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Mechanics of dielectric elastomers: materials, structures and devices

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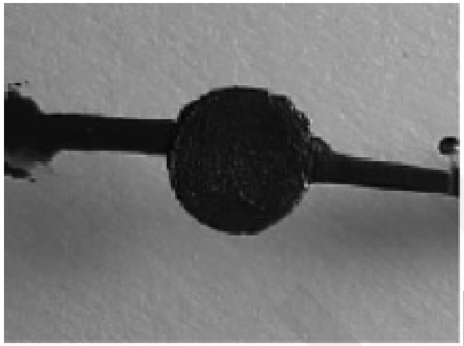
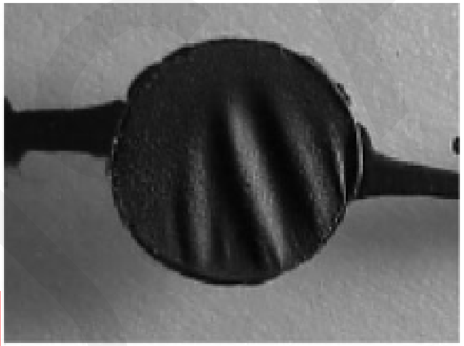
Dielectric elastomers and artificial muscles

Dielectric elastomer (DE):

to generate large deformation under electric stimuli



Voltage Off



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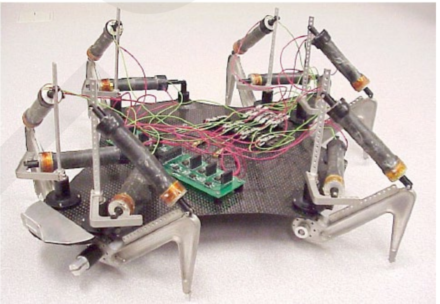
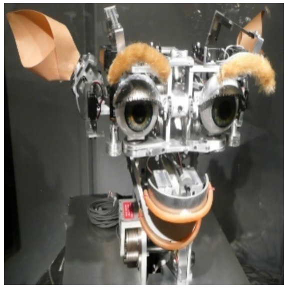
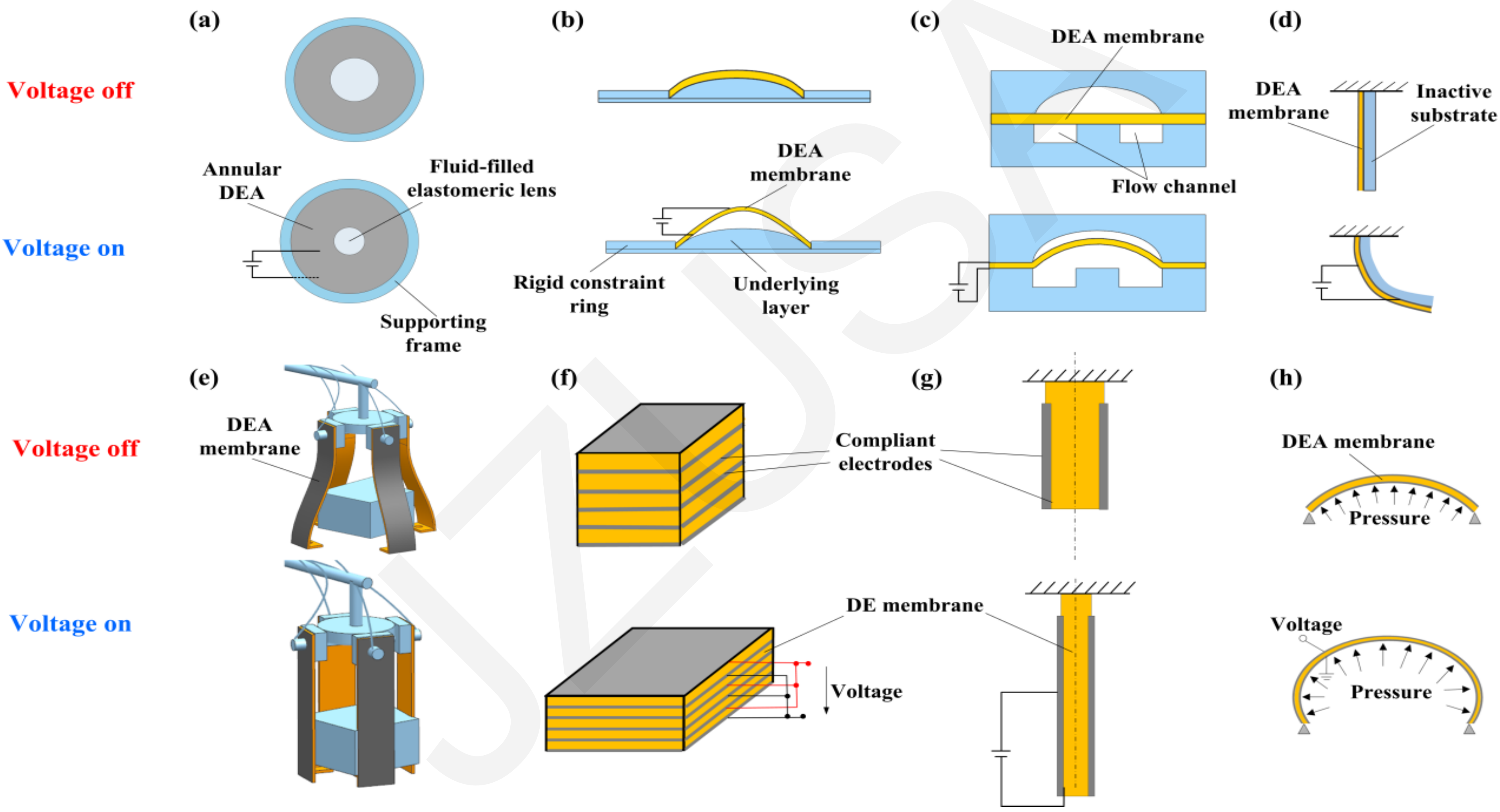


