# Time dependent P reversal

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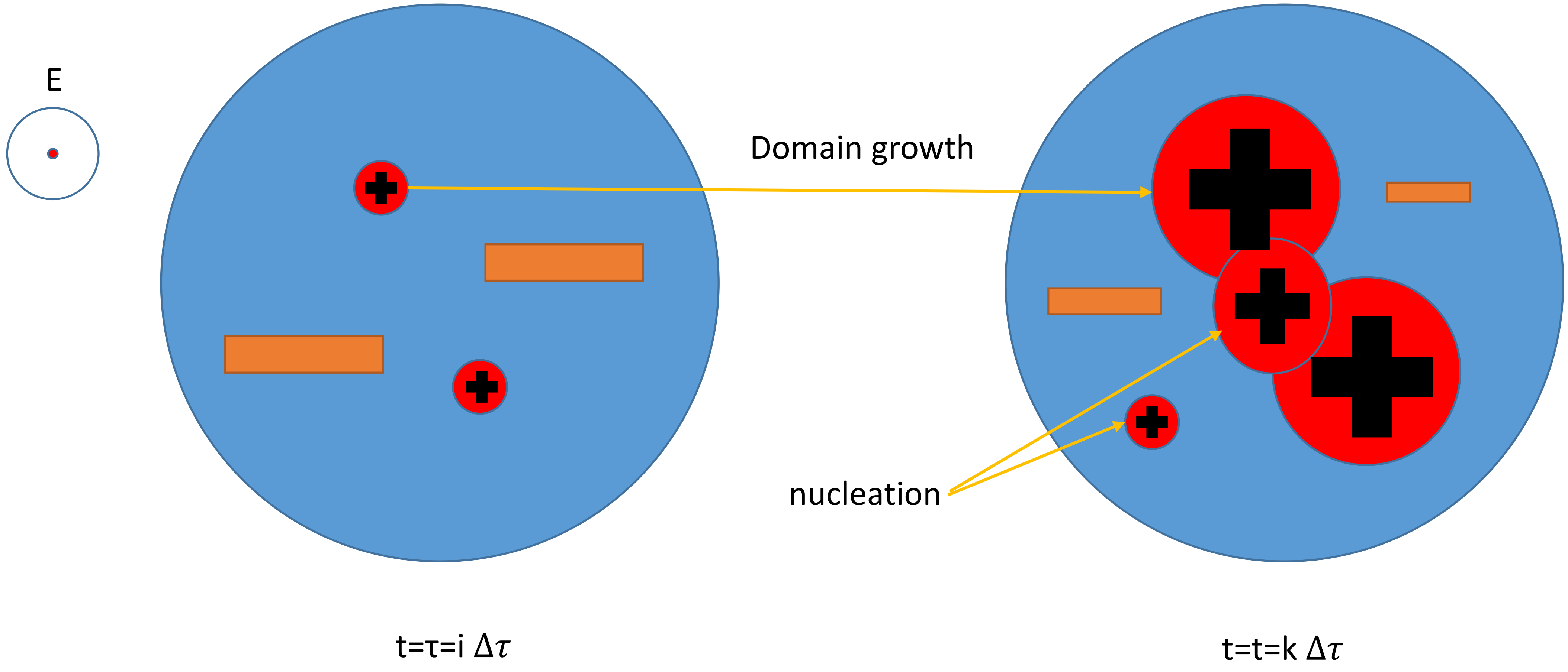
Yoshihiro ISHIBASHI, J. Phys. Soc. Japan, 1990, **59**, 4148-4154

# P reversal=Nucleation + Domain growth

Infinite FE film sandwiched by two electrodes with switching field applied.



