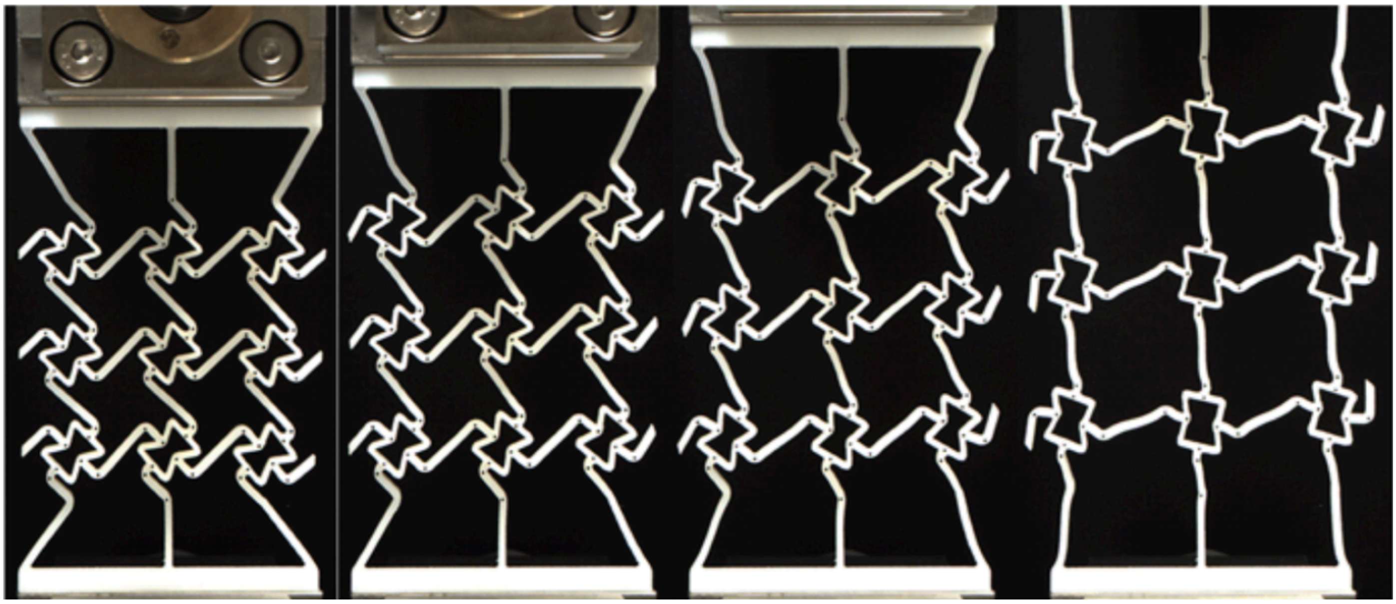
# Project idea: Metamaterial visual output S