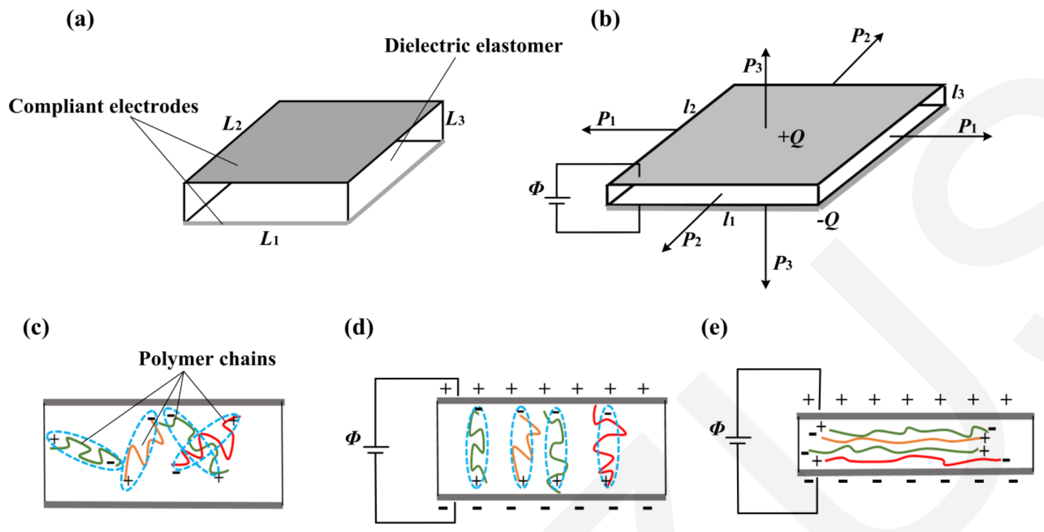


in mimicking motions of natural muscles

Representative DE actuators



Working principle of DE actuators



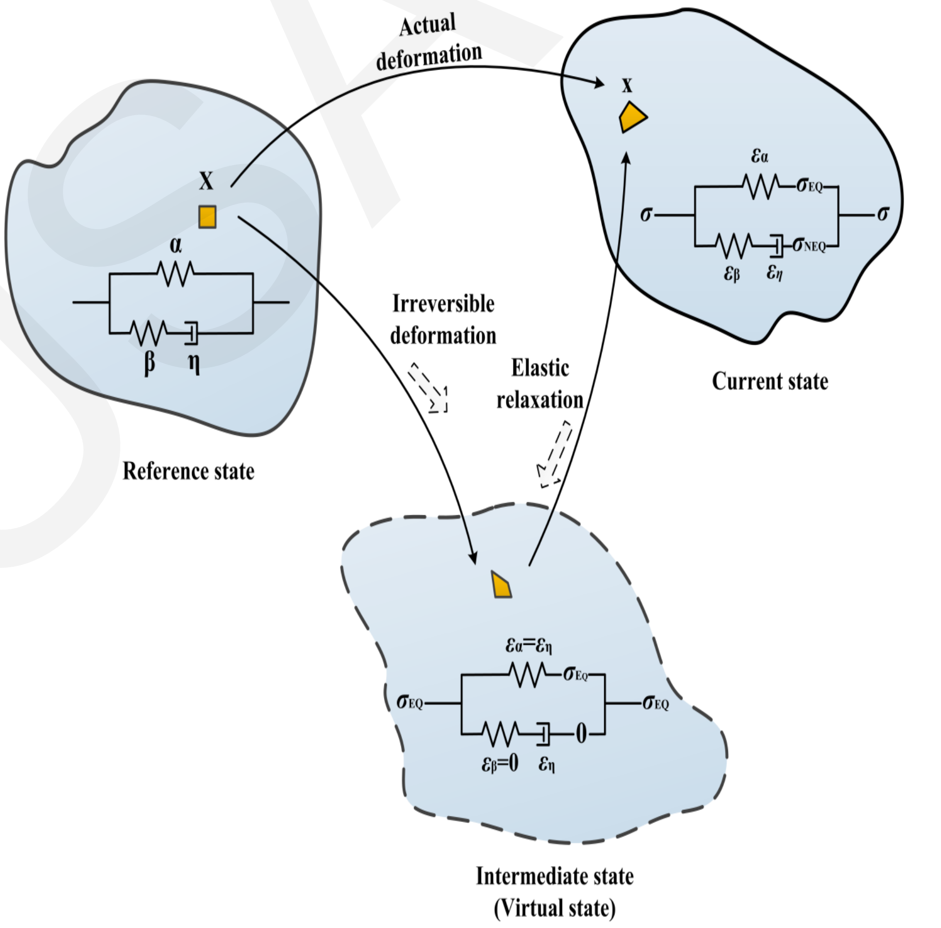
- Electromechanical coupling