# Calculation of switched area C(t)

- Since switched area may be overlapped, C(t)=1-q(t), q(t) is unswitched area.
- $q(t) = \prod_{i=0}^{k}(1 - J(i\Delta\tau)S(k\Delta\tau, i\Delta\tau)\Delta\tau), J(i\Delta\tau)$ means number of nucleis at $i\Delta\tau$ per area, $S(t,\tau) = \pi(v(t-\tau))^2$ is the switched area. For more dimentions, $S(t,\tau) = C_d(v(t-\tau))^d$.
- $lnq(t) = -\int_0^t J(\tau)S(t,\tau)d\tau,$

  when J(t)=R (thermal activated nuclei),

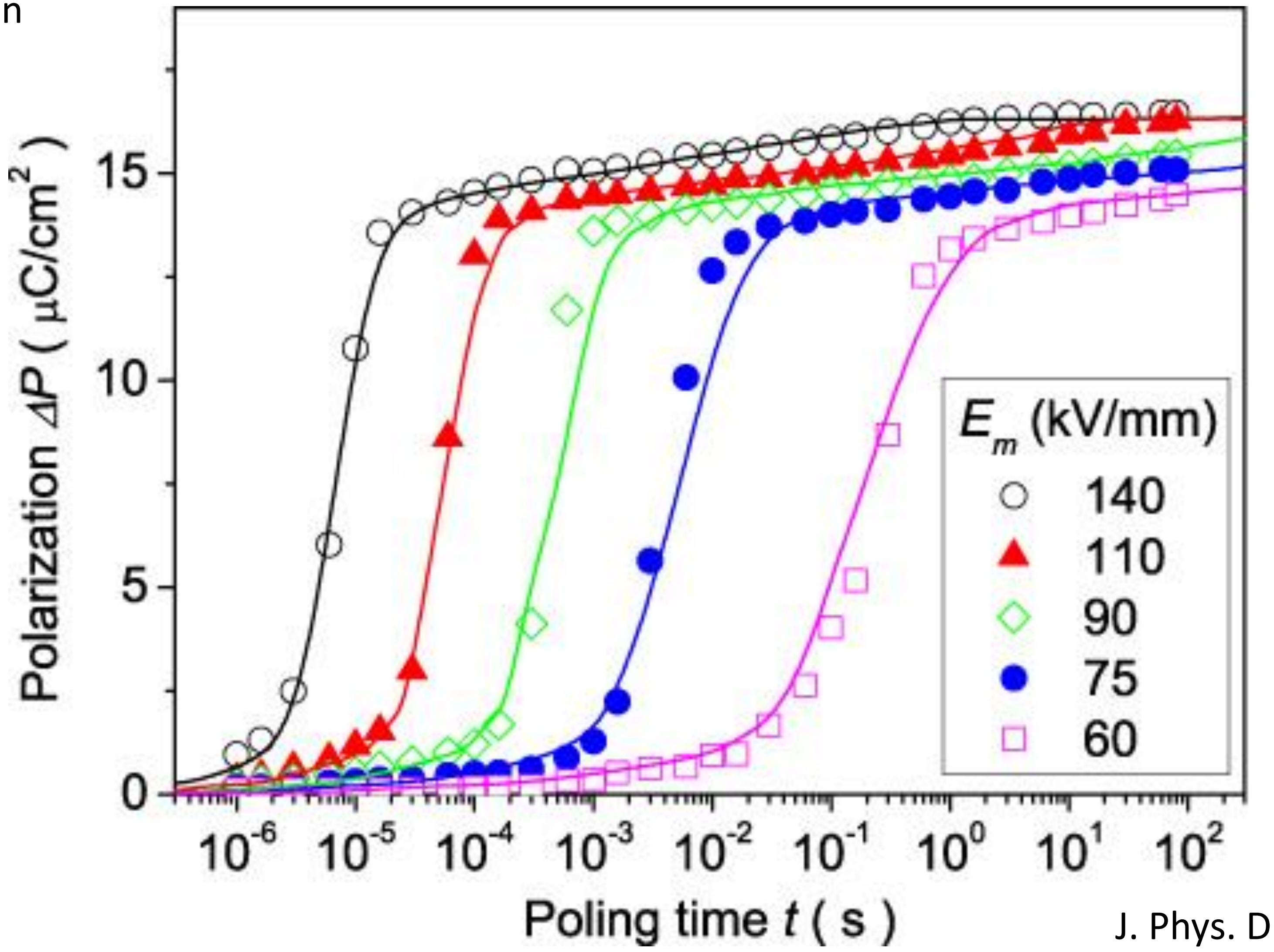
$$C(t) = 1 - \exp\left(-\left(\frac{t}{t_I}\right)^{d+1}\right), \left(\frac{1}{t_I}\right)^{d+1} = R\,\frac{C_d\ v^d}{d+1}$$

  when J(t)=N$\delta(t)$ (latent nuclei),

$$C(t) = 1 - \exp\left(-\left(\frac{t}{t_{II}}\right)^{d}\right), \left(\frac{1}{t_{II}}\right)^{d} = C_d N v^d$$

$$P(t) = 2P_s c(t)$$

50nm electrode on top of 9um PVDF

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# Calculation of $p$ in domain wall

