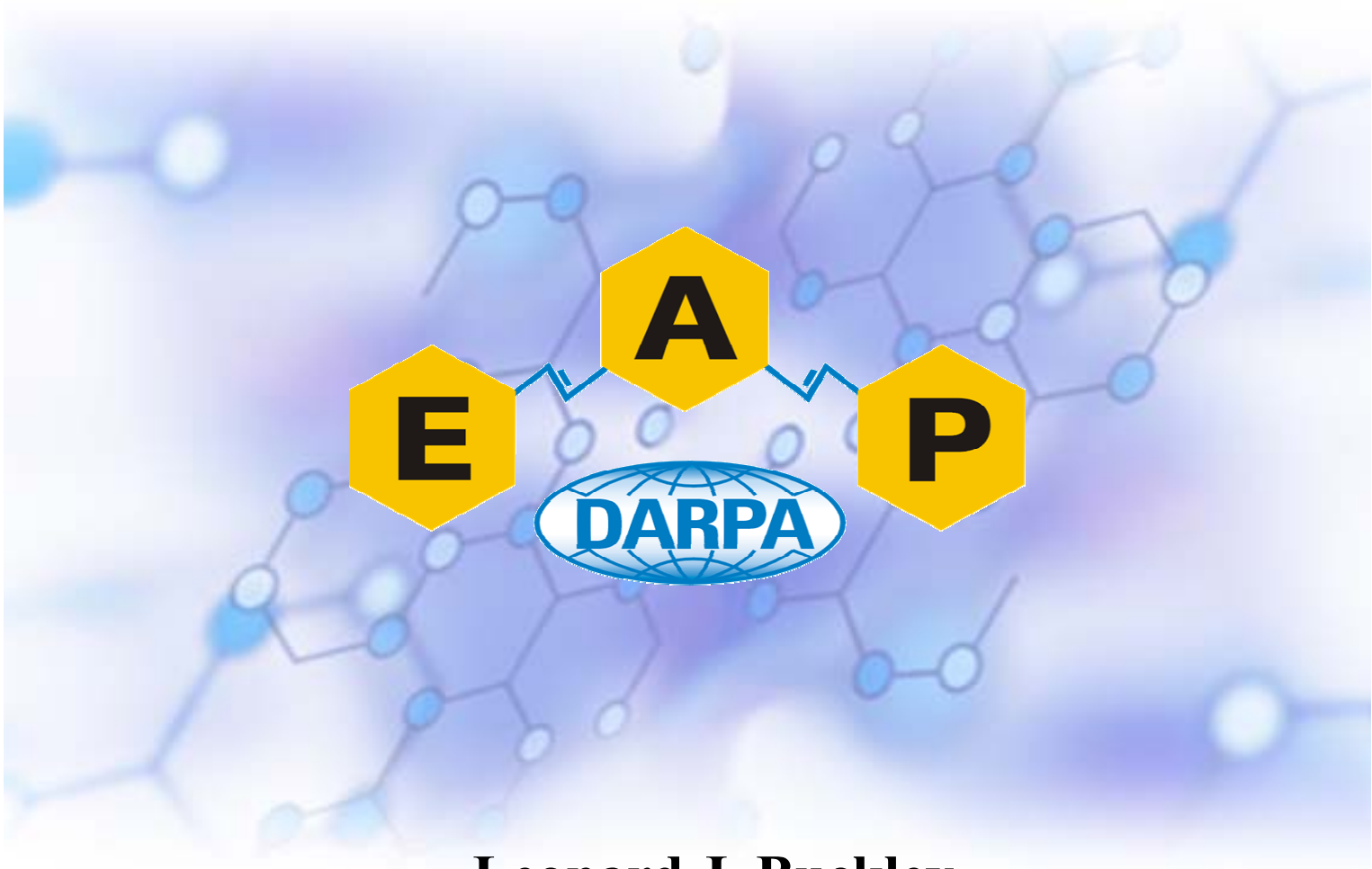


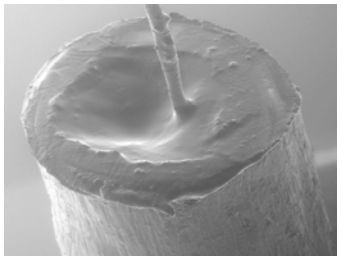
Leonard J. Buckley
Defense Science Office
Lbuckley@darpa.mil

