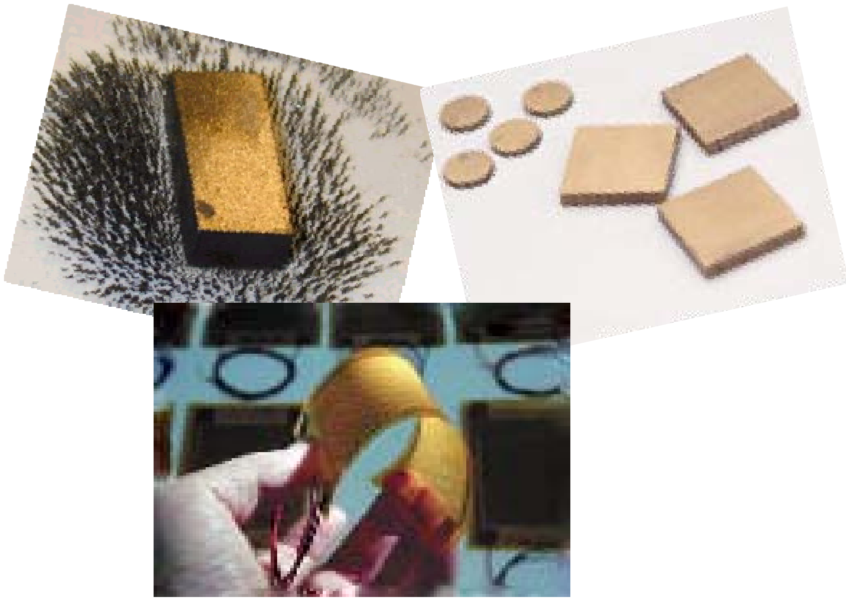
Overview of Smart Materials



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Topics Covered in the Last two Lectures

- **What is Magnetostriction?**
- **What are the different effects of Magnetostriction?**
- **The Constitutive Relationship**
- **Actuators Developed using Terfenol-D**
- **Sensors Developed using Terfenol-D**
- **Magnetostrictive Composites**

LECTURE 5:

Active Smart Polymers (Part 1)

