# Constitutive Modeling of Polymer Composites made from LBL Manufacturing Technique

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# Outline

- Introduction
- Overview
- Exponential- Layer-by-layer manufacturing
- Mechanical Behavior of Polymer Composites
- Constitutive Modeling of Polymer Composites
- Concluding Remarks

# Introduction

- Goal of the project
  - Development of a constitutive model for polymer composites and their application in computing fracture toughness
- Advantages of using polymer composites
  - Lightness
  - Resistance to corrosion
  - Ease in manufacturing
- Applications
  - Military
    - Light-weight body armor
    - Weapon systems
  - Automobiles
    - Body structures/components

# Overview

Understand the mechanical behavior of polymer composites

Develop a constitutive model for the material based on experimental data

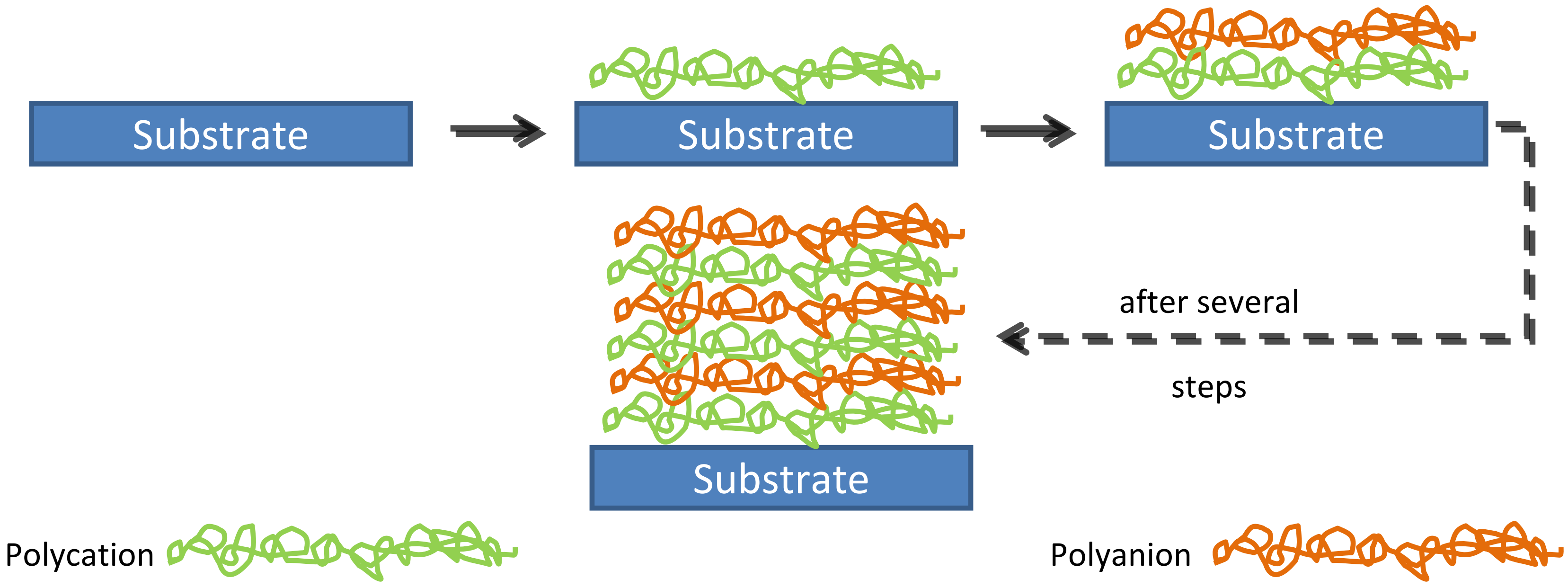
Perform experiments with double edged notch (DENT) specimens

Finite element simulation of DENT experiments with constitutive model and discrete cohesive zone elements

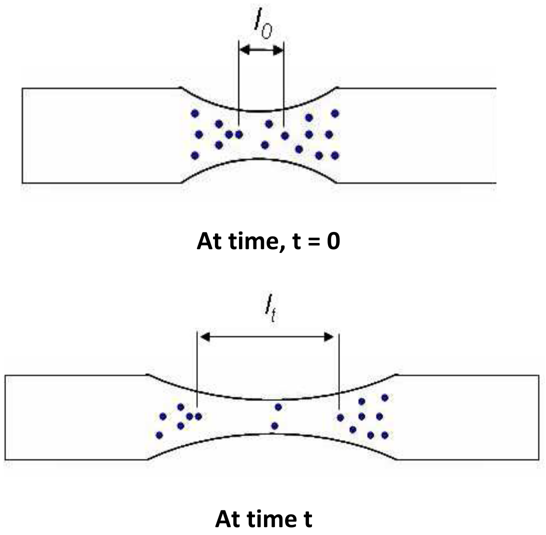
Extract amount of energy dissipated through fracture