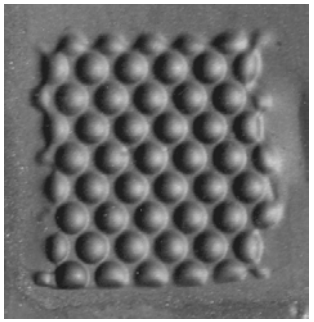
Electroactive Polymers

Objective: To exploit the electronic, mechanical, and optical responses of electroactive polymers for applications in sensing, actuation and light emission

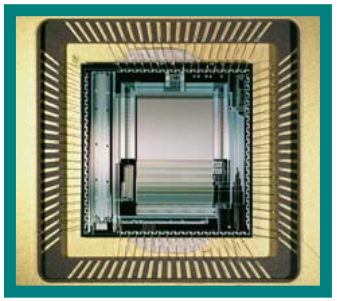
Chemistry, Processing, Properties

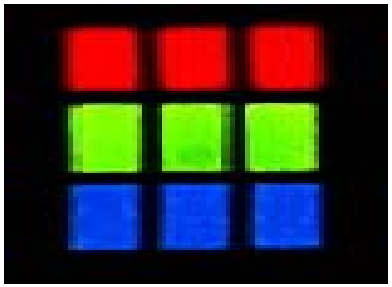
Actuation

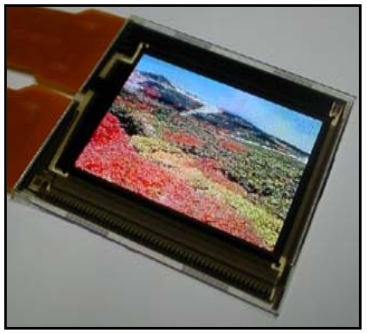




Electro-Optical Response







Actuators-Pneumatics

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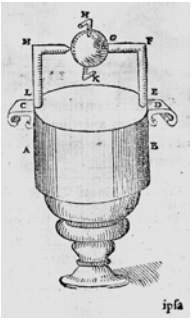
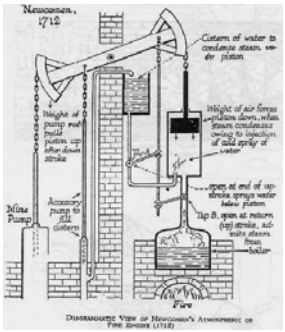
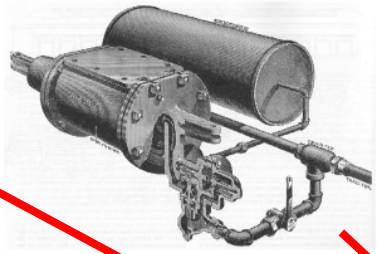
Hero of Alexandria Pneumatics



