

# PhD Interview - ETH Zürich

## Multiphase Modeling of Alpine Mass Movements and Process Cascades

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- ① Introduction
- ② Master's thesis
- ③ PhD project interpretation

# Academic Background

## Education

- Bachelor in Physics
- Master in Computational Science: Materials Science

## Scientific interests

- Numerical modelling
- Optimization problems
- Materials science and statistical mechanics
- Machine learning
- Design and innovation

## Project priorities - 80,000 hours

- ① Method
- ② Field of application
- ③ Positive impact

# Programming experience

## High level

- Python
- Julia
  - More efficient alternative to python

## Low level

- C / C++
  - High performance computing (HPC)

## Function based / Modules

- LAMMPS
  - Efficient workflow for MD simulations
- PyTorch / TensorFlow
  - Machine learning platforms

# Hobbies and personal interests

- Handstands and “movement”
- Skiing (5 years as ski instructor)
- Hiking / Outdoor
- Photography



# Master's thesis

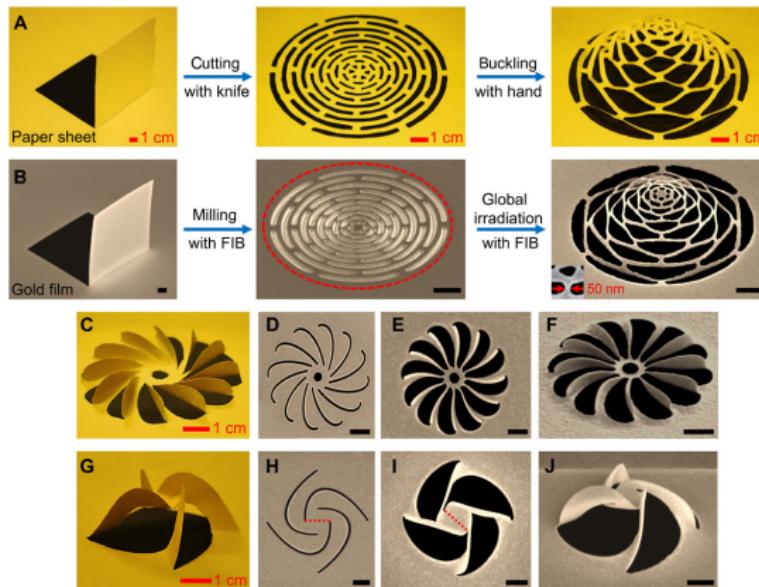
## 3 Phases

Tuning frictional properties of graphene sheets using kirigami inspired cuts and inverse design

- ① Sheet kirigami: Alter graphene sheet using atomic scale cuts
- ② Forward simulation: Calculate frictional properties of the sheet using MD simulations
- ③ Inverse design: Predict cut patterns based on frictional properties and optimize for desired properties using machine learning
  - Low/high friction coefficient
  - Coupling between stretch and friction
  - Negative friction coefficients

# Motivation

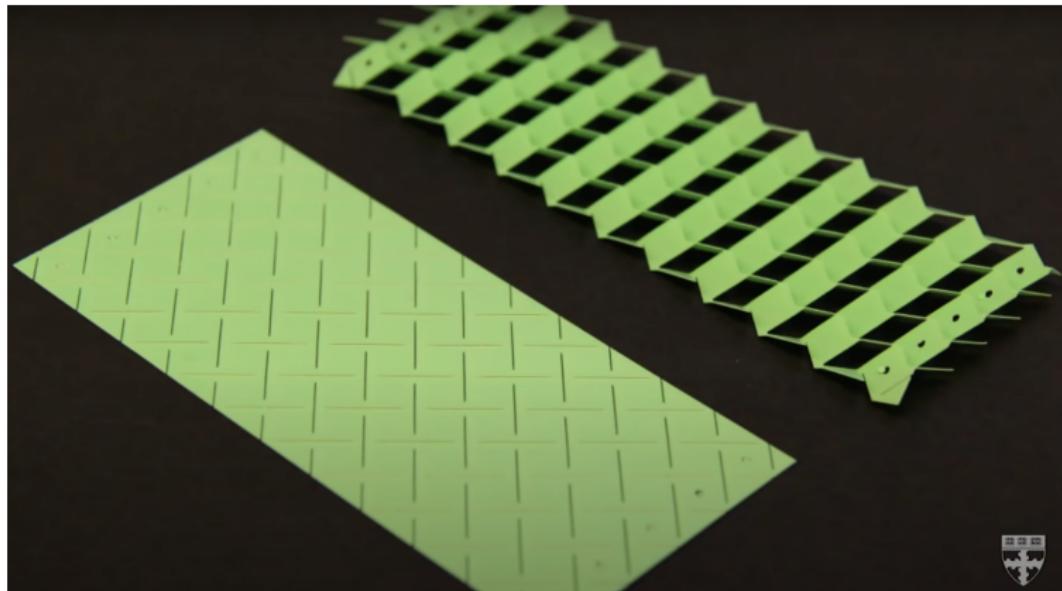
- Kirigami: Variation of origami with cuts permitted
- Macroscale → Nanoscale



**Figure:** Example of transition from macro- to nano-kirigami using a focused ion-beam (FIB) (Nano-kirigami with giant optical chirality, ZHIGUANG LIU, 2018).

