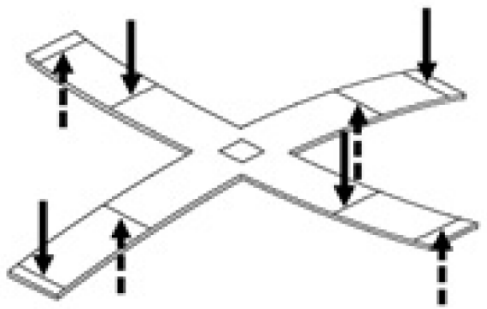




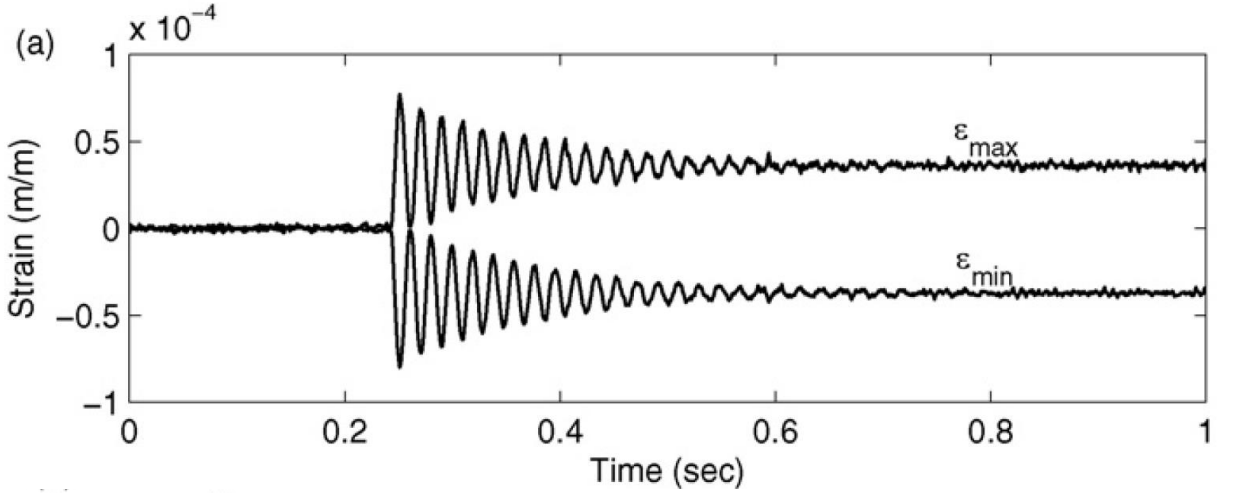
$$D_3 = d_{31}\frac{E}{1-\nu}(\varepsilon_1 + \varepsilon_2)$$

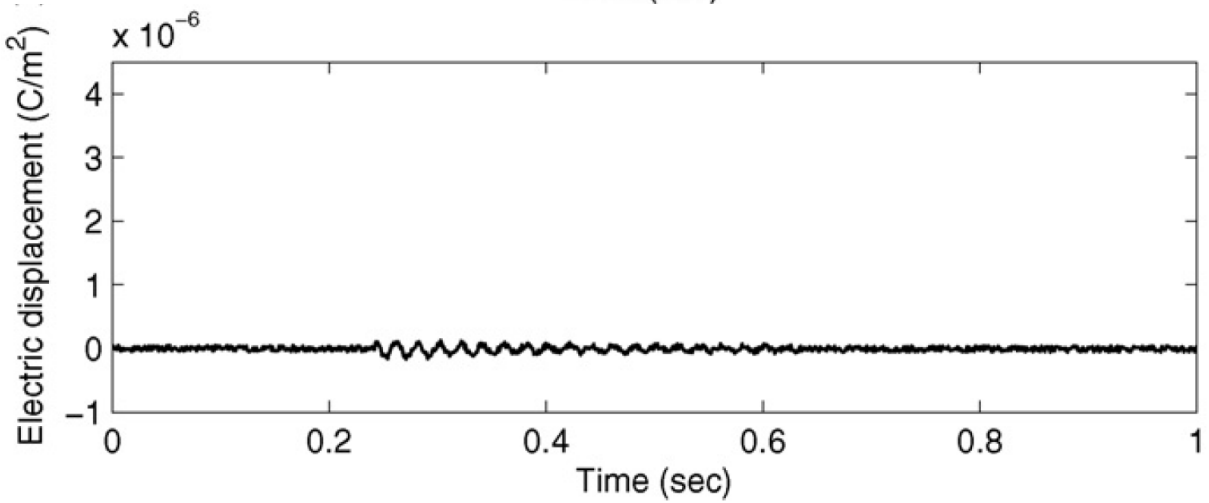
Validación experimental

Experiment 3



Biaxial opposite bending moment



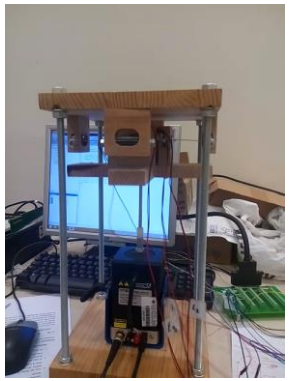


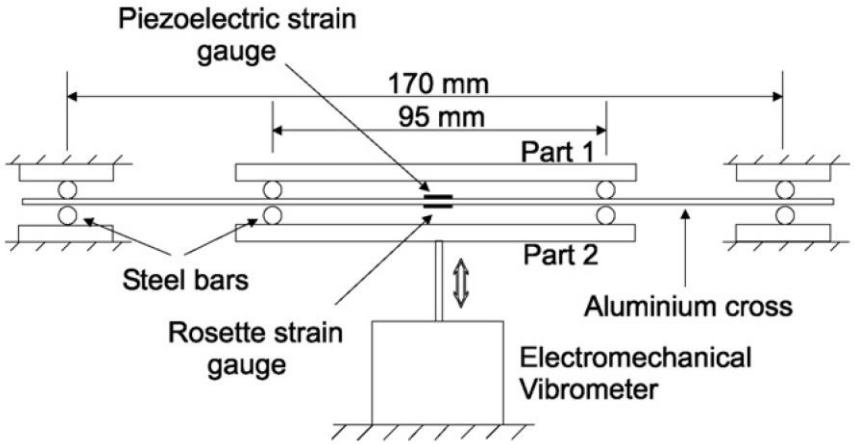
$$D_3 = d_{31}\frac{E}{1-\nu}(\varepsilon_1 + \varepsilon_2)$$

