Why Memories in Materials Matter to Most Everyone

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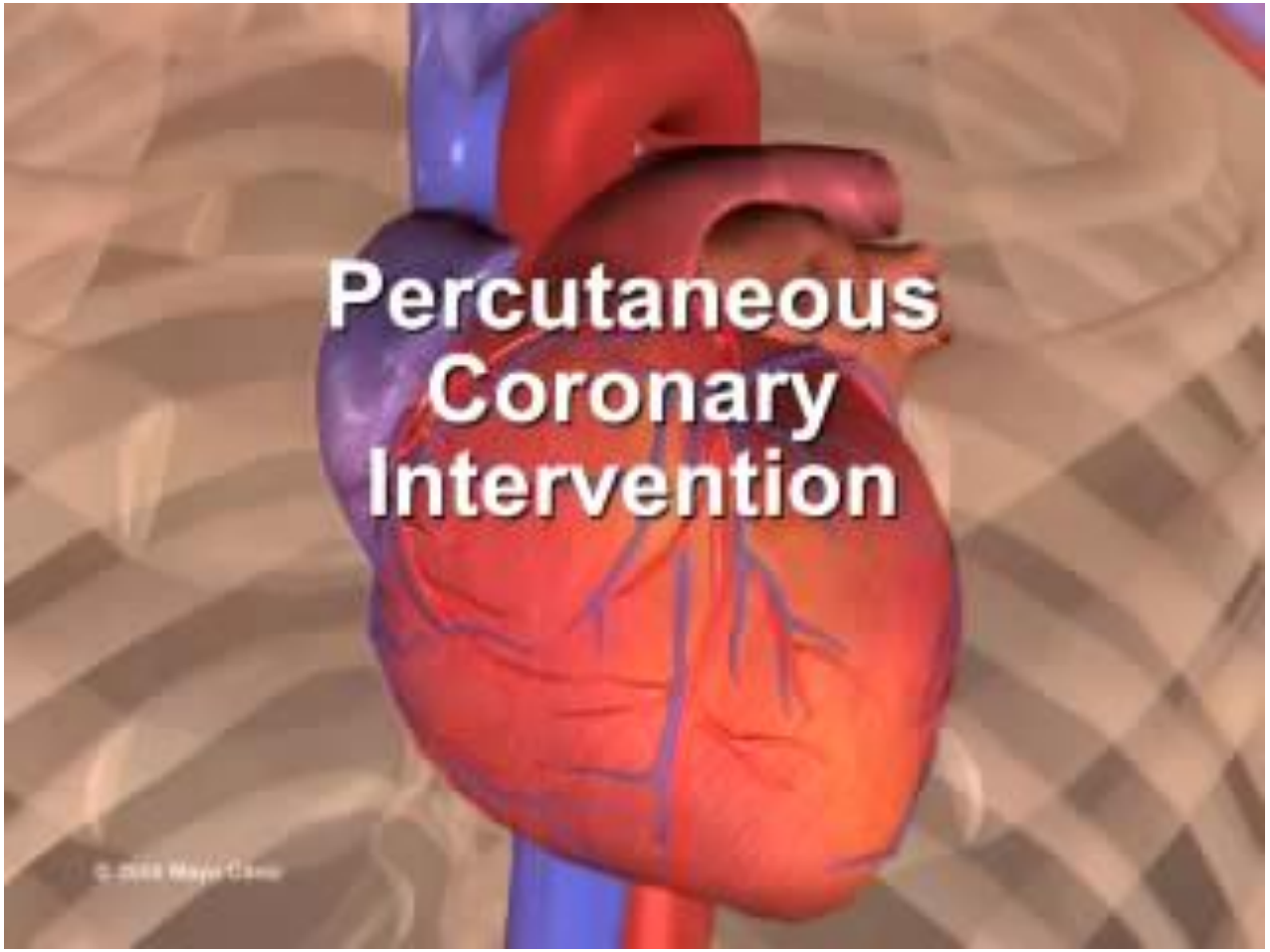
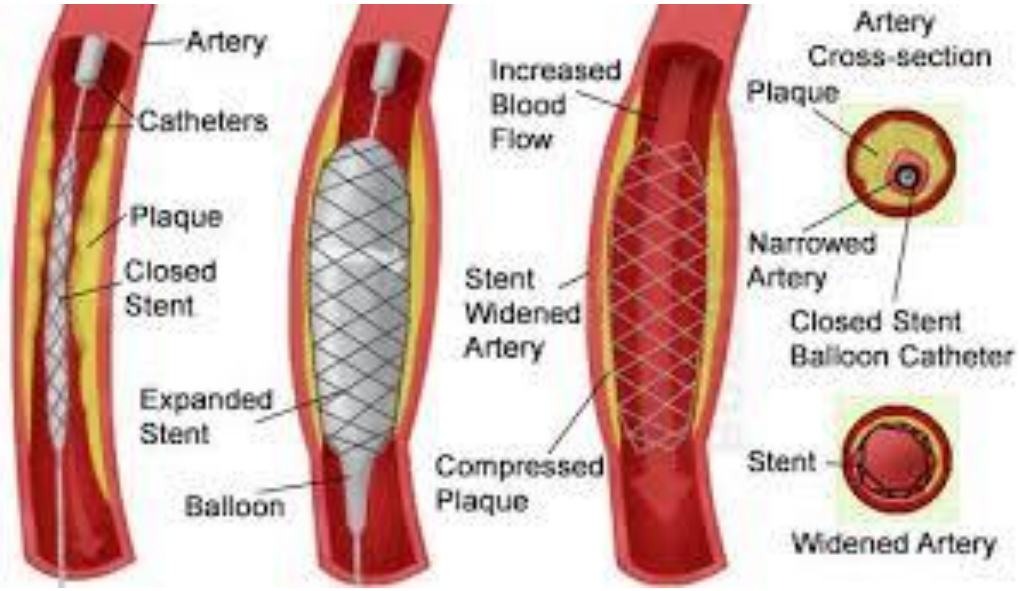
Why do I care about memories in materials?