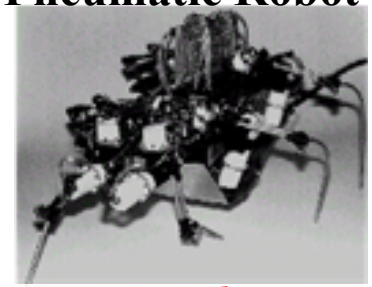
Newcomen Steam Engine



Westinghouse Air Brakes

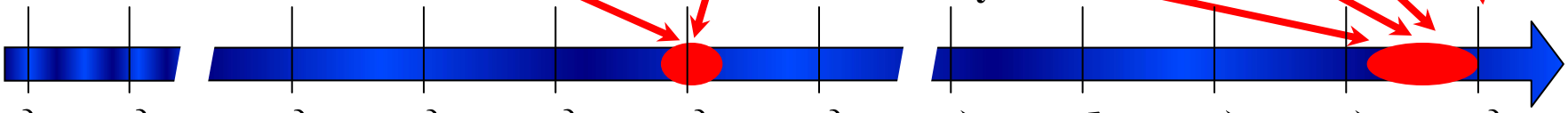


MIT Pneumatic Robot



Ctesibios Robotics

Galileo/Torricelli Theory



2,600,000 BC | 2,400,000 BC | 200,000 BC | 20,000 BC | 2,000 BC | 200 BC | 20 BC | 100 AD | 500 AD | 1000 AD | 1500 AD | 2000 AD

Stone Tools

Wedge

Bow & Arrow

Wheel

Lever

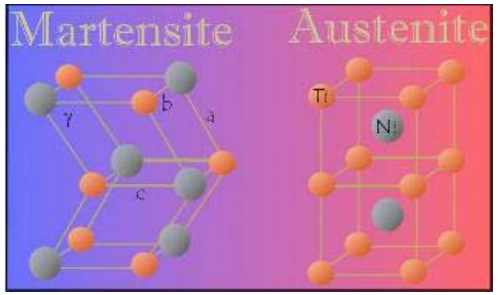
Pulley

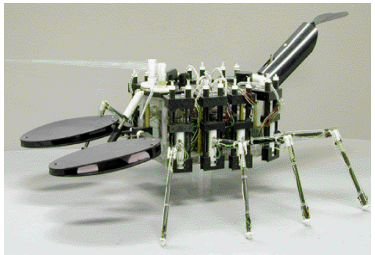
Compass

Heavy Plow

Electric Motor

Metallic Actuators





Copper Metallurgy Developed

Bronze Metallurgy Developed

Hittites Develop Iron

Steel Developed

Chang & Read AuCd

Buehler NiTi

Northeastern U

1932 1950 1970 1990

2,600,000 BC 2,400,000 BC 200,000 BC 20,000 BC 2,000 BC 200 BC 20 BC 100 AD 500 AD 1000 AD 1500 AD 2000 AD

Stone Tools

Wedge

Bow & Arrow

Wheel

Glass

Spiral Screw

Heavy Plow

Printing Press

Polymer Actuators

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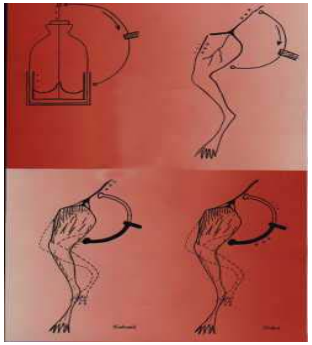
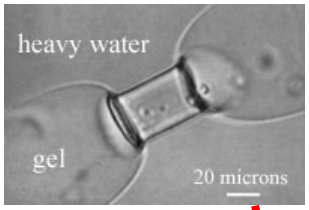
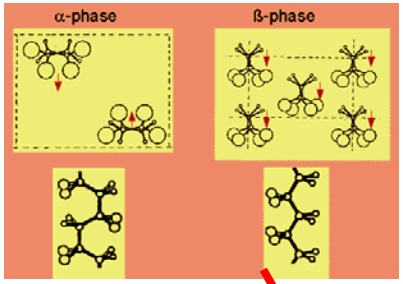
Galvani
Electroactivated Frog Muscle