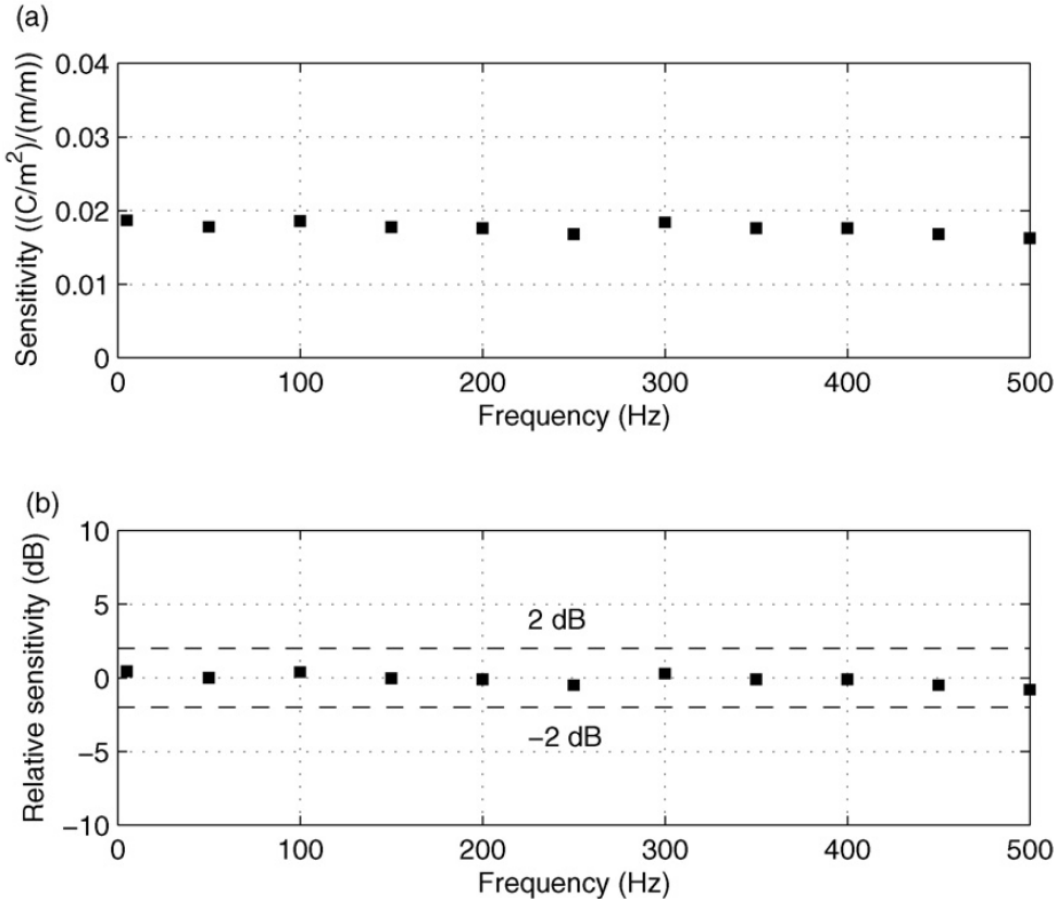
Validación experimental

Sensibilidad vs. frecuencia

$$S = \frac{D_3}{(\varepsilon_1 + \varepsilon_2)}$$





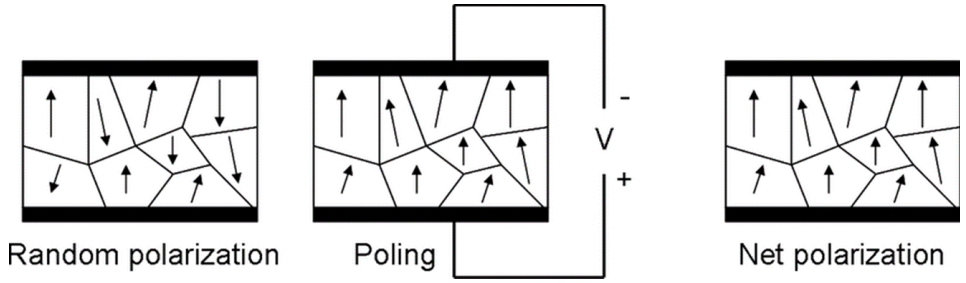


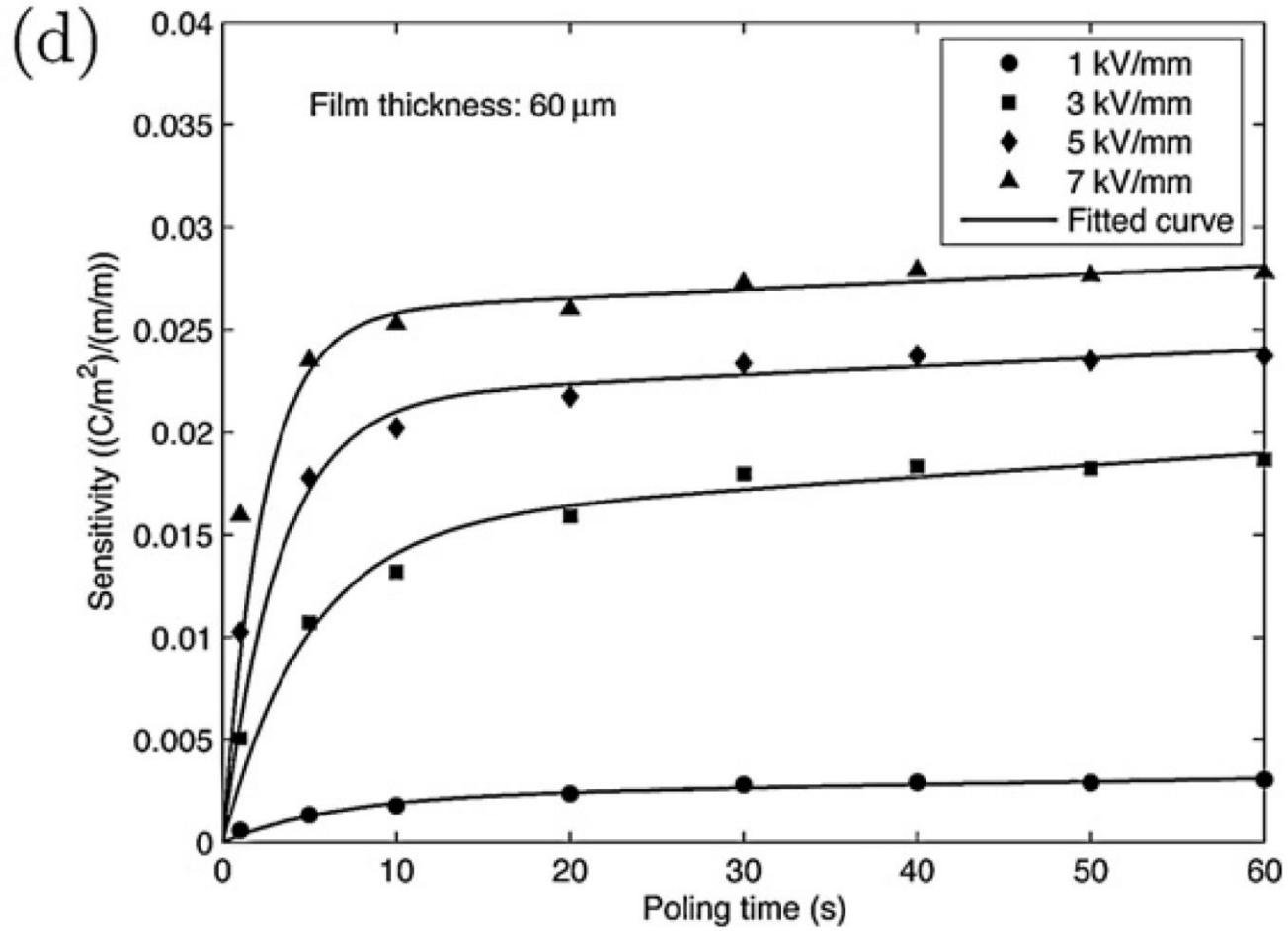
Análisis de la sensibilidad

$$S = \frac{D_3}{(\varepsilon_1 + \varepsilon_2)}$$

Parámetros que influyen:

- Polarización (campo eléctrico y tiempo aplicado)