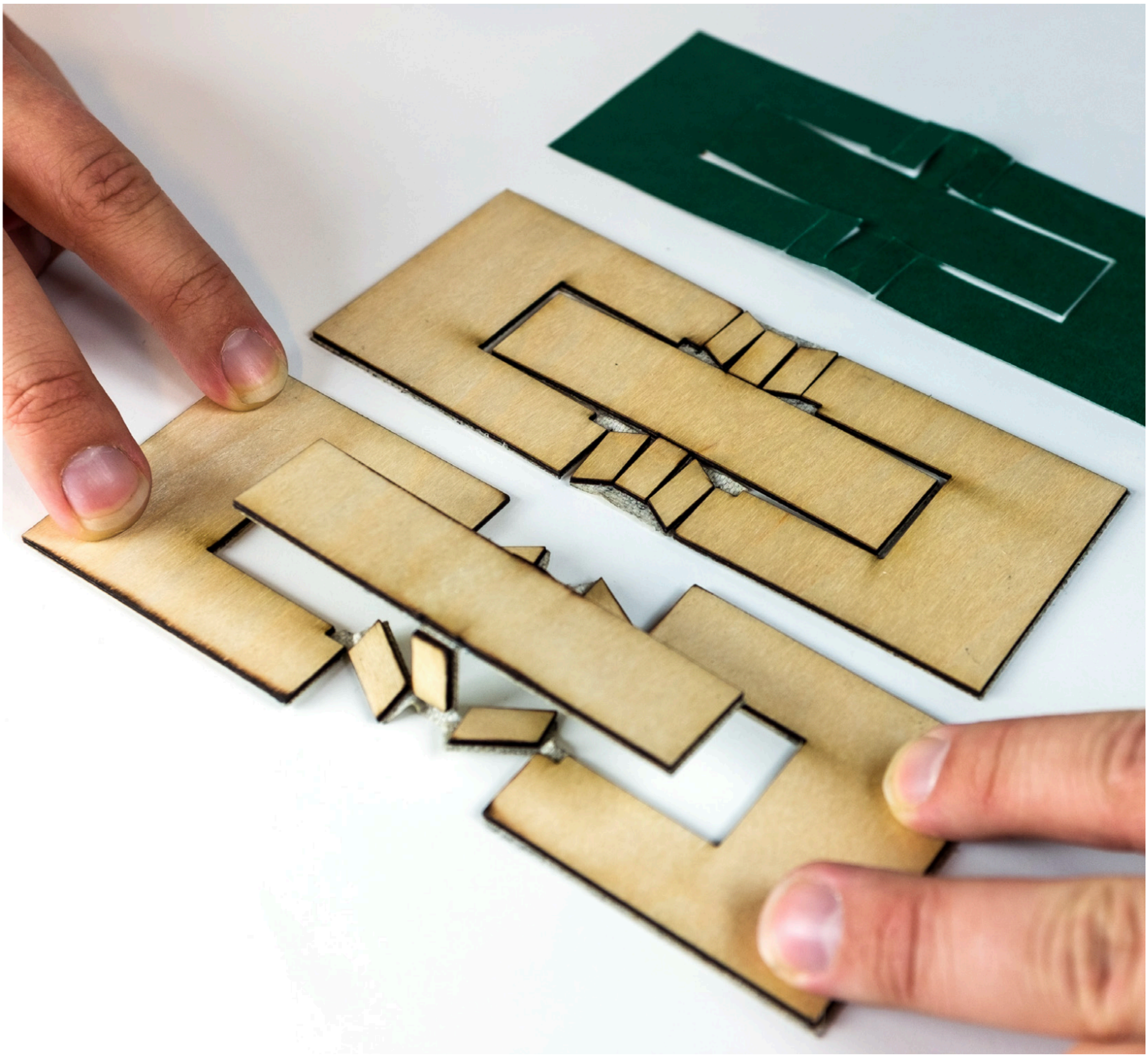
## Description

There's been a good amount of work on mechanical metamaterials—repeating structural patterns that cause a material to behave in unexpected ways when it's physically manipulated (e.g, squeezed or stretched). Most of the research has been on physical properties like stiffness and strength, but there's an opportunity to make metamaterials have *visual* effects, where manipulating the material changes its appearance in some way.

For example, reference [1] shows a material made of flexible "cells"; when the material is stretched a little bit, the cells open up a lot. This mechanism could allow an object made of one color to expose a different color behind it.



Another possibility is structures where part of them rotate out-of-plane [2–4], which could reveal another color or pattern; here, stretching the material causes part of it to lift up:



*Preliminary goals:*

1. A MM cell design that, when compressed and/or stretched, changes the color of at least 50% of the area a person is looking at.
2. A grid of at least 3x3 of these cells that can change between two patterns (e.g., "X" to "O").
3. Stretch goals:
   - more area of color change
   - a larger grid
   - more than one color

# What to do

Here are things you can do to complete this project. You should read through all of them before you start, and do them in parallel as much as practical. Ask for help from the teachers if you aren't sure what to do first or next.