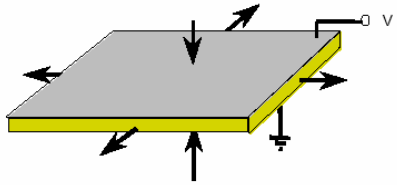
Katchalsky
Gel Actuators



Copolymer Actuators

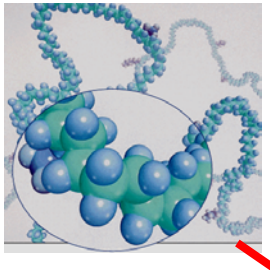


SRI
Dielectric
Material

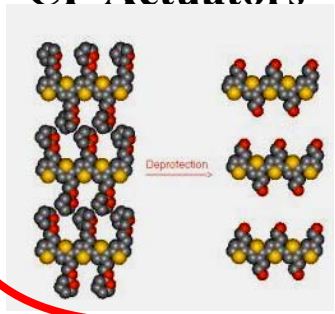


Goodyear
Rubber Process

Staudinger
Polymers



Baughman
CP Actuators



Shaninpoor
IPMC

1600 BC | 1820 | 1850 | 1880 | 1910 | 1940 | 1970 | 2000

Rubber Developed
Mesoamerica

Chardonnet
Synthetic Fiber

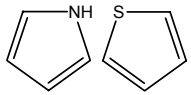
Polymer Gels

PVDF
Piezoelectrics

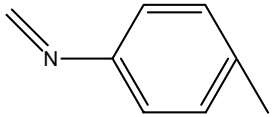
Progress in Conductive Polymers

Polysulfer Nitride
(SN)x

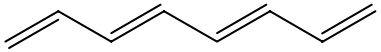
Polypyrrole
Polythiophene

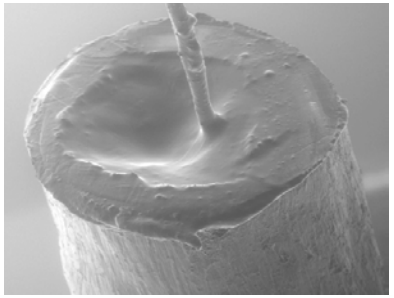


Polyaniline

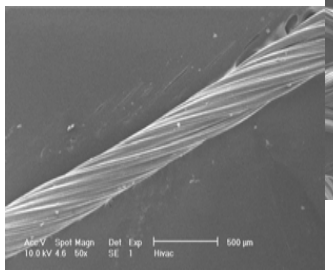


Polyacetylene



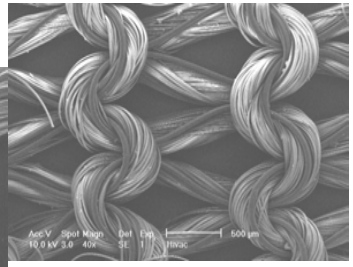


Conductive Polymer Actuation



High Quality Multifilament Polyaniline Yarn

Co-spun *fiber-in-fiber* actuator



Polyaniline/Nylon Yarn Weave

1964 **1977** **1979** **1985** **1992** **1999** **2000** **2001**

Chemistry and Physics of Conductive Polymers ***Processing and Applications***

Progress in LED's

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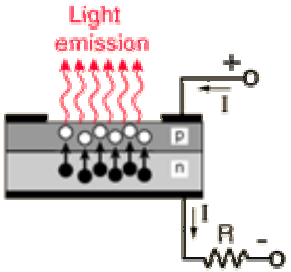
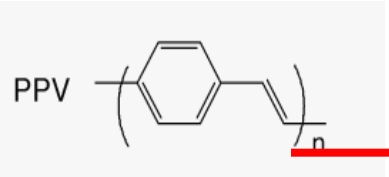
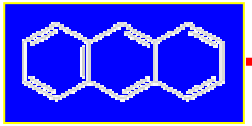