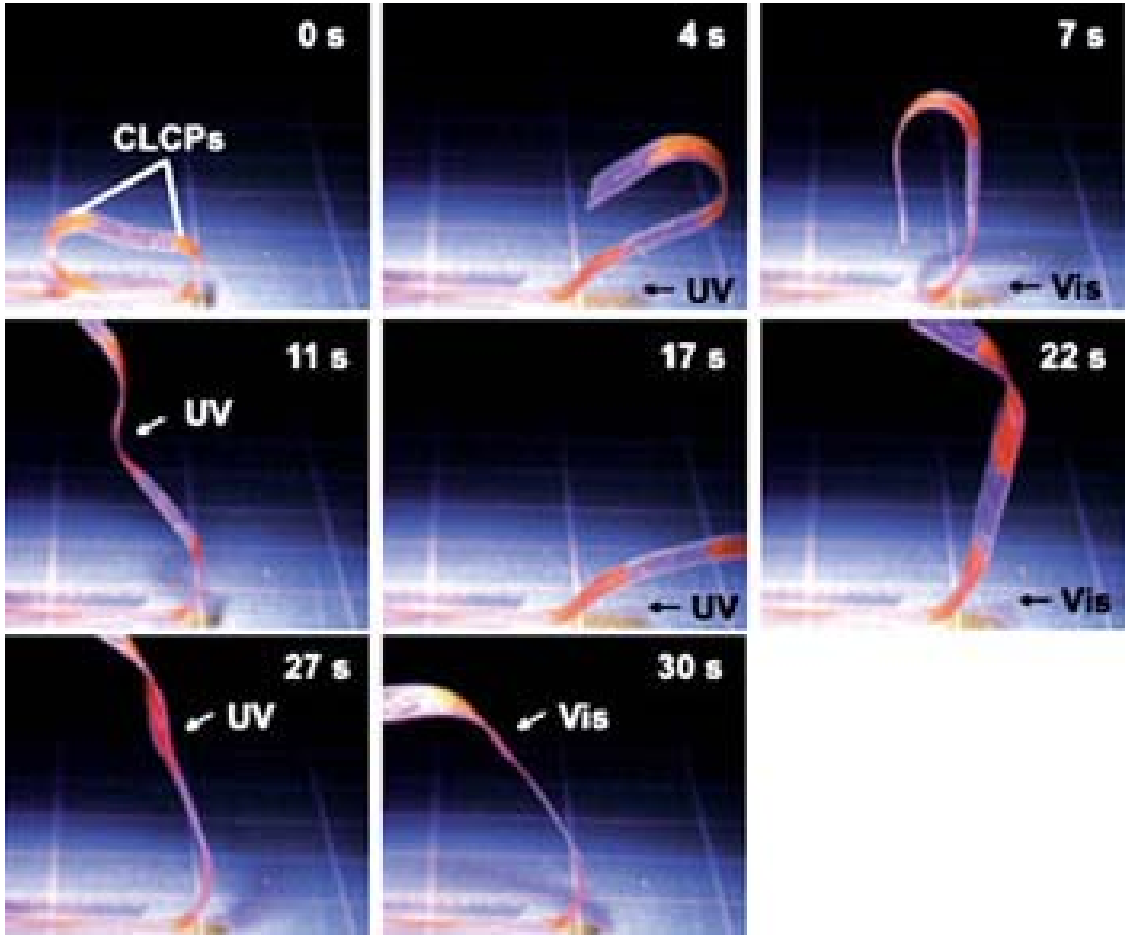
Organization

- What is Active Smart Polymer?
- Classifications of Electro-active Polymers
- The Constitutive Relationship
- Actuators Developed using EAP
- Sensors Developed using EAP
- Future of IPMC

What is Active Smart Polymer?

- Polymers that respond to external stimuli by changing shape or size are known as active smart polymer. These are of two categories:
- Active Polymers that respond to input stimuli such as pH, magnetic field and light
- Electro-active Polymers that respond to the change of electrical input. Also known as EAP

Active Smart Polymer



http://www.rsc.org/Publishing/ChemScience/Volume/2009/01/Polymers_strut_stuff_spotlight.asp

Response to light due to Azobenzene groups contain N=N double bonds.

Under visible light N=N bonds have a *cis* conformation - the polymer is *bent*.

Under UV light source the bonds become *trans* and the polymer *flattens*.

Classifications of Electro-active Polymer (EAP)

EAPS are broadly classified into two groups
– Electronic EAP and Ionic EAP

Electronic EAP (EEAP)	Ionic EAP (IEAP)
Dielectric EAP	Ionic Polymer Gels (IPG)
Electrostrictive Paper	Ionic Polymer Metal Composite (IPMC)
Ferroelectric Polymers	Conducting Polymers
Liquid Crystal Elastomer	Carbon Nanotubes (CNT)