## Read related work

There are several papers listed under [Resources] below. You should also search for papers on your own, using [Google Scholar] (https://scholar.google.com) or the [ACM Digital Library] (https://dl.acm.org). There are a *lot* of papers and many aren't relevant. You should first skim through the papers below to get a general idea of the possibilities for a mechanism that could work, then try targeted searches to get more ideas. Ask for help if you feel lost.

## Decide on 2D or 3D

One approach for this project is to 3D print structures in a flexible filament (TPU) which will easily compress or, less-easily, stretch a bit (see references [1,5]). TPU is a little bit annoying to work with but will allow you to make a wide variety of flexible designs.

Another option is to use a cutting machine to make 2D designs. We have a laser cutter and a blade-based cutter. These can help you make kirigami-based metamaterials (see references [2–4]), where a pattern of cuts makes the material behave in interesting ways when it's stretched.

## Complete required lab skill modules

For this project, you'll need to acquire at least the 2D skills or the 3D skills, depending on how you want to proceed:

- 2D skills
  - **Lab skill: 2D design** (lab-skill-2d-design)
  - **Lab skill: Lasercutting** (lab-skill-lasercutting) and/or **Lab skill: Cut with the Cricut** (lab-skill-cut-with-the-cricut)
- 3D skills
  - **Lab skill: 3D design** (lab-skill-3d-design)
  - **Lab skill: Learn to 3D Print** (lab-skill-learn-to-3d-print)

## Recreate some existing examples

Based on the papers you read, fabricate a few cells based on existing designs, and test them out so you start to get an intuition for what they do and how they do it.

## Brainstorm and test ideas

After deciding on 2D or 3D, and getting a sense of how metamaterials work, sketch a bunch of ideas of what you might design and print. Test as many of your ideas as you can as quickly as possible. Start small—fabricate just one or a few cells at a time to see how they react.

## Update project goals and discuss with instructors

There are some preliminary goals listed above, but based on your reading and thinking about the project, you may want to come up with some new or modified goals for yourselves. Discuss your ideas with the instructors.

# Resources

## Research papers

1. Jiang, Yunyao, and Yaning Li. 2018. "3D Printed Auxetic Mechanical Metamaterial with Chiral Cells and Re-Entrant Cores." **Scientific Reports** 8 (1): 2397. https://doi.org/10.1038/s41598-018-20795-2 (https://doi.org/10.1038/s41598-018-20795-2) .
2. Tang, Yichao, Yanbin Li, Yaoye Hong, Shu Yang, and Jie Yin. 2019. "Programmable Active Kirigami Metasheets with More Freedom of Actuation." **Proceedings of the National Academy of Sciences** 116 (52): 26407–13. https://doi.org/10.1073/pnas.1906435116 (https://doi.org/10.1073/pnas.1906435116) .
3. Dias, Marcelo A., Michael P. McCarron, Daniel Rayneau-Kirkhope, Paul Z. Hanakata, David K. Campbell, Harold S. Park, and Douglas P. Holmes. 2017. "Kirigami Actuators." **Soft Matter** 13 (48): 9087–92. https://doi.org/10.1039/C7SM01693J (https://doi.org/10.1039/C7SM01693J) .
4. Kaspersen, Magnus H., Sebastian Hines, Mark Moore, Majken K. Rasmussen, and Marcelo A. Dias. 2019. "Lifting Kirigami Actuators Up Where They Belong: Possibilities for SCI." In **Proceedings of the 2019 on Designing Interactive Systems Conference**, 935–47. DIS '19. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3322276.3323688 (https://doi.org/10.1145/3322276.3323688) .
5. Bertoldi, Katia, Vincenzo Vitelli, Johan Christensen, and Martin van Hecke. 2017. "Flexible Mechanical Metamaterials." **Nature Reviews Materials** 2 (11): 17066. https://doi.org/10.1038/natrevmats.2017.66 (https://doi.org/10.1038/natrevmats.2017.66) .