Most cardiac stents are made from materials called “shape memory alloys”

Shape memory property ensures that stent can be compressed into the catheter and then keeps it shape accurately once it is placed in the artery.

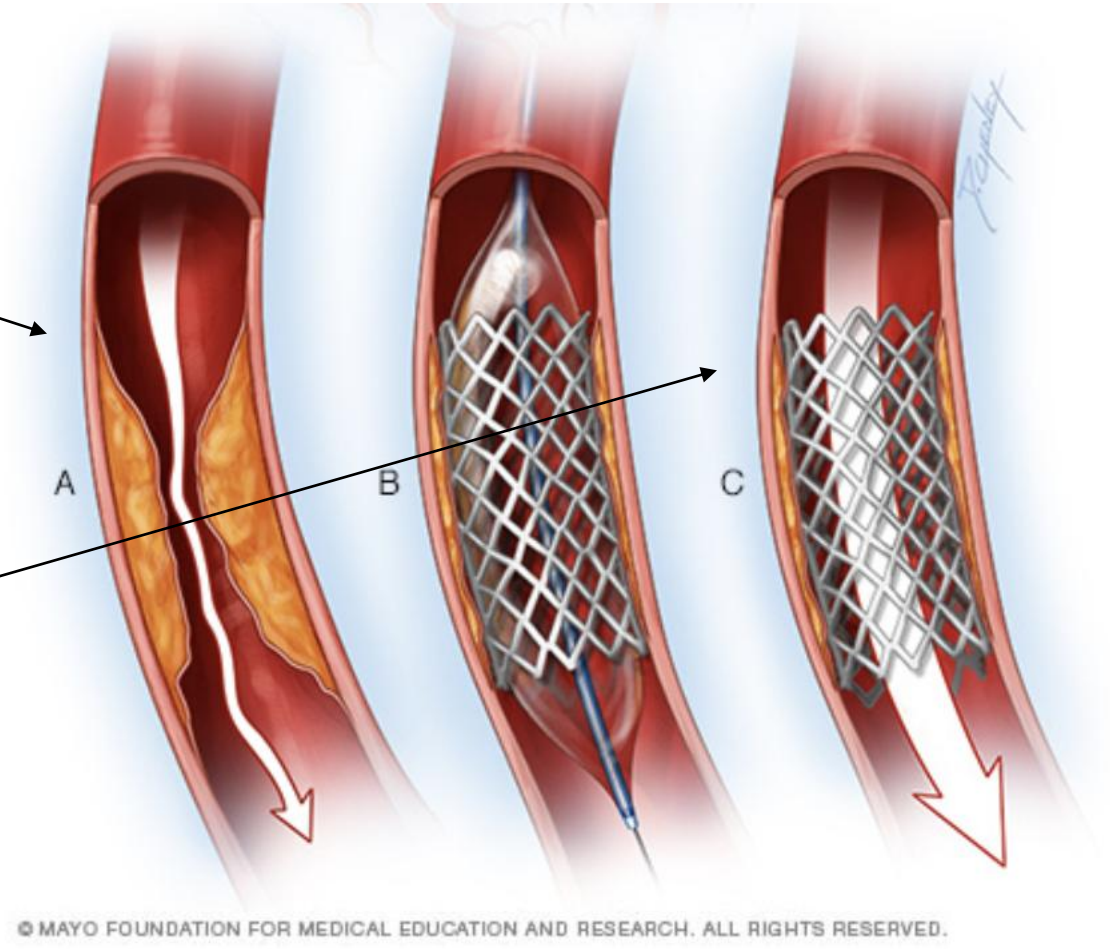


David Segal, “Materials for the 21st Century, Oxford University Press (2017)

The stent remembers its shape even when highly distorted at low temperatures.