# Layer-By-Layer Manufacturing

- **Composition of Polymer composite**
  - Cationic Polyurethane (PU) / Polyacrylic acid (PAA)
- **Layer-by-layer (LBL) technique**
  - Sequential deposition of mono-layers of oppositely charged poly-electrolytes on a glass substrate



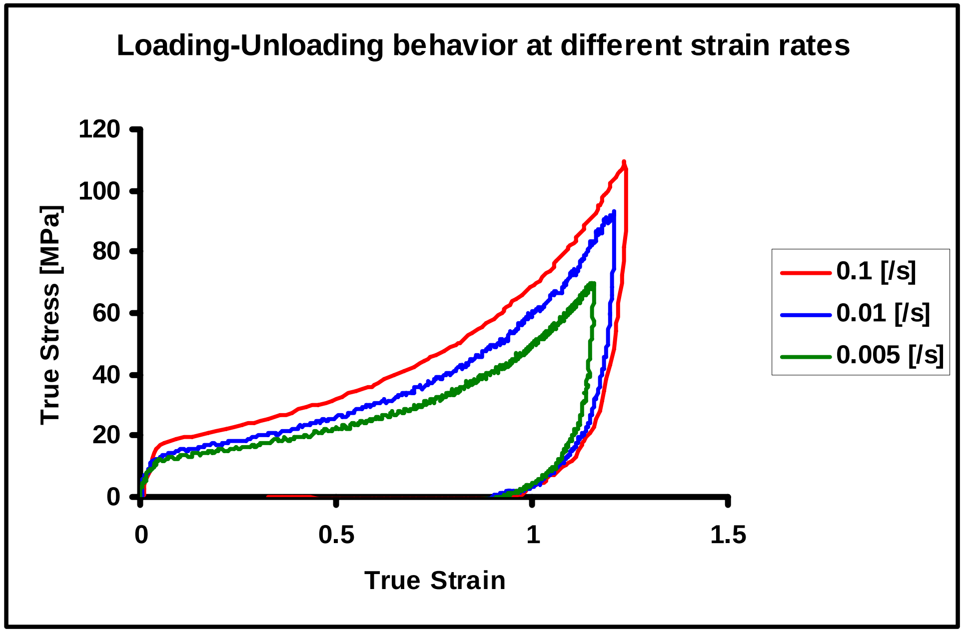
# Mechanical Behavior of Polymer composites




- **Uniaxial Tensile Tests at Low Strain Rates**
  - In-house tensile testing set-up
  - Non-contact strain measurement
    - Tracking of 25 mm spheres adhered to the surface
    - Displacement of gage marks on the surface

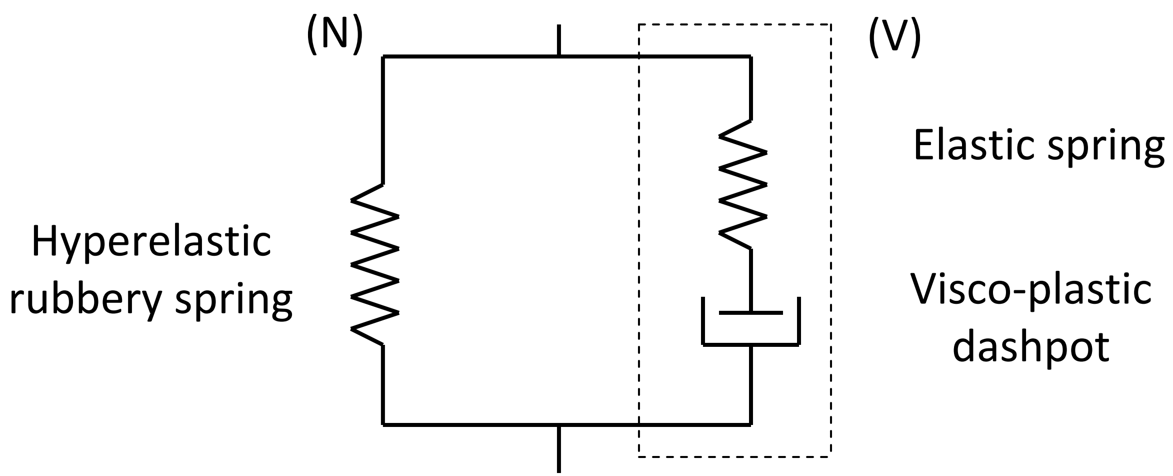
# Mechanical Behavior of Polymer composites