# Stage 1 - Sheet Kirigami

Choosing a cut pattern



**Figure:** New pop-up strategy inspired by cuts, not folds - Leah Burrows, Harvard John A. Paulson School of Engineering and Applied Sciences.

# Stage 1 - Sheet Kirigami

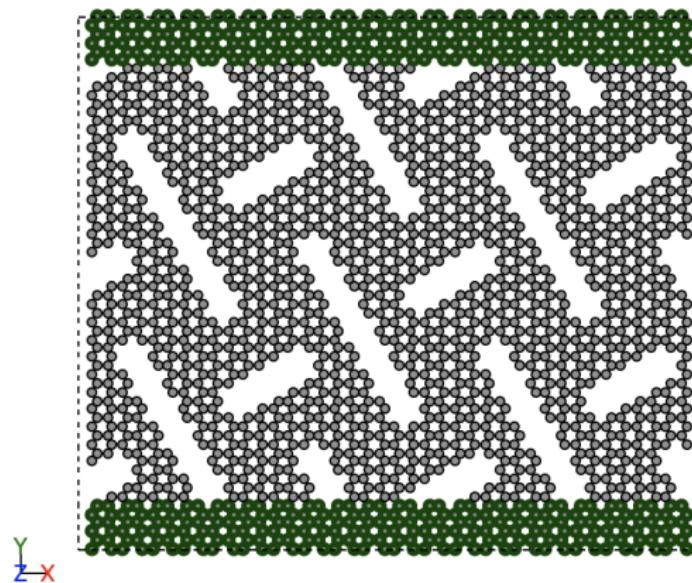
Choosing a cut pattern



Figure: Scotch Cushion Lock Protective Wrap.

# Stage 1 - Sheet Kirigami

## Implementation



**Figure:** Example of “popup” cut pattern. Grey color marks the cuttable sheet while green marks added blocks for stretching and dragging the sheet.