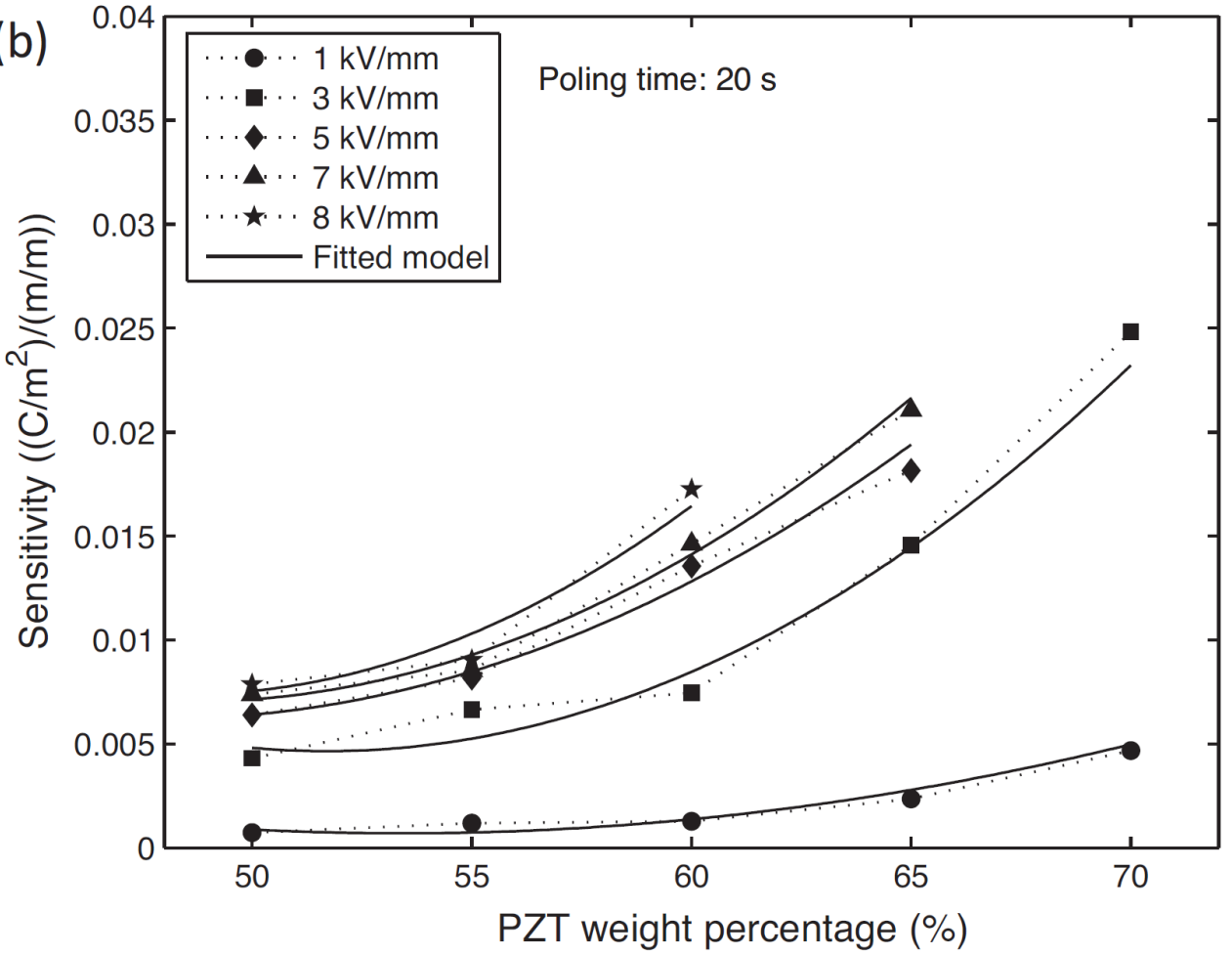


Análisis de la sensibilidad

Parámetros que influyen:

- % polvo piezoeléctrico

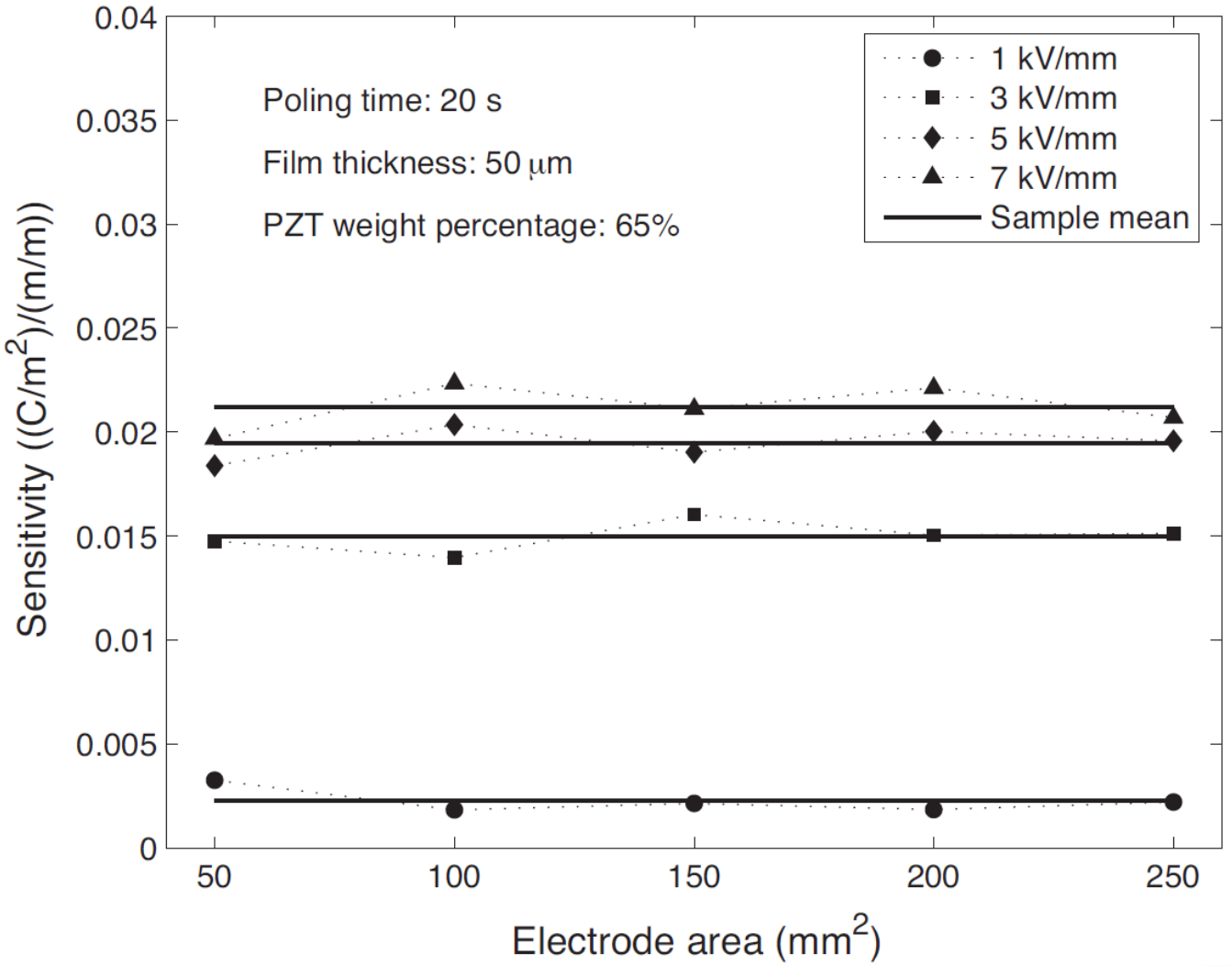
Material activo
(polvo piezoeléctrico)



Análisis de la sensibilidad

Parámetros que influyen:

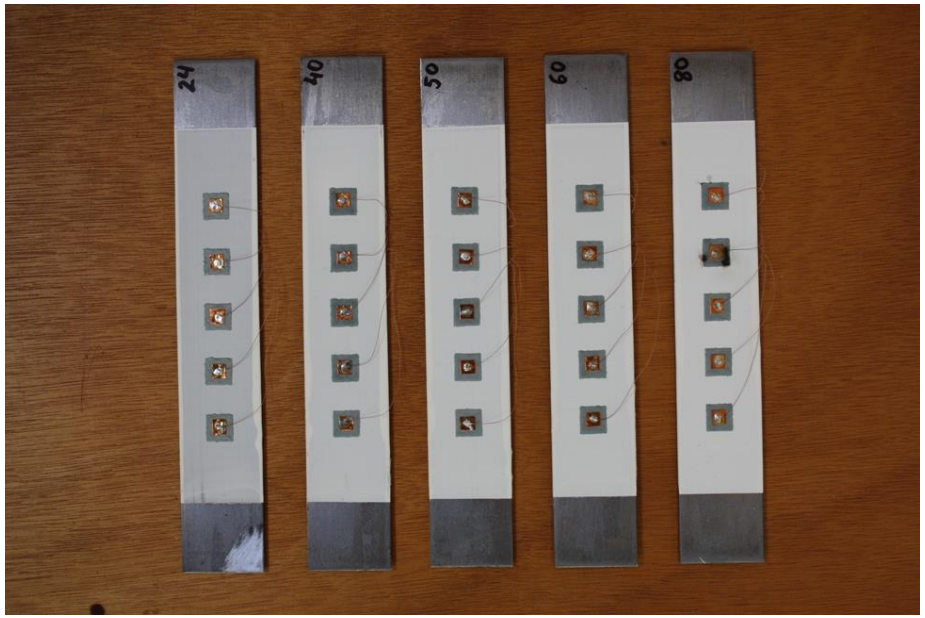
- Área del electrodo

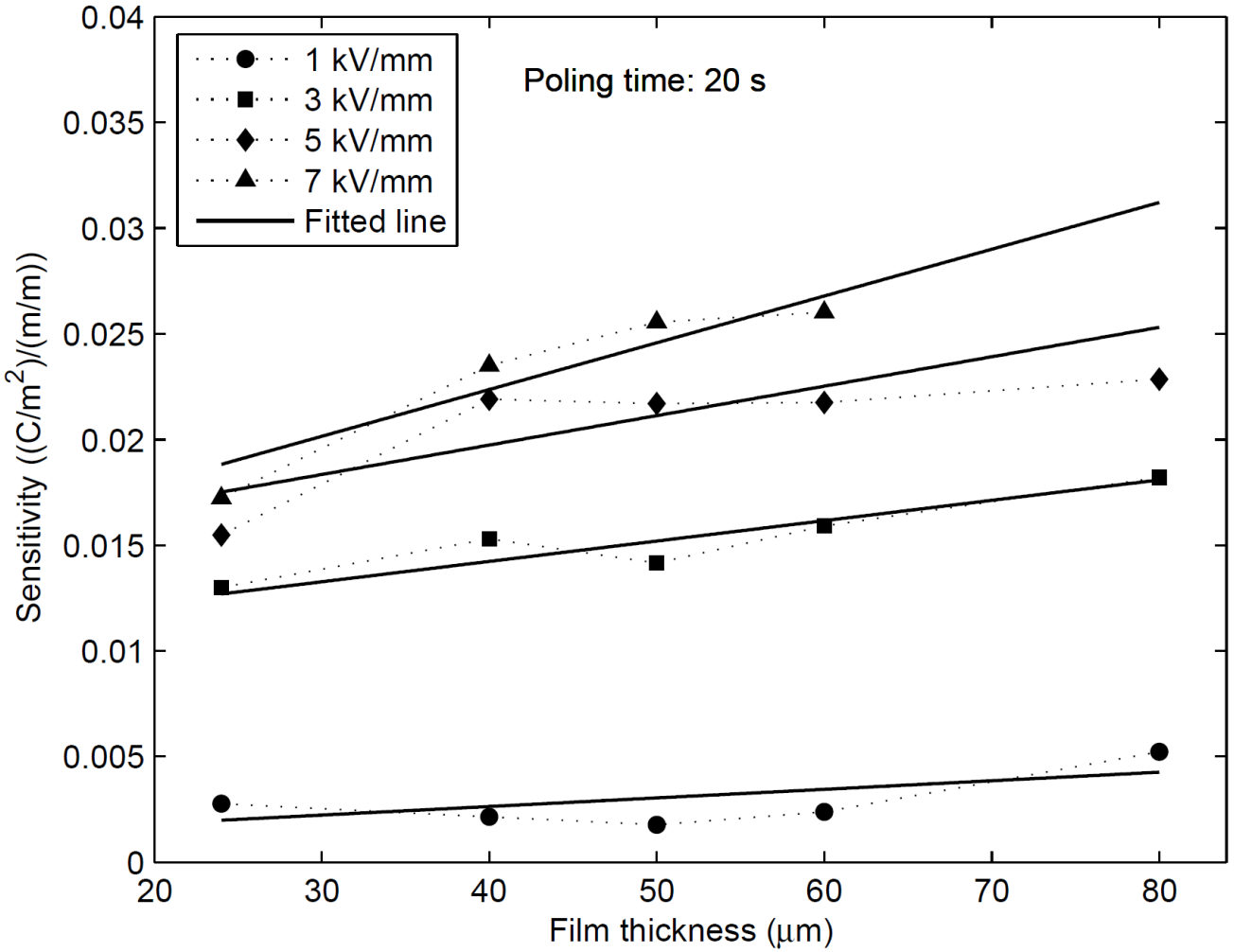


Análisis de la sensibilidad

Parámetros que influyen:

- Espesor de la pintura



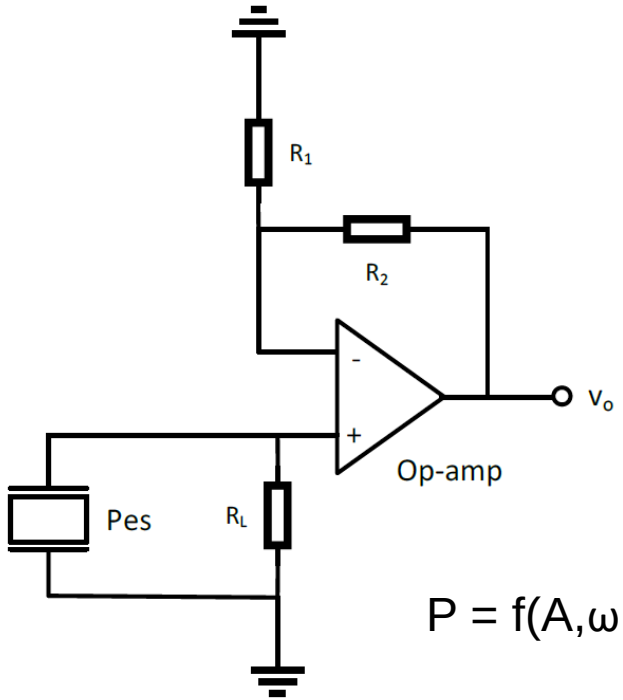


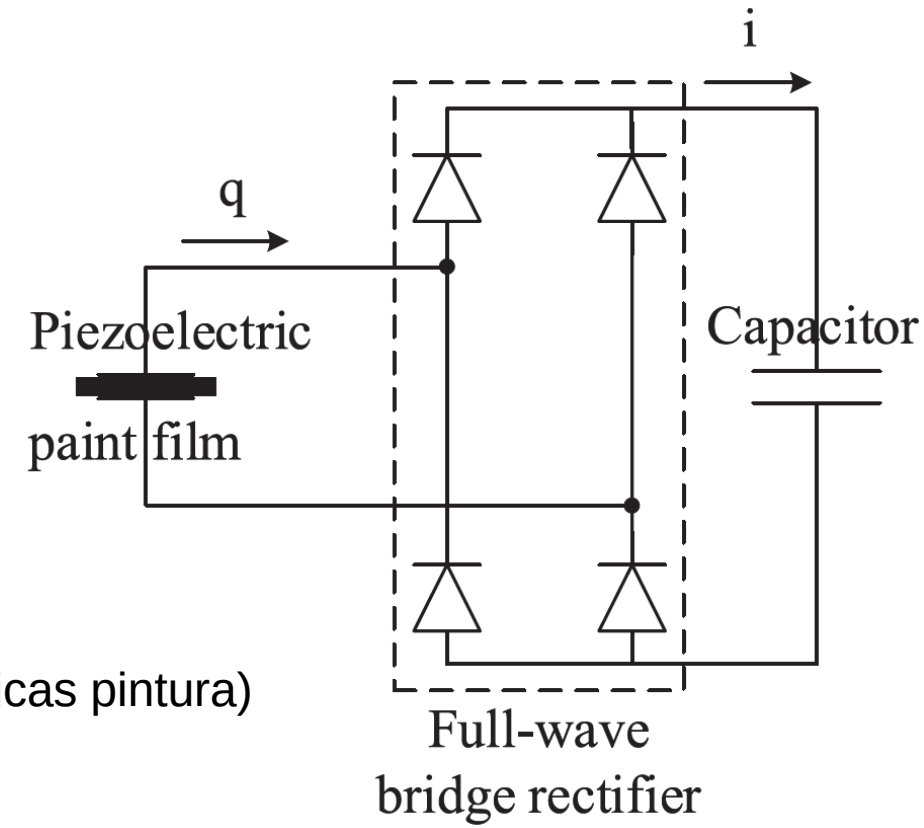
Análisis de la sensibilidad

Resumen:

$$S = B(1 - e^{-at_p}) + Ct_p$$

Pintura piezoeléctrica como generador





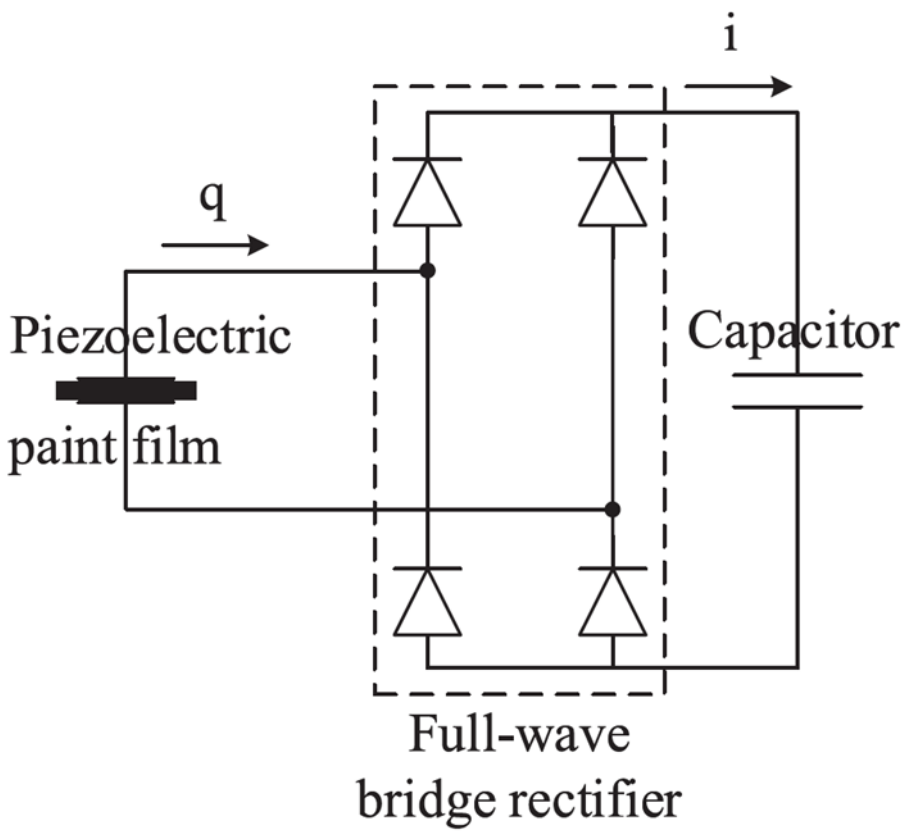
P = f(A,ω,R_L,características pintura)

