Photomechanical Materials

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Introduction

- Photomechanical materials are materials that undergo various modes of mechanical deformation (bending, twisting, jumping etc.) when exposed to light stimulus.

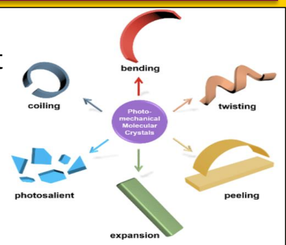

Fig. 1: Photomechanical effect [1]

- These materials can be used for a variety of different objectives for applications such as switches, sensors, actuators and soft robots in which motions can be induced by these light-actuated materials.

Research Objective

Professor Balakrishna's research objective is to discover what are the properties that cause these crystals to undergo these various mechanical deformations from bending, twisting, and hoping. By identifying the properties that causes these motions, they can be adapted to improve in the various tasks e.g. (smart switches, sensors, etc.).

Crystalline Structure

- In amorphous materials (e.g. polyethylene) the atoms are randomly distributed, however, crystalline materials have ordered arrays that are repeated to make the crystal structure.
- A crystal structure is defined by the lengths of three cell edges (a, b, c) as well as the angles between these edges (α, β, γ).

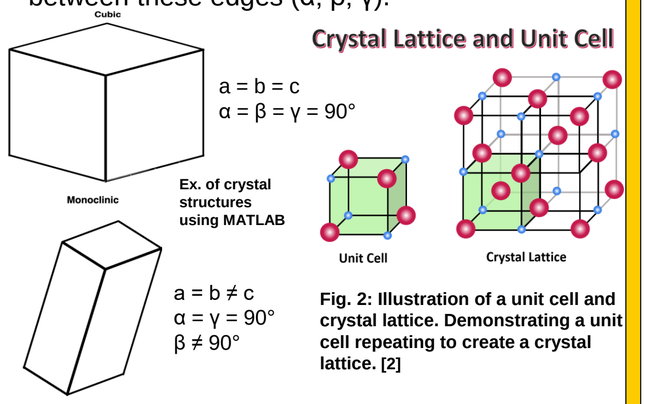

Fig. 2: Illustration of a unit cell and crystal lattice. Demonstrating a unit cell repeating to create a crystal lattice. [2]

Research

Shape Memory Alloys

- Shape memory alloys (SMAs) are materials that can be deformed when cold but returns to its pre-deformed stage when heated Ex.Nitinol (Nickel + Titanium)
- The SMAs exhibit the property because of the existence of distinct phases at hot(austenite) and cold(Martensite) temperature.
- 'Phase' here refers to material existing in a particular crystal structure

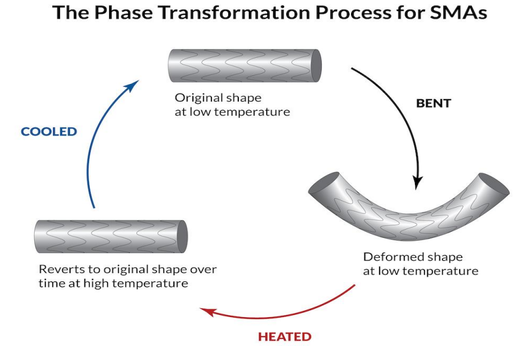

Fig. 3: Phase Transformation SMAs. [3]

Light-Induced deformation in Photomechanical Materials

- Photo-mechanical materials when irradiated with external light stimulus undergo phase transformation changing the unit cell structure.
- Stresses caused by change in crystal structure results in macroscopic deformation.
- Taniguchi et al studied the light-induced bending of a material in a computational experimental study (Fig. 4).

Video of deformation

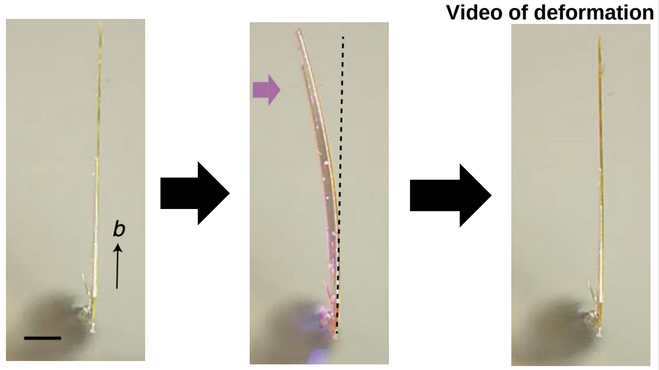

Fig. 4: Light-induced bending in photochromic chiral salicylideneamine crystal. [4]

Learning Process

- Studied about unit cells and crystal structures to understand material micro-structure.
- Wrote MATLAB script to visualize cubic unit cells.
- It helped build foundation for understanding the phase change in materials.
- It was interesting to read and see videos about shape memory alloys.
- Read papers on photo-mechanical materials and their applications.
- Ran a MATLAB code given by my Mentor to visualize bending effect similar to the experiments (Fig. 5).

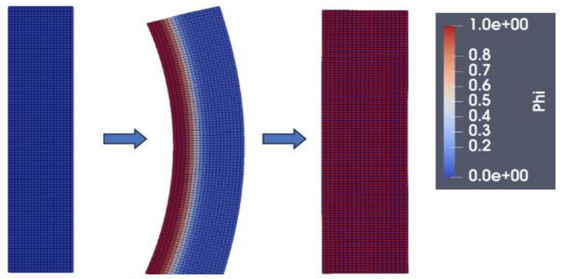

Fig. 5: Demonstration of photomechanical material bending using computational model

Skills Learned

- Practiced on MATLAB writing scripts for a couple mathematical problems to get a brief understanding of what it's like to use a software like MATLAB.
- In addition, I was reading a vast amount of research papers and scholarly websites which helped me build high level reading skills for highly informative pieces of writing that I will be sure to encounter when I go to college.
- I got to focus on advancing my chemistry skills as I got to learn new concepts, I was never able to in my high school chemistry course such as crystal systems and the unit cell types including how they correspond with each other.

Next Steps for You and Advice for Future SHINE Students

- Thanks to the opportunity offered by SHINE this summer as my college application process is approaching this coming school year I have a deeper sense of what I want to major in.
- My educational goal is now to hopefully achieve a BS in mechanical engineering and a MS in aerospace engineering.
- To any future SHINE students just know that it is definitely a difficult process to adjust and understand the research these professors and PhD students but it is just a matter of perseverance.

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[1]Tong, F., & Qu, D.-H. (2022, April 11). *Engineering shapes and sizes of molecular crystals ... - ACS publications*. Engineering Shapes and Sizes of Molecular Crystals to Achieve Versatile Photomechanical Behaviors. https://pubs.acs.org/doi/10.1021/acs.langmuir.2c00414
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