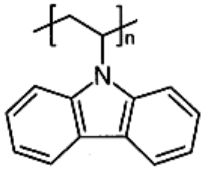
PPV Invented
Dow Chemical



Pope Discovery
Organic EL

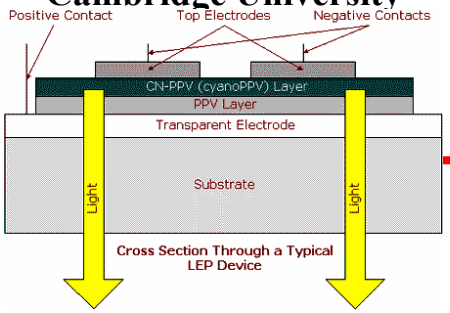


Partridge
Polyvinylcarbazole

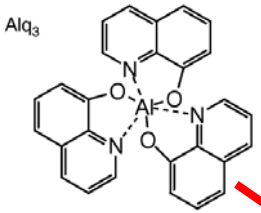


Dow Chemical
1st Patent on
Organic EL device

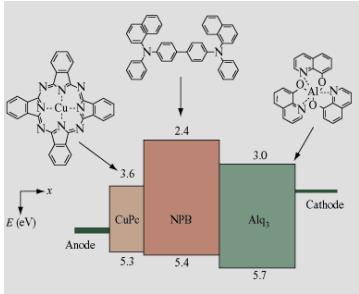
PPV Display
Cambridge University



Tang/Kodak
Alq



Kodak/Sanyo
2.4" TFT-OLED



1879 | 1900 | 1960 | 1968 | 1976 | 1984 | 1992 | 2000

Edison's Light Bulb
1% Efficiency

Round
SiC LED

Holonyak invents
GaAsP LED

Conductive
Polymers

Nakamura blue LED
InGaN

Dow demonstrates
Polyfluorene blue LED

Fullerene Technology

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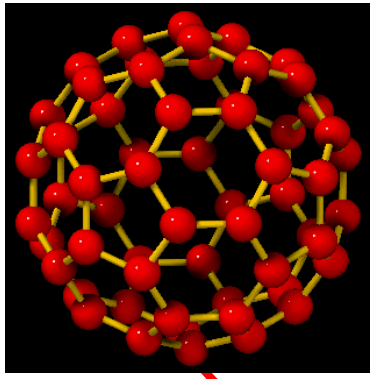
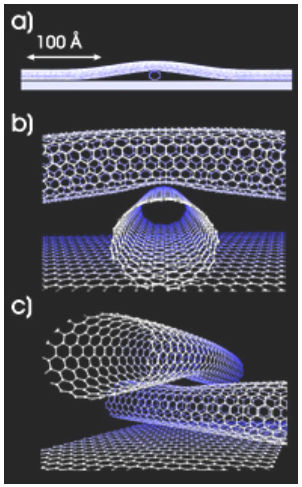
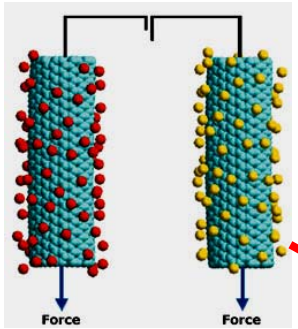
C_{60} Discovery Smalley



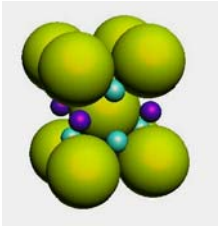
CNT Discovery Iijima



Baughman CNT Actuators

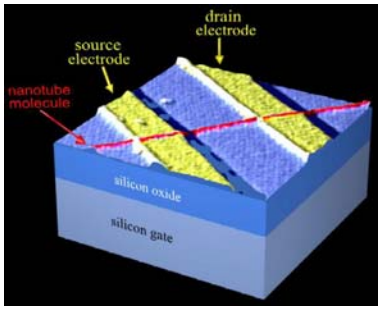


A_3 C_{60} *fcc* structure

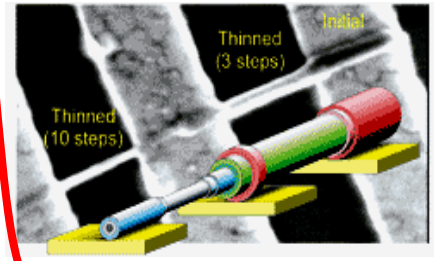


Superconductive

CNT Transistor Demo Delft University



CNT Transistor Demo IBM



1980 1984 1988 1992 1996 2000

HTS Discovery Bednorz & Muller

C_{60} Superconductivity Measured

Armchair CNT predicted to be metallic (White, NRL)