- Constitutive laws
- Viscoelastic behaviors
- Electromechanical instability
- Energy function

Analytical models:
non-equilibrium thermodynamics

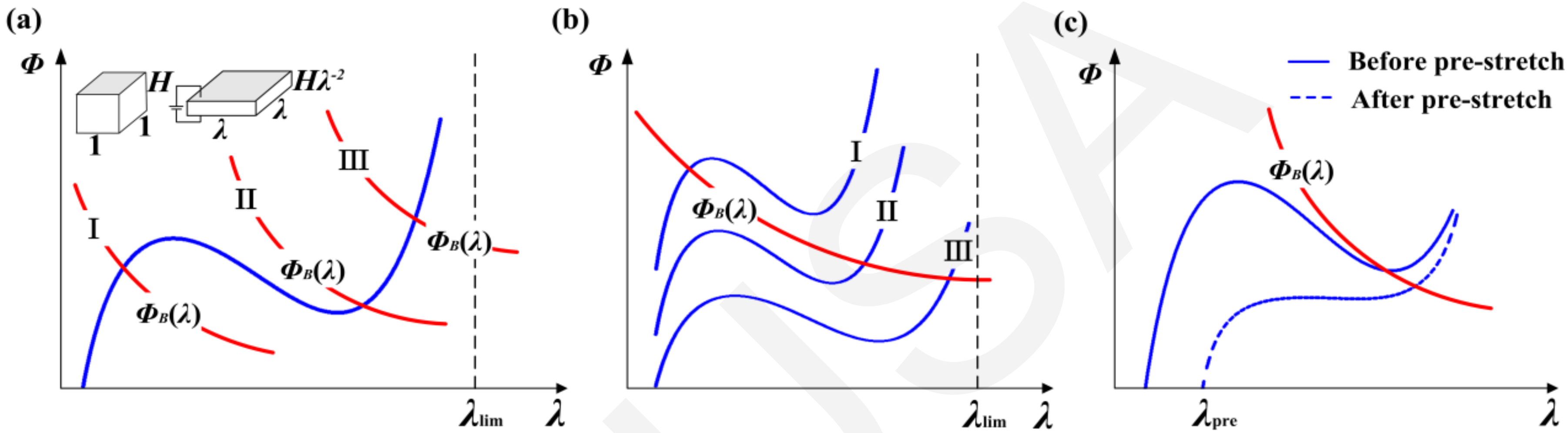
Computational models:
finite element method