# Stage 1 - Sheet Kirigami

Investigating 3D buckling

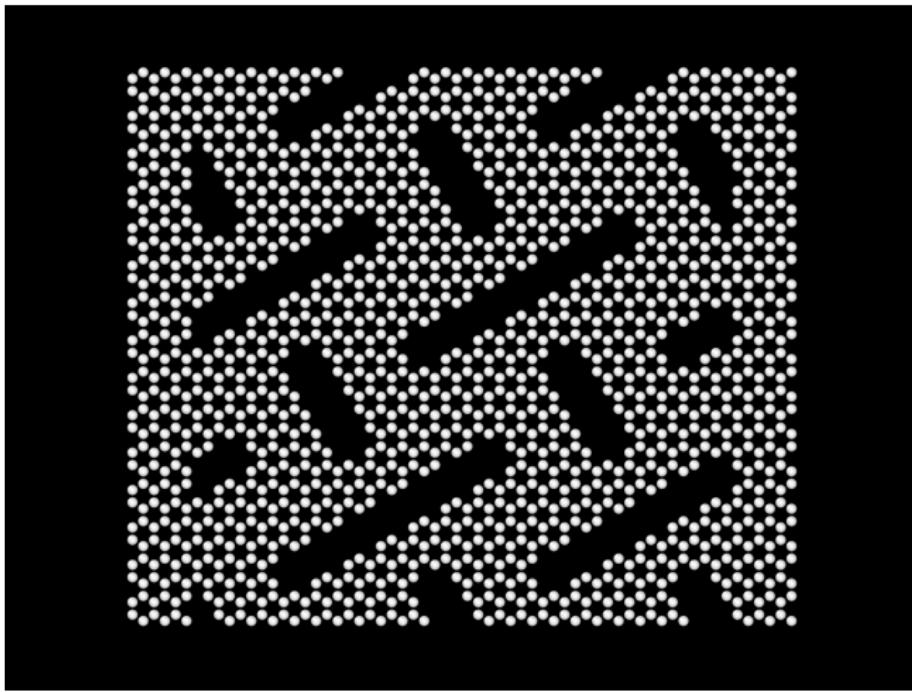
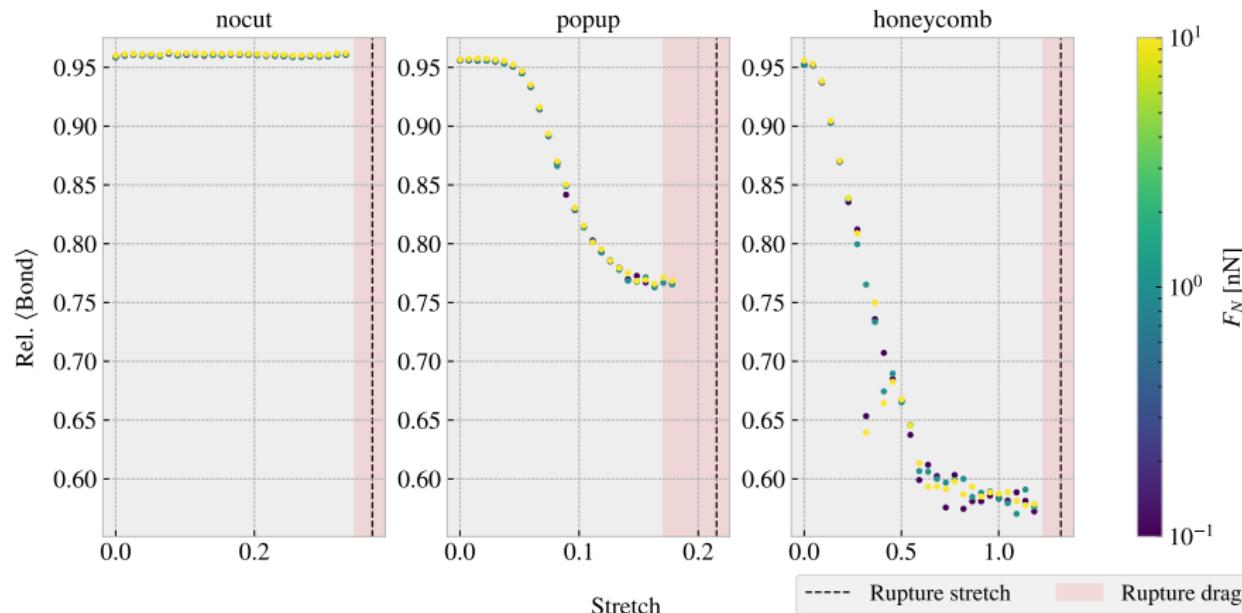


Figure: Kirigami sheet stretch in vaccuum.

# Stage 2 - Forward Simulation

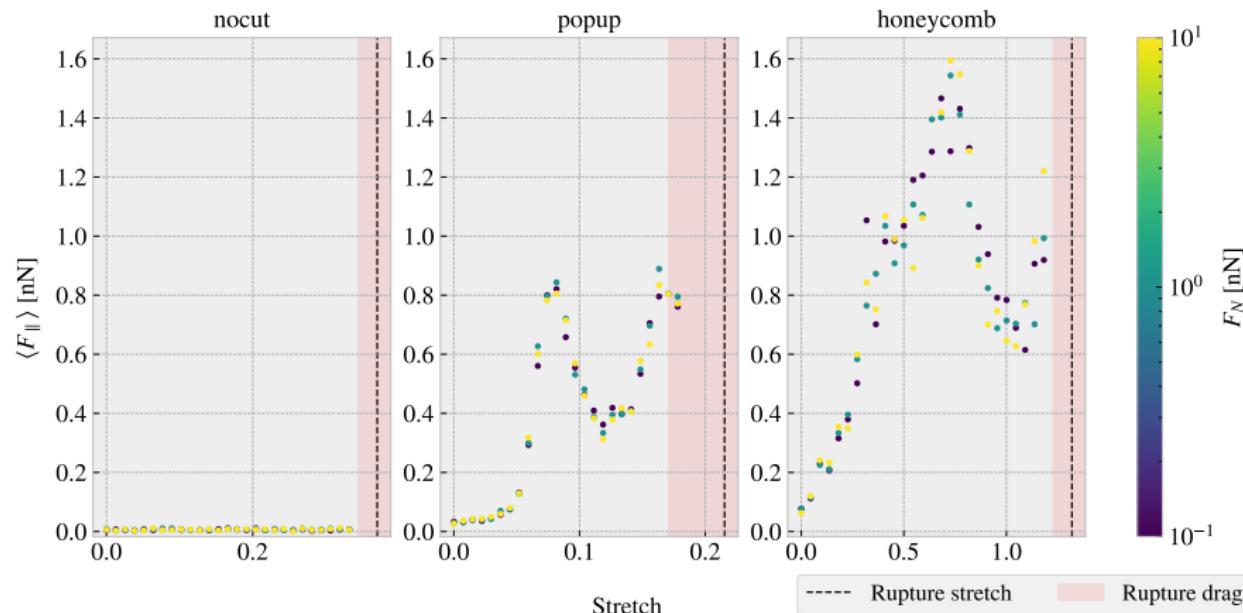
Contact vs. Stretch



**Figure:** Average relative amount of bonds between sheet and substrate as a function of stretch for different cut configurations.