$P_R = V_p^2/(2R)$

E = P·t

E = ½CV^2

Modelo electromecánico



$$v_c(t) = k\ \varepsilon_s(t)$$

$$\varepsilon_s(t_i) = \int_{t_{i-1}}^{t_i} |\ \dot{\hat{\varepsilon}}(\tau)|\ \mathrm{d}\tau + \varepsilon_s(t_{i-1})$$

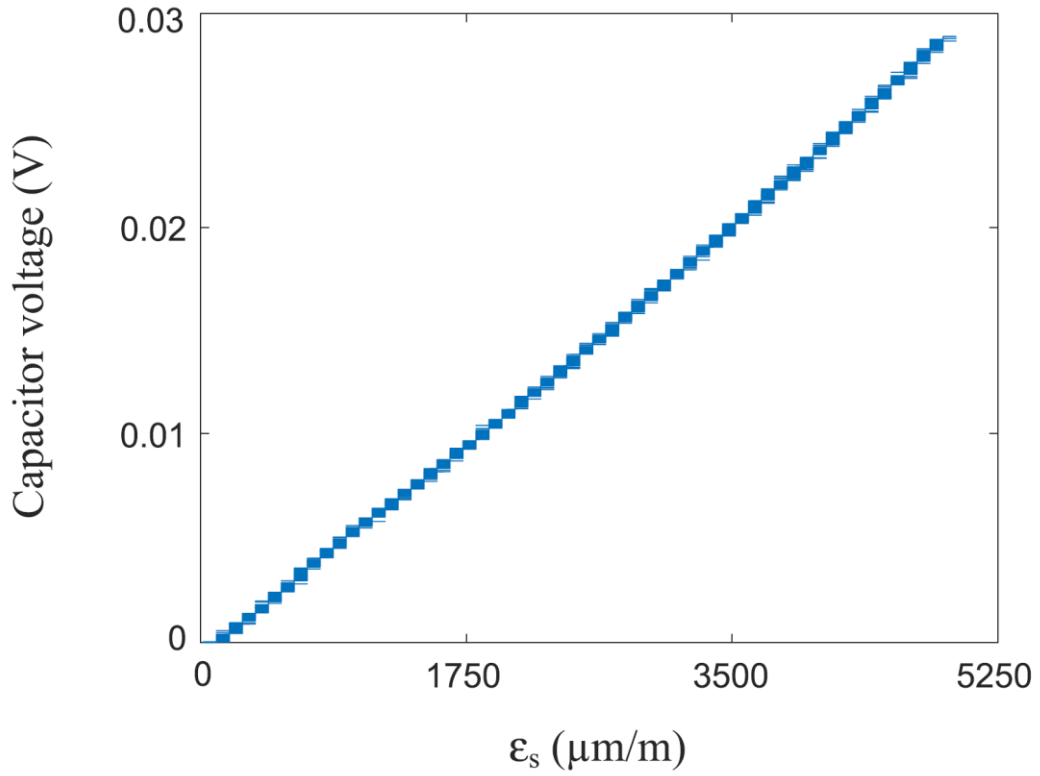
$$k = \frac{A\ d_{31} E}{C(1-\nu)}$$

$$E(t) = \frac{1}{2}\ C\ k^2\ \varepsilon_s^2(t)$$

Validación experimental

Tensión eléctrica en el condensador

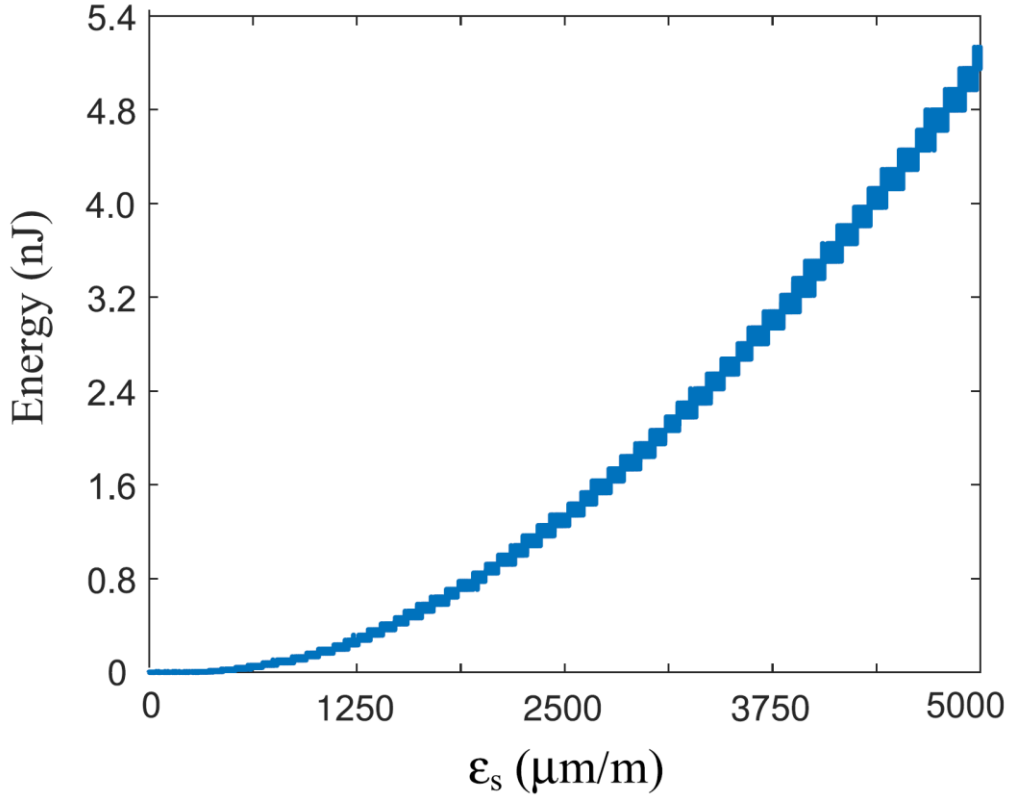
$$v_c(t) = k\ \varepsilon_s(t)$$



Validación experimental

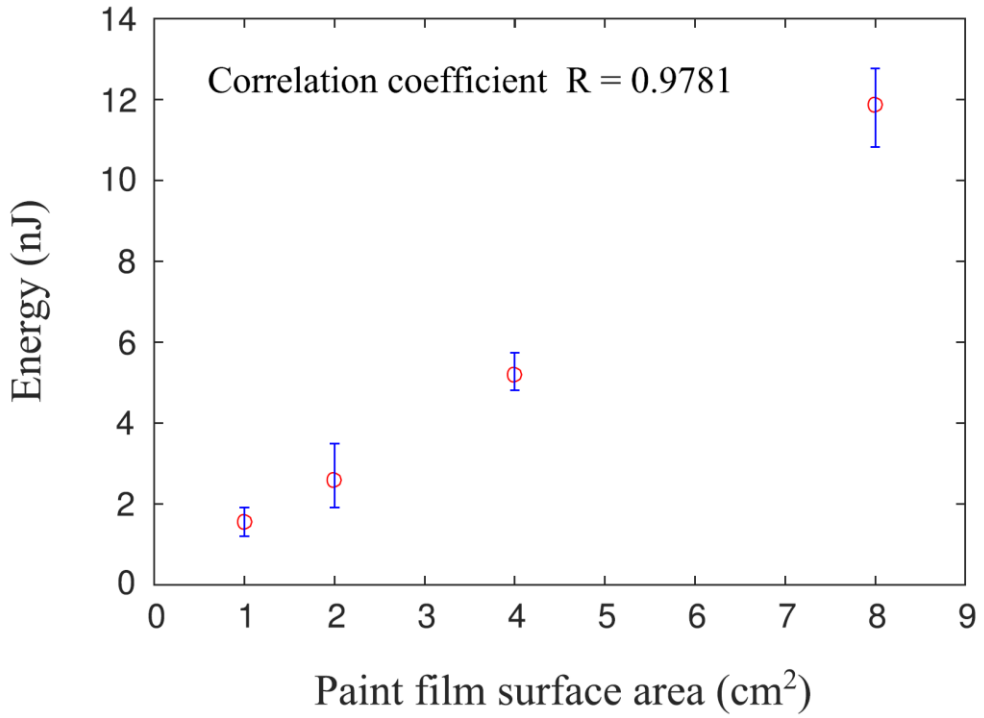
Energía eléctrica almacenada en el condensador