- One dimensional $p^4$ system model for domain wall

$$f=\frac{1}{4}(1-p^2)^2+\frac{k}{2}\left(\frac{dp}{dx}\right)^2, k>0,$$

$$k\ represents\ interaction\ with\ neighbors.$$

Euler-Lagarange equ. $\frac{df}{dp}=\frac{d}{dx}\frac{\partial f}{\partial\frac{dp}{dx}}$

$$k\frac{d^2p}{dx^2}+p-p^3=0$$

Boundary condition, $p=\pm1, \frac{dp}{dx}=0$ @ $x=\pm\infty$

$$p=tanh\frac{x}{\sqrt{2k}}$$

Domain wall width $d=\sqrt{2k}$

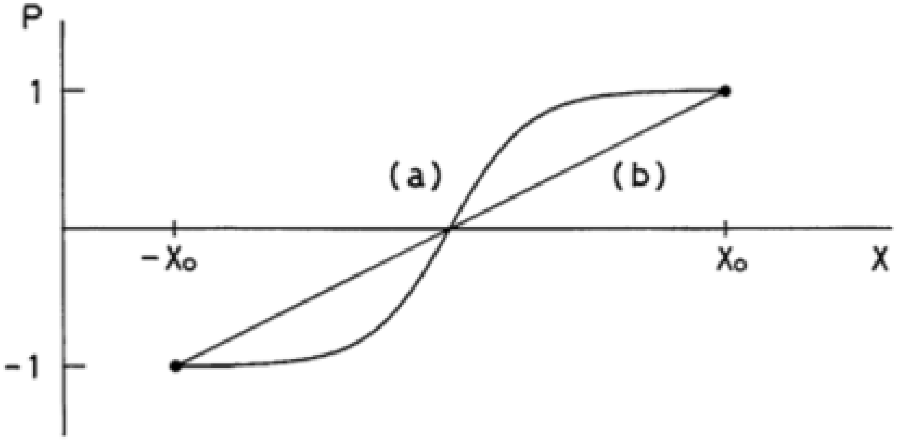



Fig. 3. A domain wall in the continuum. (a) $x_0>2d$, (b) $x_0<2d$.

# Calculation of $v$ for domain wall move

- Equate the rate of the energy lost by viscosity and the electric energy supplied by external field. –pe is added to f(x). Total energy $F = \int f(x)dx$
- Time evolution