- The deformation of the gage section is mostly homogeneous
- Strain rate dependent response of the material
  - Increase in yield strength with increase in strain rate
  - Minor change in amount of hardening with increased strain rate
  - No effect of strain rate on the amount of unloading



# Constitutive Model of Polymer Composite

- **Schematic representation of the constitutive model**

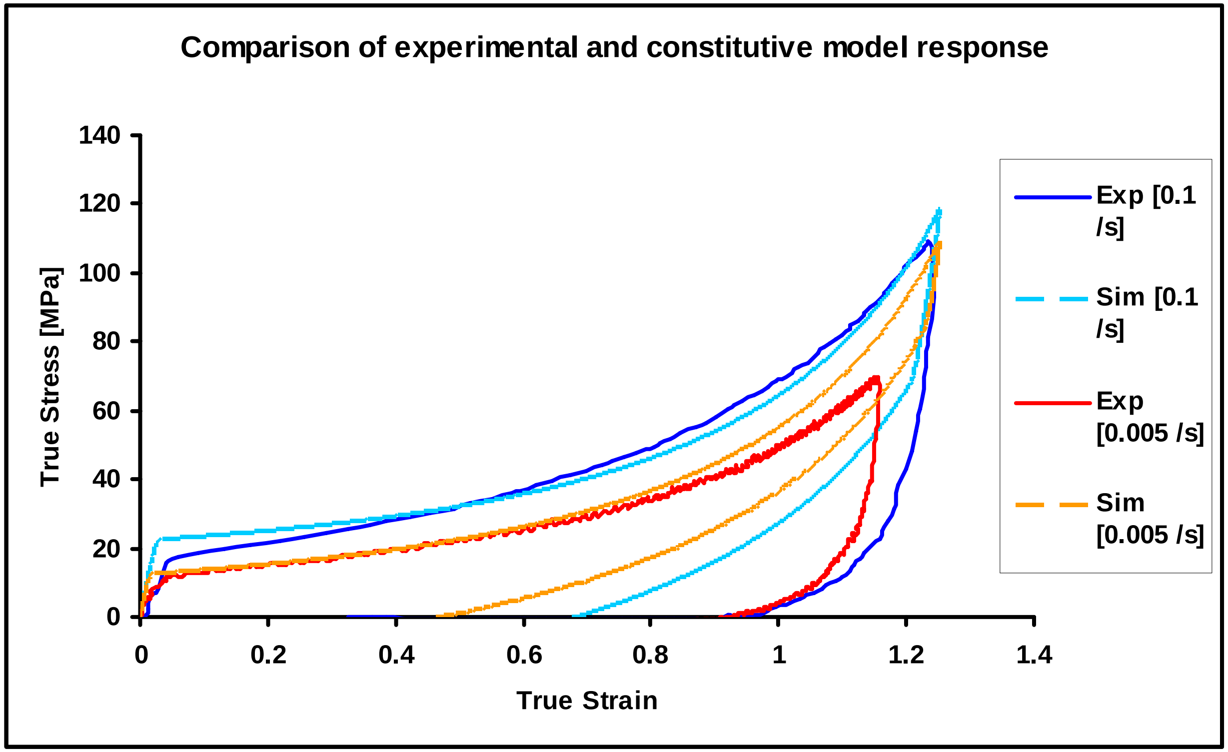



$$F = F^N = F^V \qquad T = T^N + T^V$$

- **Elasto-Viscoplastic response of the polymer composite**

# Constitutive Model of Polymer Composite

- **Identification of material parameters for the model**
- **Implementation of user material routine in Abaqus 6.5**

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# Concluding Remarks

- The model is successful in capturing the loading part of the response
- The amount of unloading in the constitutive model is greater than that observed in the material
- Strain rate dependent effects are taken into account in the design of the constitutive model