$$E(t) = \frac{1}{2} C\, k^2\, \varepsilon_s^2(t)$$



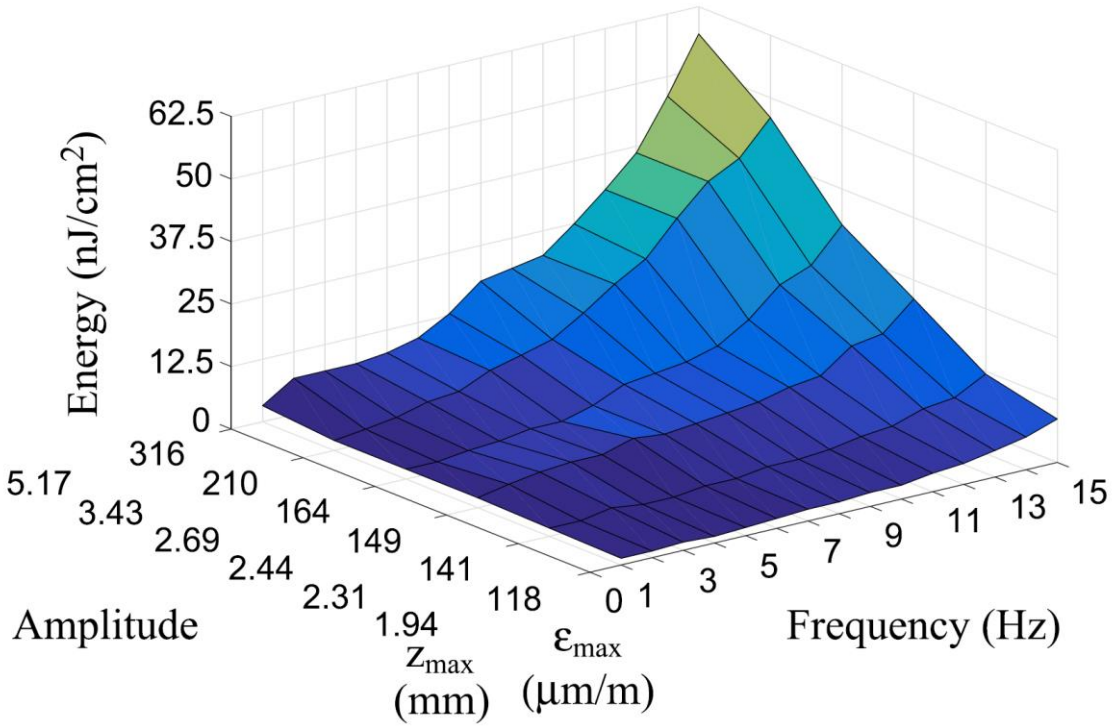
Validación experimental

Energía vs. área de la pintura piezoeléctrica



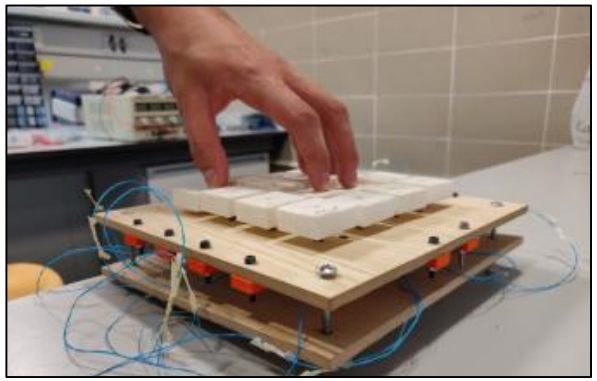
Validación experimental

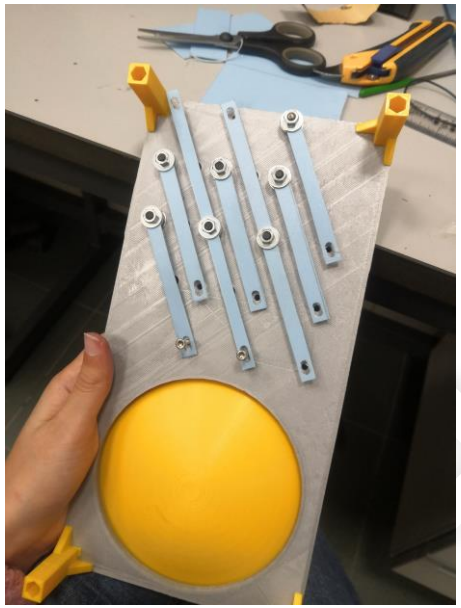
Energía vs. vibración

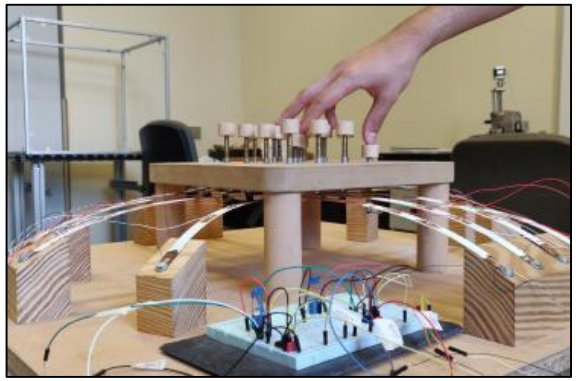


Aplicaciones desarrolladas en la UCLM

Dispositivos para la rehabilitación de la mano