Stent is highly deformable at low temperature and it fits inside small catheter

Stent accurately remembers its original shape at high temperature



https://www.mayoclinic.org/tests-procedures/coronary-angioplasty/about/pac-20384761

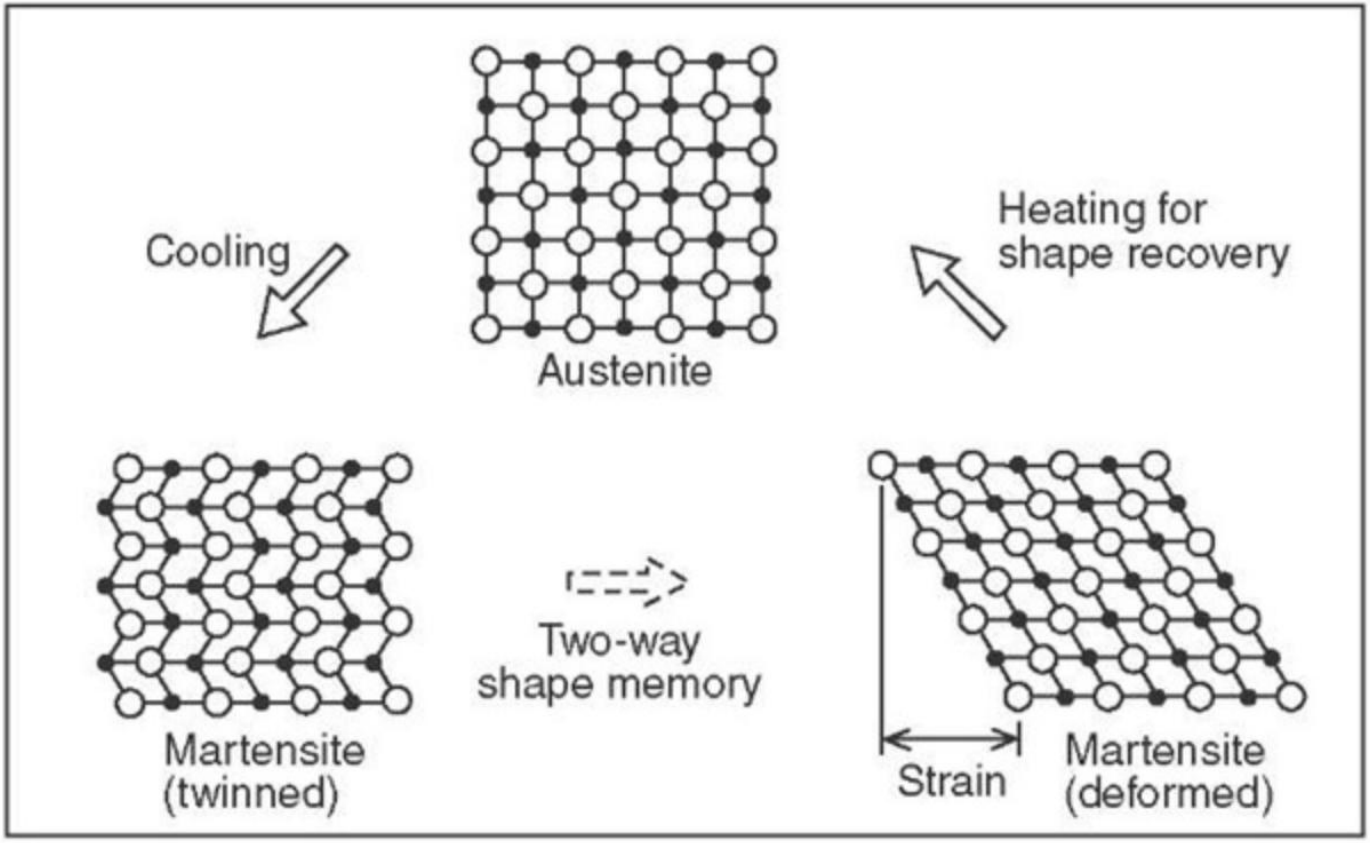
Shape memory materials undergo a phase transition (from austenite to martensite)