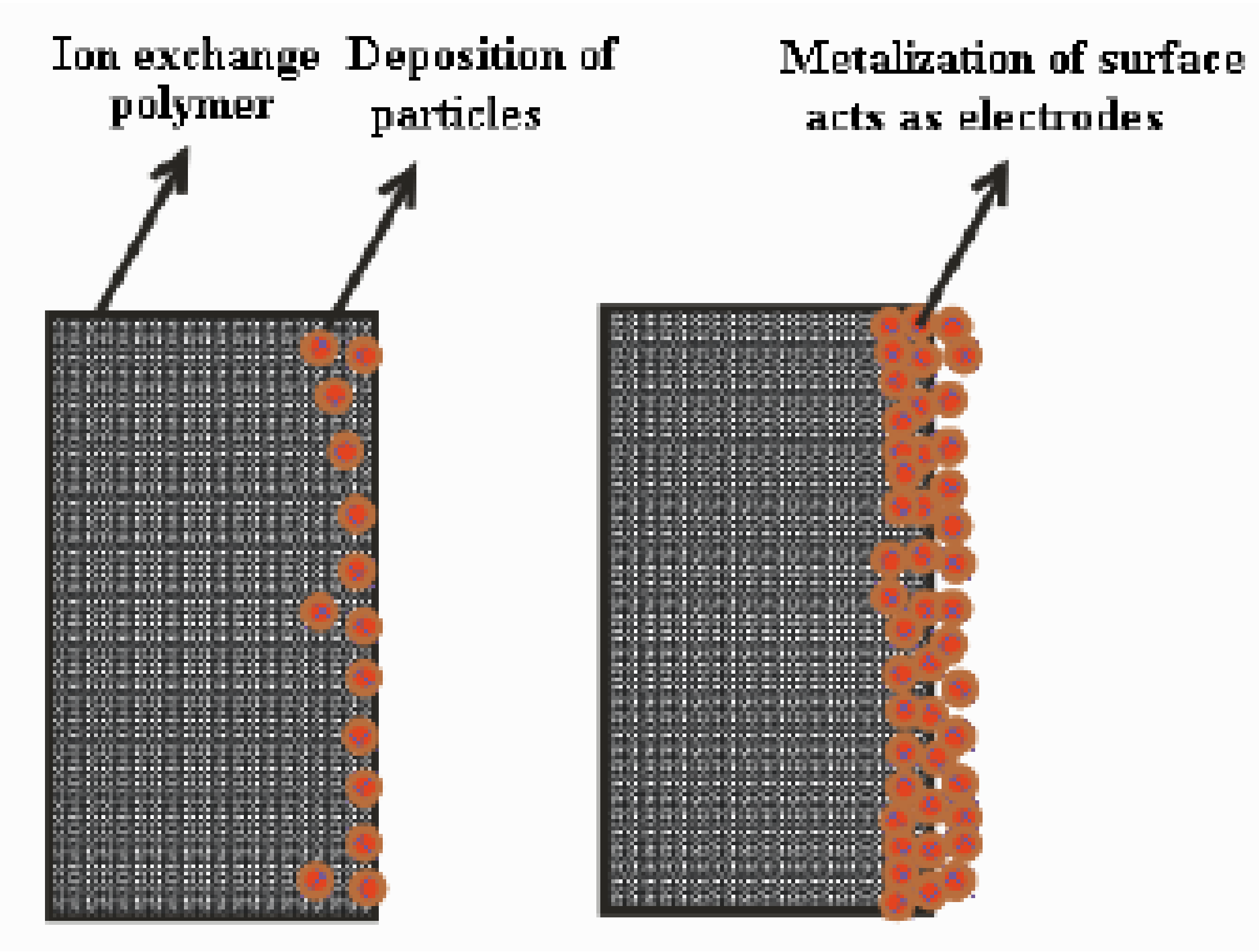
Comparisons between EEAPS and IEAP

- Electronic EAPs need high activation voltage (> 150 V/µm).
- Materials have high energy density and rapid response time in milliseconds.
- IEAPs require small driving voltage (1-5V).
- However, IEAP has slow response time and performs better under wet condition.

Timeline of Development

- 1978 - Toyoichi Tanaka – Smart Hydrogel – Gels swelling 1000 times of its volume
- 1993 – Oguro – Electroactive Nafion
- 2000 – Schreyer – Electroactive PAN Fibre
- 2002 – Shahinpoor – Ionic Polymer Metal Composite

Electro Active Polymer



How does an IPMC work?

- IPMC consists of a Polymer matrix sandwiched between two metallic layers
- The polymer consists of a fixed network with negative charges balanced by mobile positive ions.
- When subjected to DC voltage – there will be accumulation of cations near cathode – water molecules will move towards this side causing hydrophilic expansion.

How does an IPMC work - ..?

- The polymer matrix will bend towards the anode side.
- With time, there will be a back diffusion of water molecules causing a slow relaxation towards cathode.
- Extent of Actuation depends on type of polymer, type of counter ion, presence of moisture, quality of metallization.

Comparison of Properties with other smart materials

Property	Ionic polymer-Metal Composites (IPMC)	Shape Memory Alloys (SMA)	Electroactive Ceramics (EAC)
Actuation displacement	>10%	<8% short fatigue life	0.1 - 0.3 %
Force (MPa)	10 - 30	about 700	30-40
Reaction speed	µsec to sec	sec to min	µsec to sec
Density	1- 2.5 g/cc	5 - 6 g/cc	6-8 g/cc
Drive voltage	4 - 7 V	NA	50 - 800 V
Power consumption	watts	watts	watts
Fracture toughness	resilient, elastic	elastic	fragile

Sahinpoor and Bar-Cohen 1998

References

- Electroactive Polymers for Robotics Applications – Kim and Tadokoro
- Smart Structures – Paolo Gaudenzi

END OF LECTURE 5