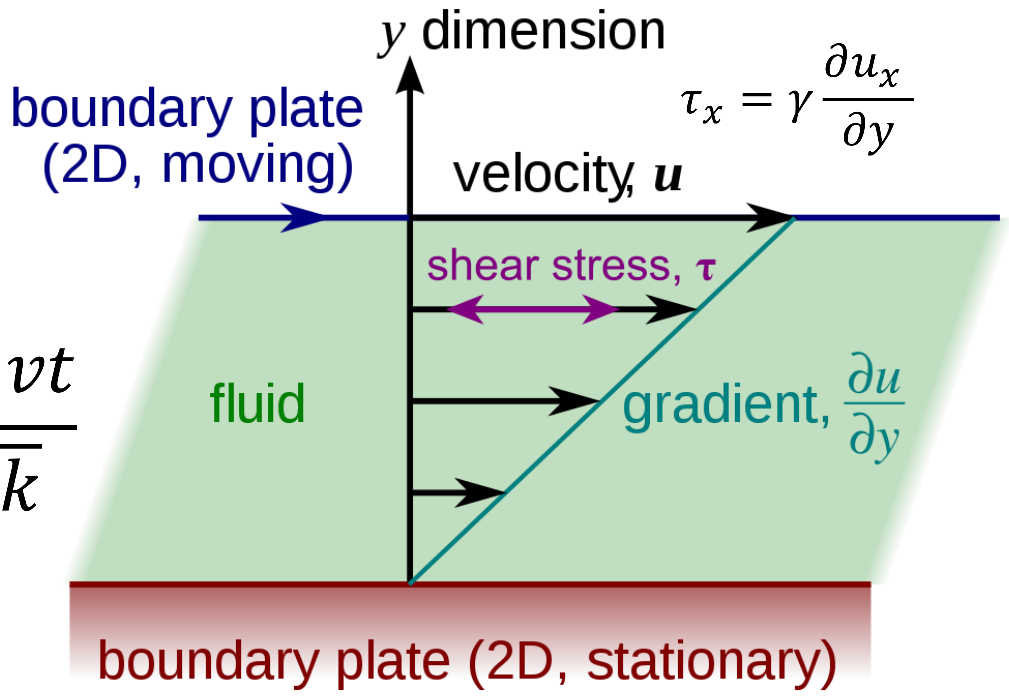
$$\gamma \frac{dp}{dt} = -\frac{\delta F}{\delta p} \text{ ?}$$

- For a moving domain wall,

$$p(x,t) = tanh\frac{x - vt}{\sqrt{2k}}$$

- Solving the equation,

$$v = \frac{3\sqrt{2k}}{2}e = \frac{3d}{2}e$$



# Switching time vs applied field

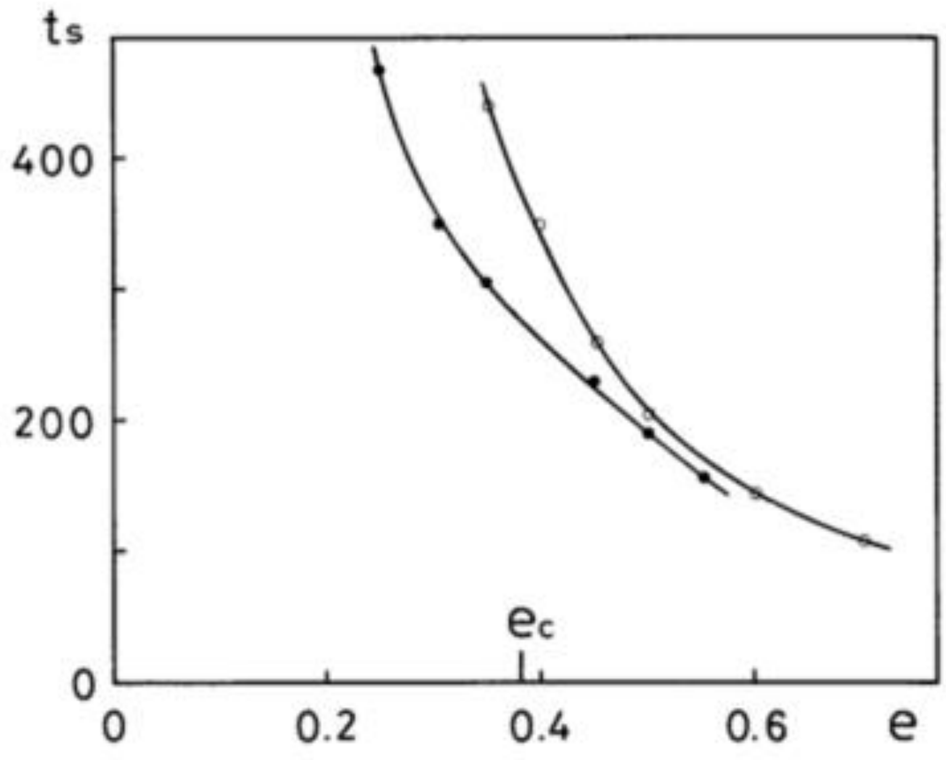



Fig. 7. The applied field (e) dependences of the switching time $t_s$, for two cases with different distribution of nuclei ($m_+ = m_- = 5$ in both cases). $t$ is measured with the unit of $\Delta t = 0.02$.