High temperature:

Austenite

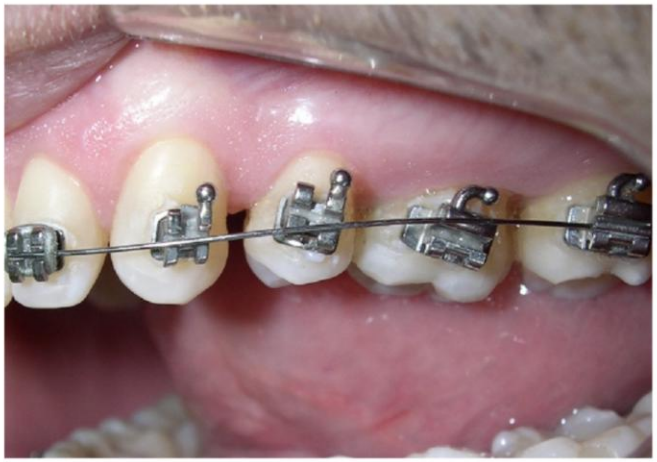
Low temperature: Martensite

Deformable because domain boundaries can rearrange



http://what-when-how.com/materialsparts-and-finishes/shape-memory-alloys/

Another use for shape memory alloys: braces



(a)

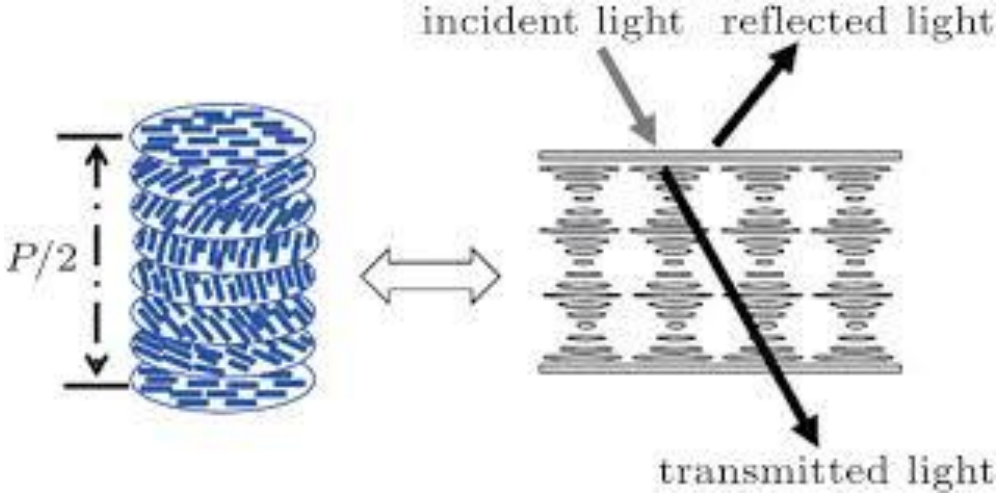
Shape memory property: wire remembers configuration where teeth are straightened

This material is also superelastic: wire can be strained a lot at the beginning and still remembers its ”proper” shape and exerts gentle force until it is reached.

D. J. Fernandes, ISRN Dent. 2011, 132408 (2011).

Some materials have properties that depend a lot on the environment

- Examples:
  - Hydrogel (sodium polyacrylate): absorbs enormous amount of water, so you can tell if it has been exposed to water
    - used in disposable diapers (absorbs about 30 times its own weight in urine)
  - "Cholesteric" liquid crystals: color depends on temperature



Spiral alignment of rod-like molecules has a pitch that depends on temperature; light is reflected when its wavelength matches the pitch.