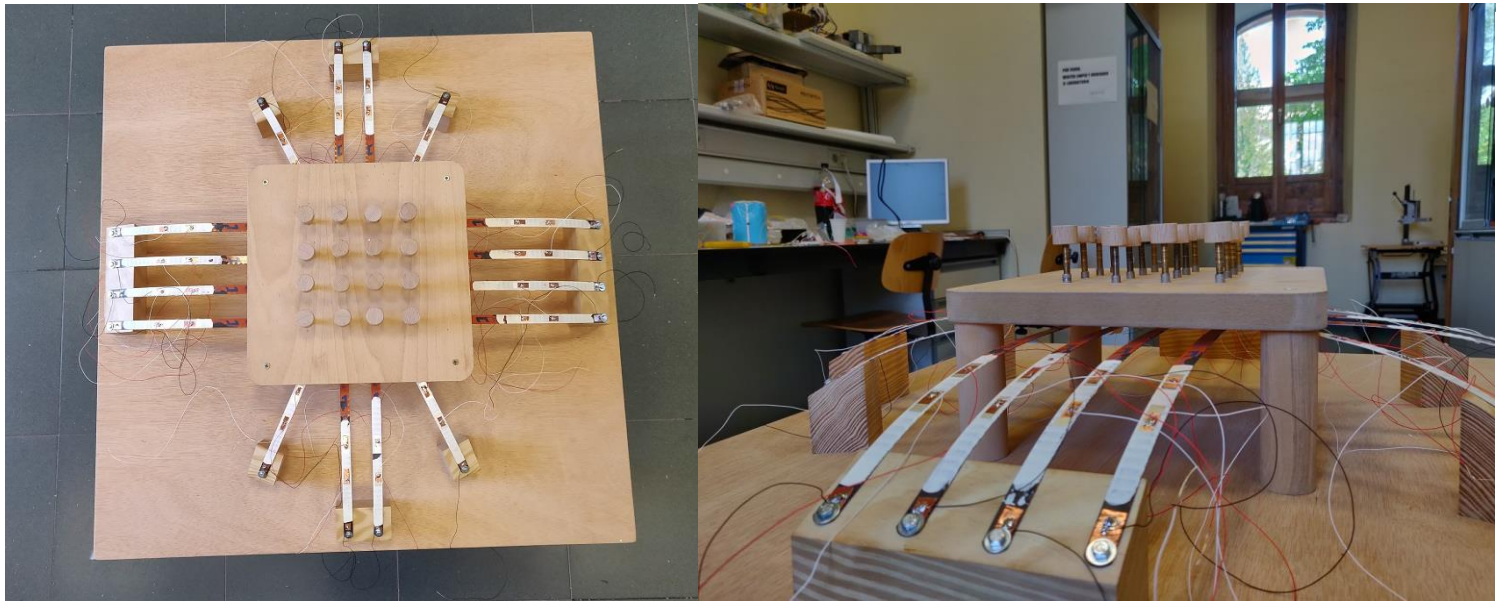


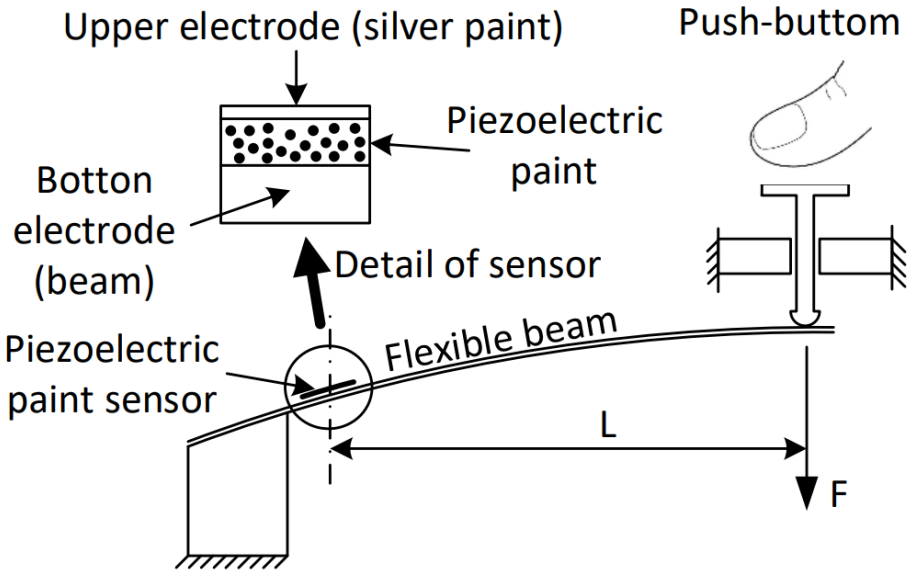




Aplicaciones desarrolladas en la UCLM

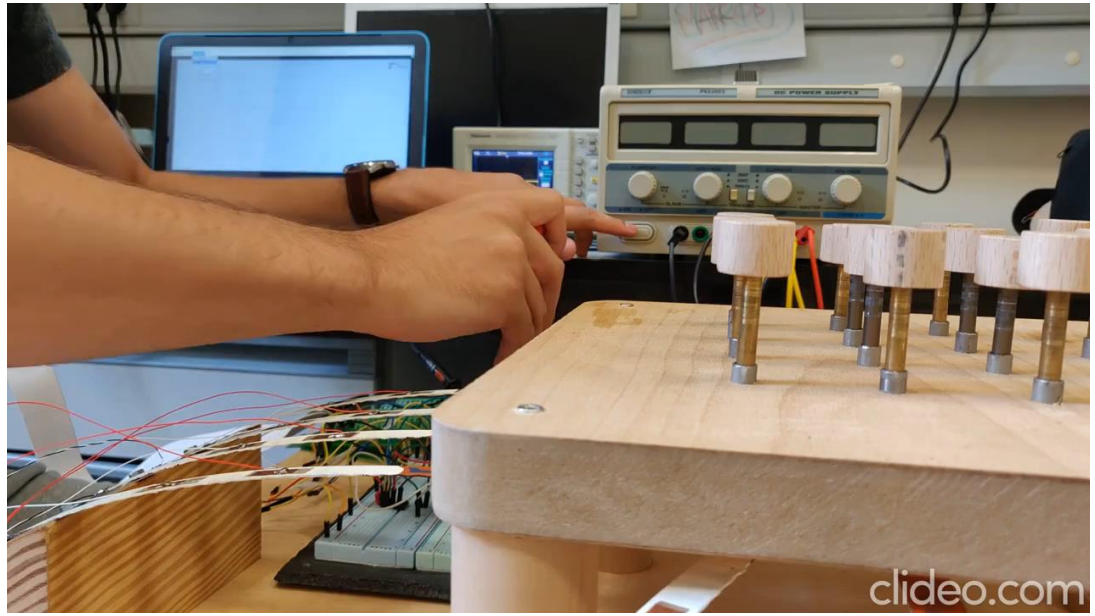
Dispositivo para la rehabilitación de la mano

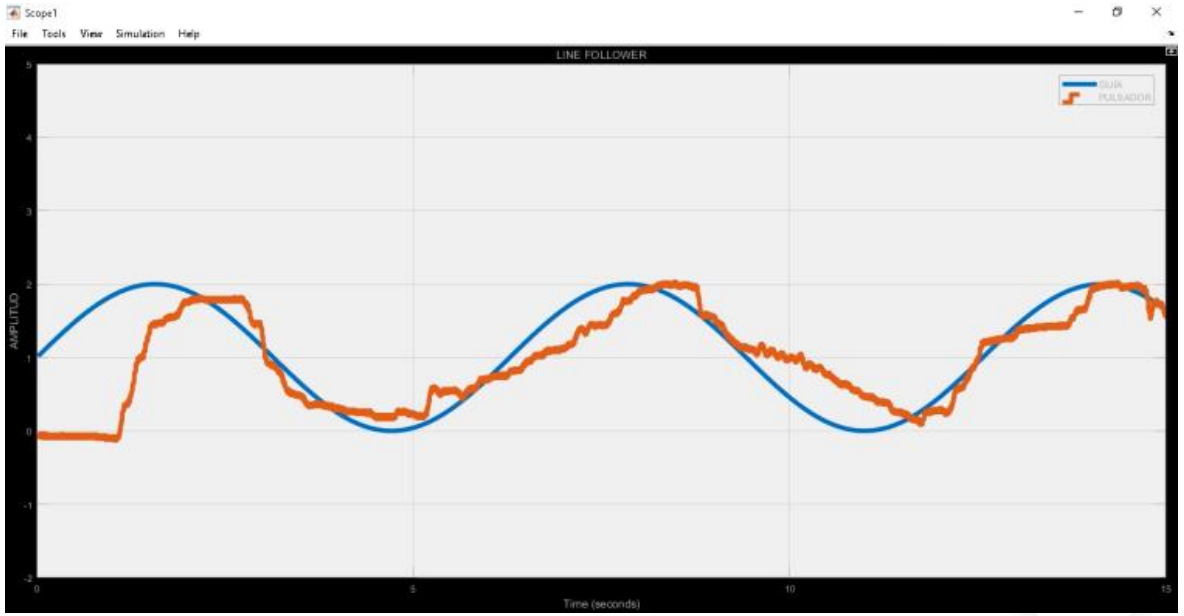




Aplicaciones desarrolladas en la UCLM

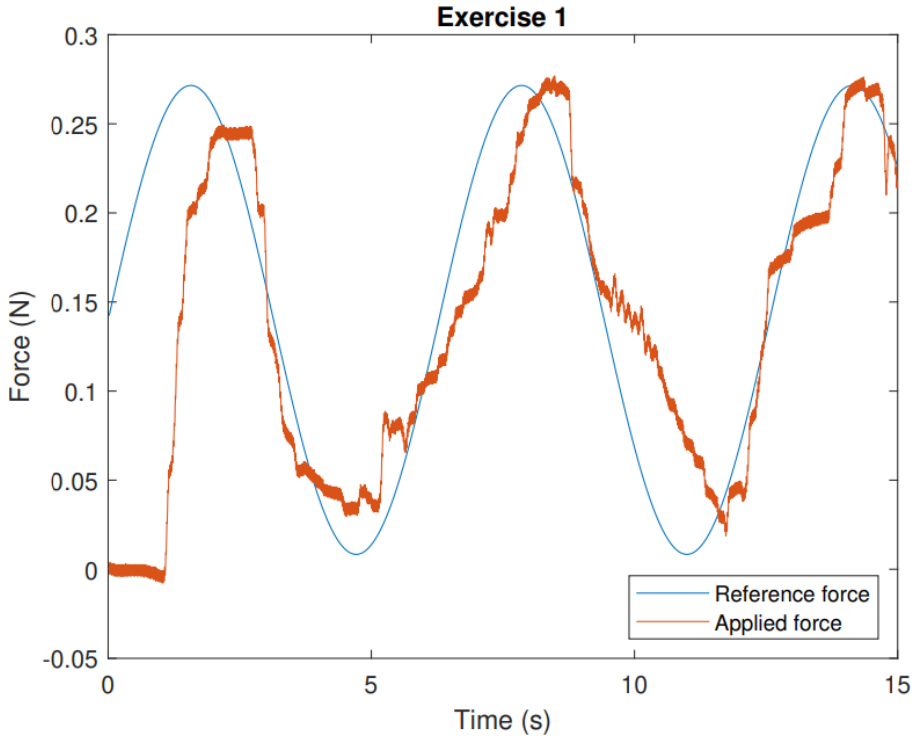
Dispositivo para la rehabilitación de la mano