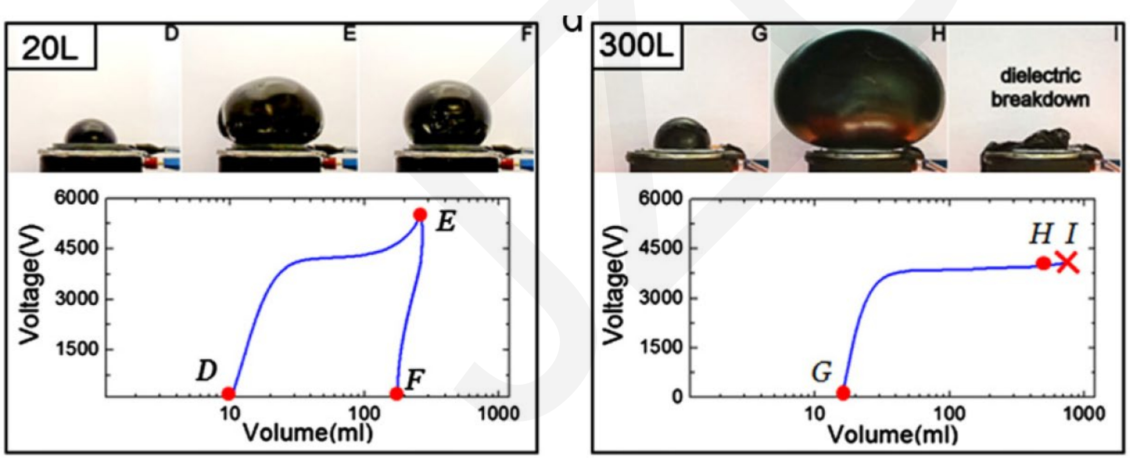
Deformation: energy function & viscoelasticity

Energy functions	Function forms
neo-Hookean Model	$W_s = \frac{G}{2}(\lambda_1^2 + \lambda_2^2 + \lambda_1^{-2}\lambda_2^{-2} - 3)$
Gent Model	$W_s = -\frac{GJ_{\lim}}{2}\log(1 - \frac{\lambda_1{}^2 + \lambda_2{}^2 + \lambda_1{}^{-2}\lambda_2{}^{-2} - 3}{J_{\lim}})$
Mooney-Rivlin Model	$W_s = C_1(I_1 - 3) + C_2(I_2 - 3)$ $I_1 = \lambda_1{}^2 + \lambda_2{}^2 + \lambda_3{}^2,\ I_2 = \lambda_1{}^2\lambda_2{}^2 + \lambda_2{}^2\lambda_3{}^2 + \lambda_3{}^2\lambda_1{}^2$
Yeoh Model	$W_s = \frac{C_1}{2}(I_1 - 3) + \frac{C_2}{2}(I_1 - 3)^2 + \frac{C_3}{2}(I_1 - 3)^3$ $I_1 = \lambda_1{}^2 + \lambda_2{}^2 + \lambda_3{}^2$
Ogden Model	$W_s = \sum_{p=1}^{N}\frac{\mu_p}{\alpha_p}(\lambda_1^{\alpha_p} + \lambda_2^{\alpha_p} + \lambda_1^{-\alpha_p}\lambda_2^{-\alpha_p} - 3)$



Electromechanical instability of DEs





Li *et al.* (2013)

Giant voltage-induced deformation in dielectric elastomers near the verge of snap-through instability. *Journal of the Mechanics and Physics of Solids*, 61: 611-628.

Conclusive remarks and outlook

- **Involving researchers with various backgrounds:** mechanics, material science, chemistry, etc.
- **Theoretical and numerical approach:** providing a deeper understanding of the underlying electromechanical principles
- **New avenue to build DE-made soft machines with tunable properties:** biomedical devices, adaptive systems, robotics, energy harvesting, etc.