Cholesteric liquid crystals can be used as temperature sensors
They can also be used as memories.

How are sensors different from memories?

Sensors versus memories

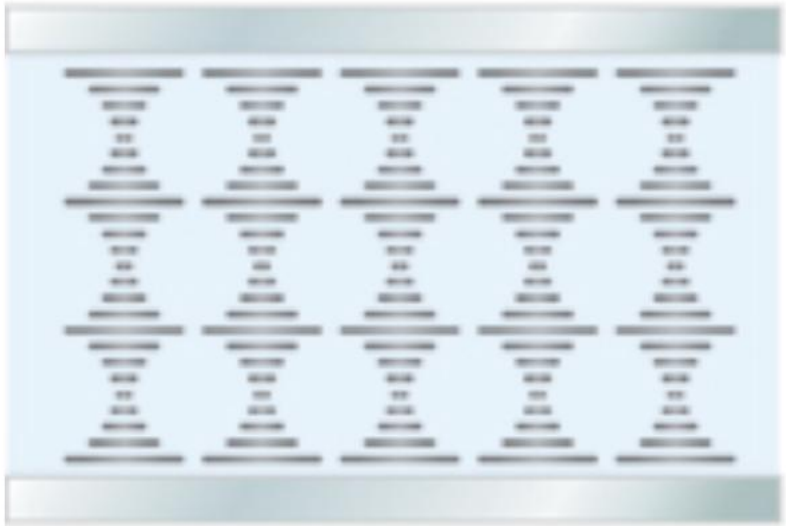
What makes a memory useful?

- Need a way to encode information about the past
- Information needs to stay stable until needed
- Need a way to read out the memory

- Optional: It is often nice to be able to erase and reuse the memory.

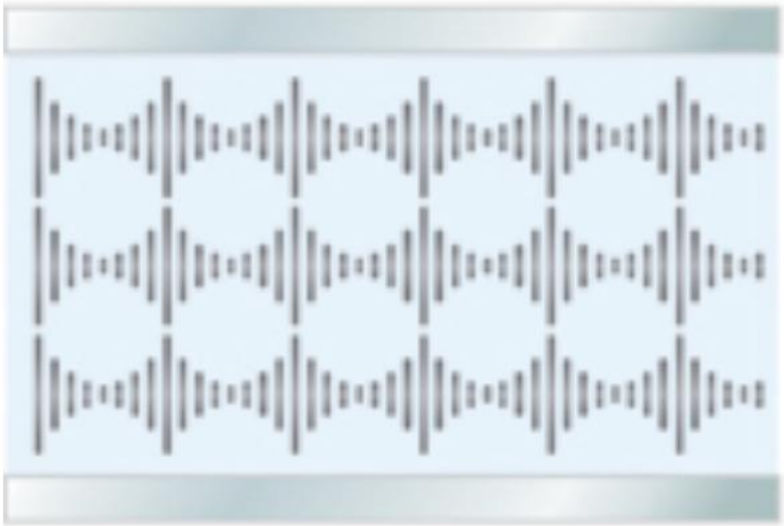
Some cholesteric liquid crystals are bistable: Stimulus promotes one state, which is then remembered after stimulus is removed.