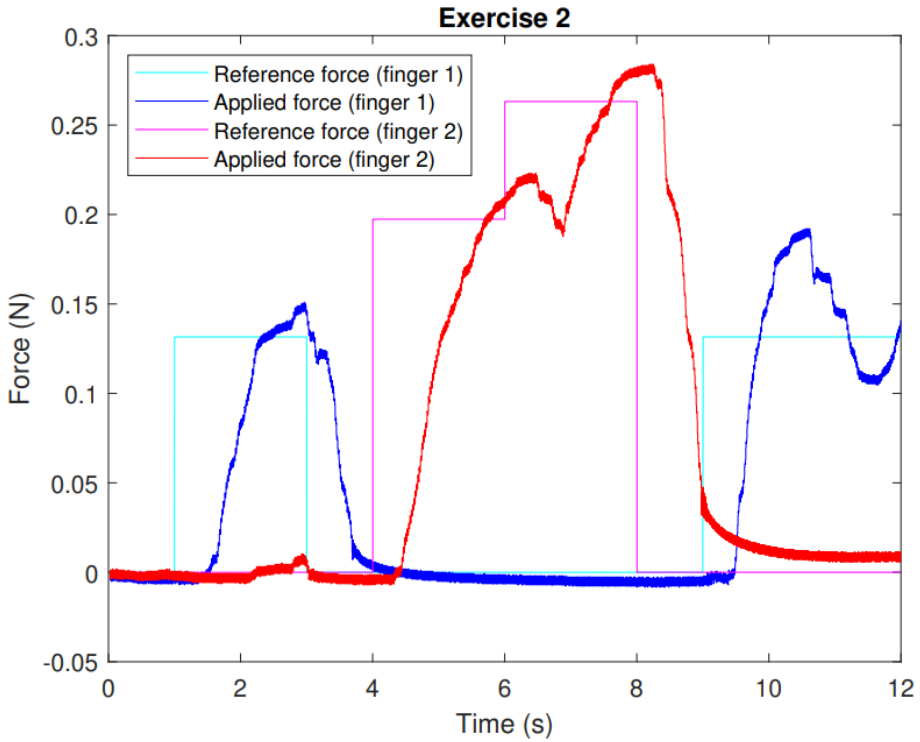




Aplicaciones desarrolladas en la UCLM

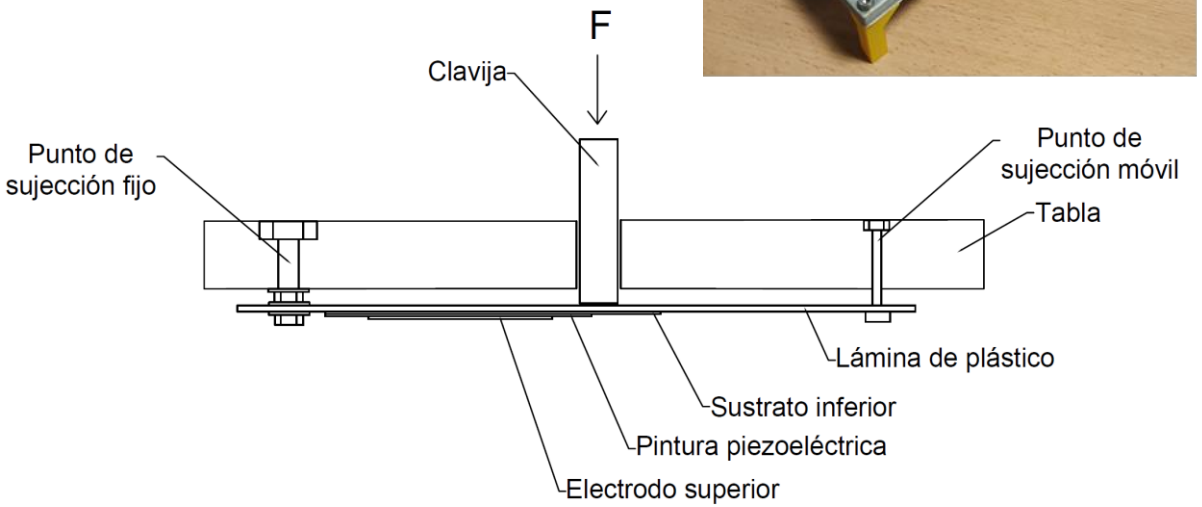
Dispositivo para la rehabilitación de la mano

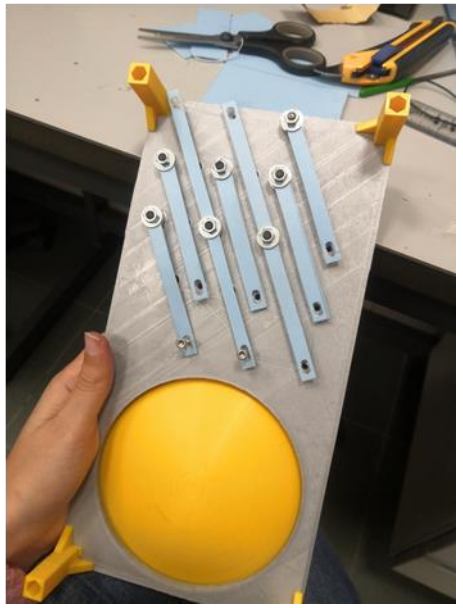


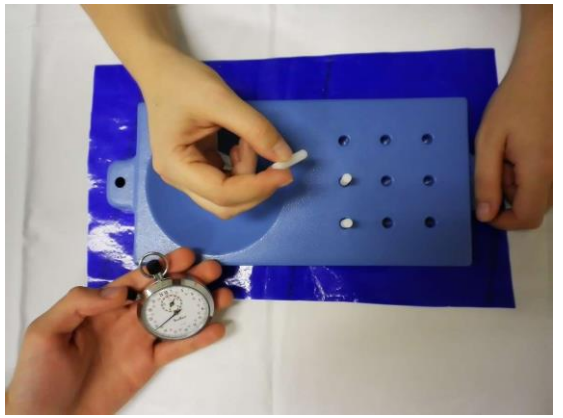


Aplicaciones desarrolladas en la UCLM

Dispositivo para la rehabilitación de la mano

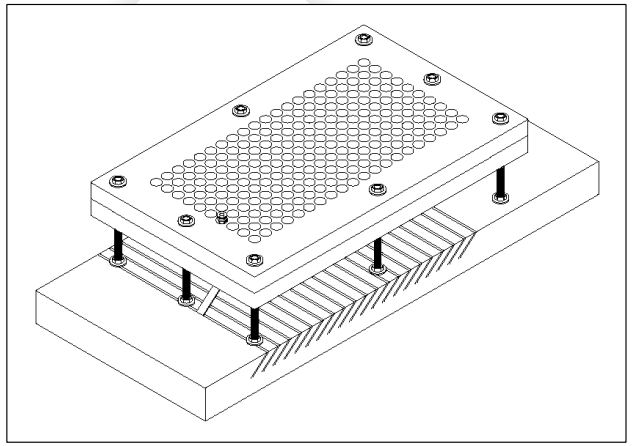


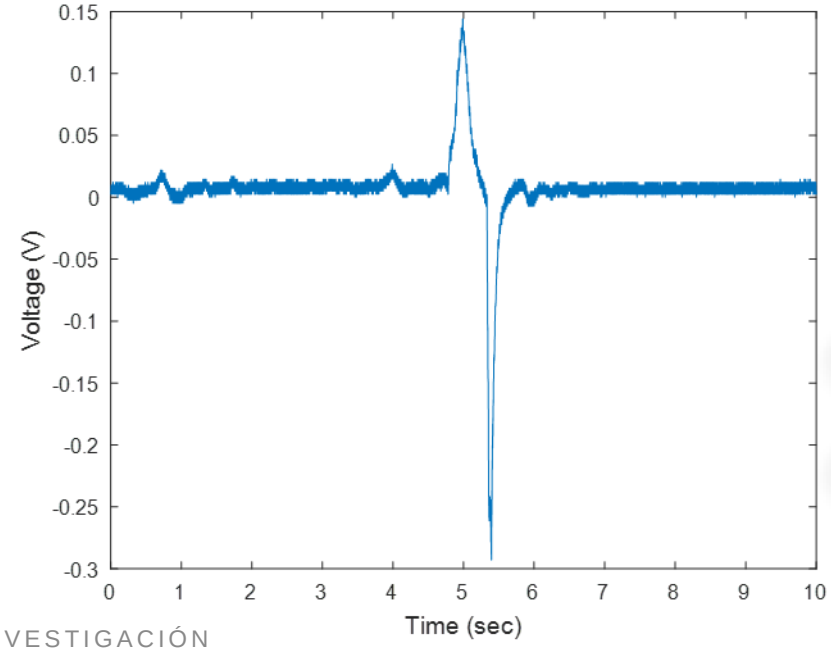




Aplicaciones desarrolladas en la UCLM

Plataforma de fuerza para el análisis del paso





Muchas gracias