# Stage 2 - Forward Simulation

## Friction vs. Stretch

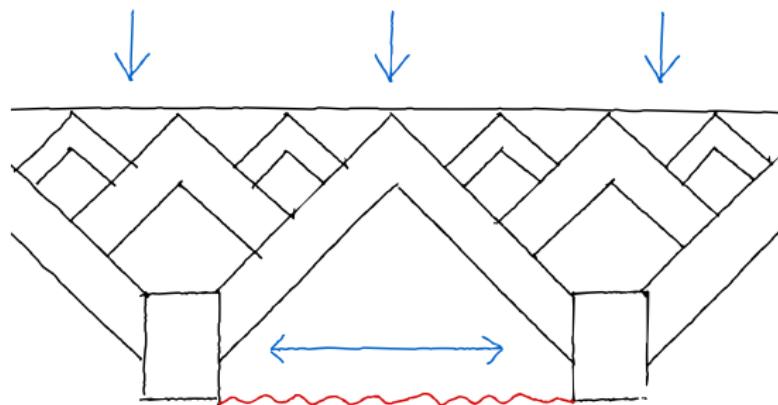


**Figure:** Mean friction force  $F_{\parallel}$  parallel to drag direction as a function of stretch of the sheet for different cut configurations.

## (Stage 4 - Nanomachine applications)

Negative friction coefficient

$$\left. \begin{array}{l} \text{Normal force : } F_f = k \cdot F_N \\ \text{Stretch : } F_f \sim s \cdot \text{stretch} \\ \text{Nanomachine : stretch} = \pm R \cdot F_n \end{array} \right\} \Rightarrow F_f \propto \underbrace{(k \pm sR)}_{\mu} \cdot F_n$$

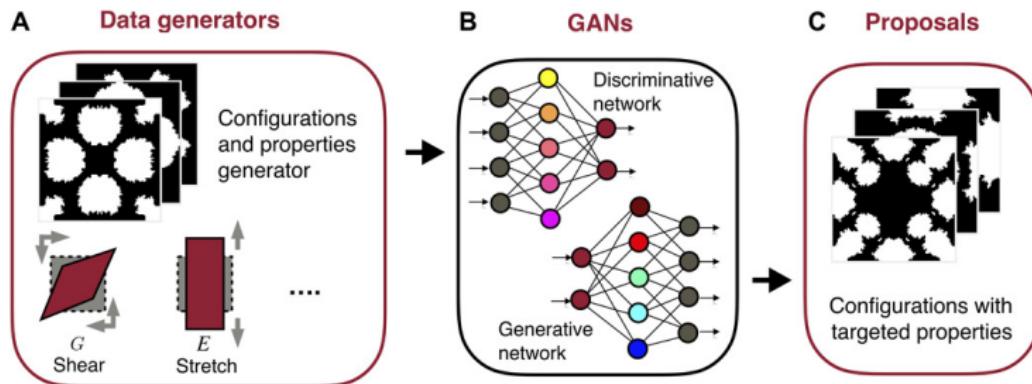


**Figure:** Sketch for nanomachine coupling normal force and stretch. Black represents nanomachine components and red the sheet.

# Stage 3 - Inverse design

## Inverse design

*Designing complex architected materials with generative adversarial networks, YUNWEI MAO, 2020.*



**Figure:** (A) Data generators to generate datasets of configurations and properties of architected materials. (B) GANs trained by the datasets. (C) New designs of architected materials with the targeted properties proposed by the GANs.

# Interpretation of PhD project

## Topic and methods

- Alpine mass movements and cascading processes
- Multi-phase material point method (MPM)

## Tasks

- Writing high performance code for solvers and data analysis
- Benchmarking different implementations
  - Melting block of ice
  - Sliding on 3D-printed topography
  - Avalanches on test sites
  - Previous disasters

## Development expectations

- Gain knowledge of snow and granular mechanics
- Gain knowledge of MPM method
- Build strong academic and social connections
- Experience the lifestyle of an alpine environment