pressure causes this



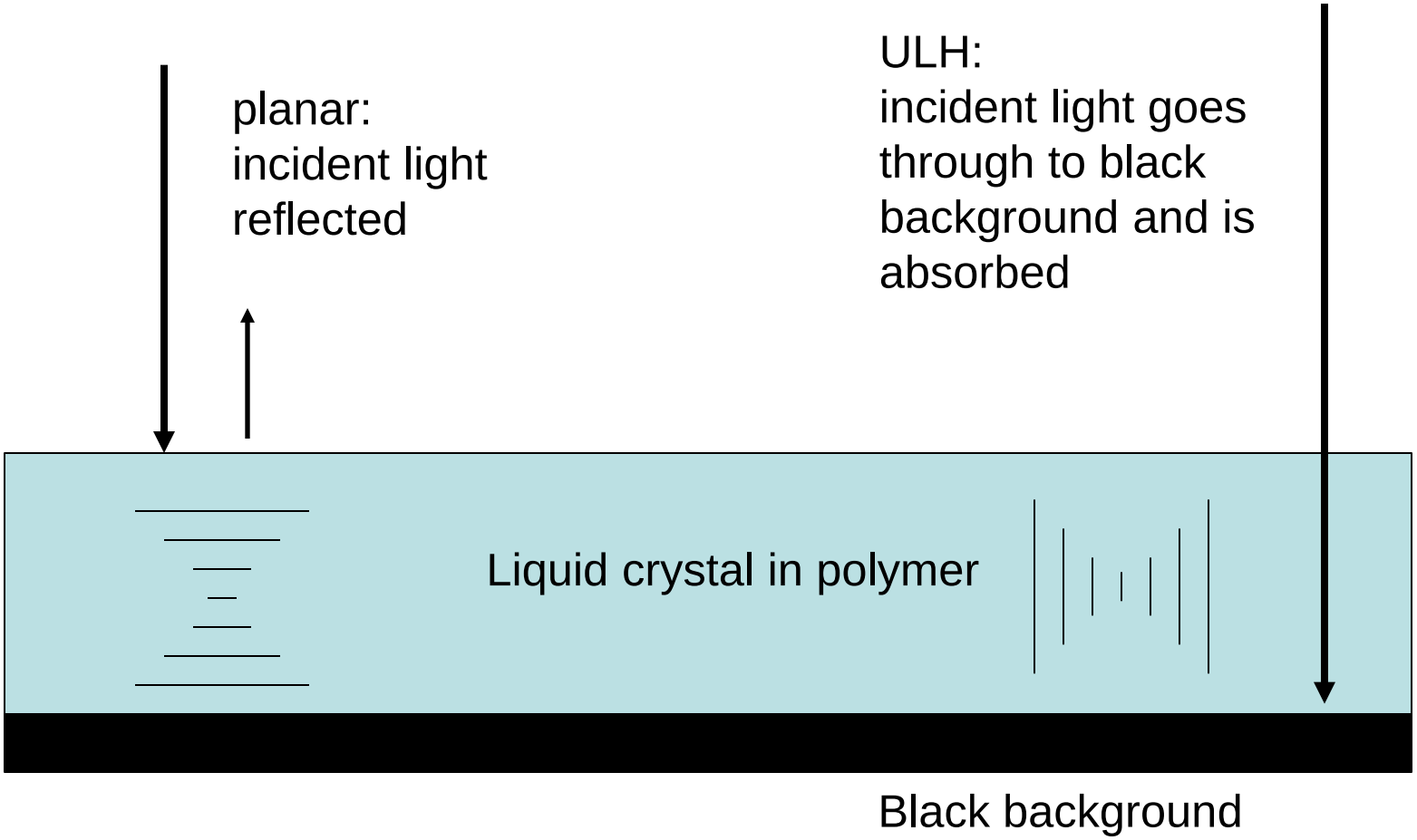
Planar (high reflectivity) – looks green

applying a voltage causes this



ULH (uniformly lying helical; high transmission, low reflectivity) – looks black

Light reflection properties depend on liquid crystal orientation



Memory of bistable cholesteric liquid crystals is used in an e-writer

Pressure induces planar region (high reflectivity) – looks green

Applying a voltage induces ULH (uniformly lying helical; high transmission, low reflectivity) – looks black (used to erase)

Making memories

- Need a way to get the material to encode information (its state must depend on something in the past)
- The material must retain the memory
- Need a way to retrieve the memory

The material’s properties can play a critical role in determining what can be encoded.

Example: kinetic sand versus typical sand

kineticsand.com

What are some current research questions on memories in materials?

1) Can we design materials so that they encode memories that we choose?

-- How can the memories be read out?

-- How many memories can be encoded?

-- Talks by Arvind Murugan and Zorana Zeravcic address this question

What are some current research questions on memories in materials?

2) Memories can be encoded in materials using dynamics.

-- How to encode a dynamical memory?

One example: “G.I. Taylor’s demo”

see https://www.youtube.com/watch?v=p08_KlTKP50

-- Other ways to encode dynamical memories?

-- How many memories can be encoded dynamically?

-- Talks by Irmgard Bischofberger and Nathan Keim address these questions.

Summary

- Encoding memories in materials enables new technologies
  - Examples of applications:
    - Cardiac stents
    - Better braces
    - E-writers
    - (plus other memories, such as computer memories)
- Understanding memories better can lead to new materials with rationally designed properties
- We are continuing to discover new ways to encode memories in materials

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