Investigation of the Mechanical and Shape Memory Properties of Polymer Fibers

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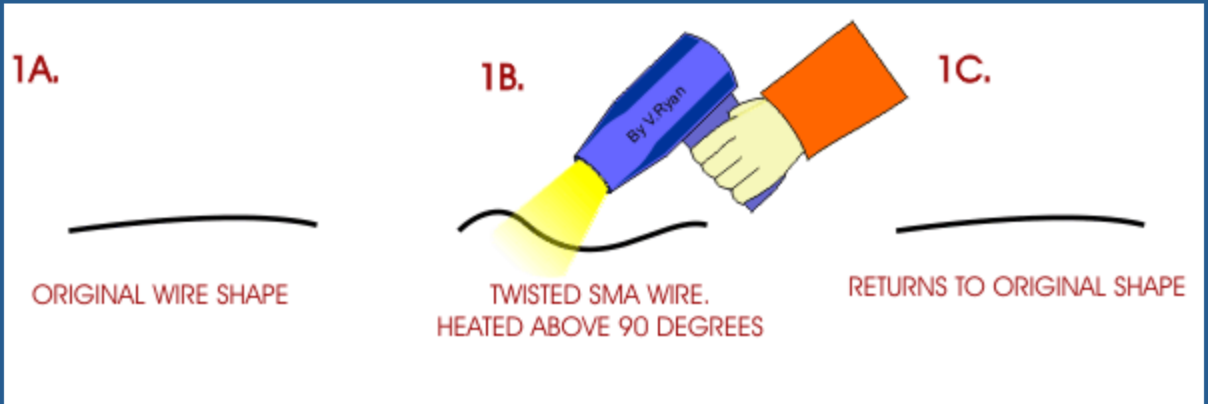
Overview

- Background
- Purpose
- Materials & Methods
- Results
- Conclusion
- Future Studies
- Acknowledgements

Background

Shape Memory Materials (SMM):

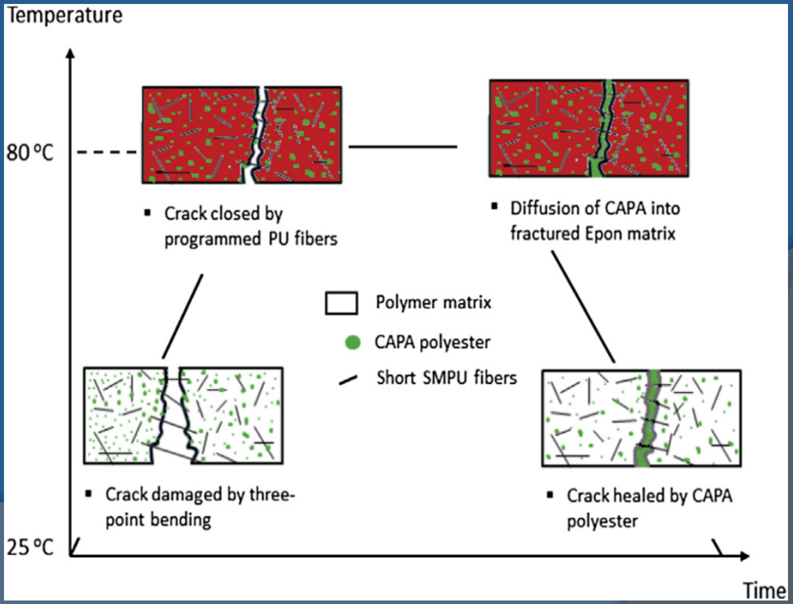
- capable of changing their shape upon application of an external stimulus
- can be used for self healing purposes



Background

Self healing composites

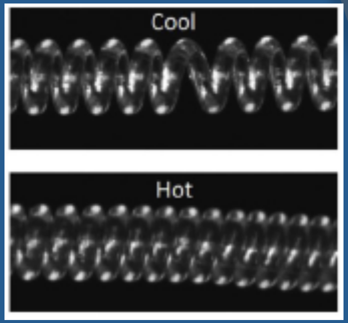
- A type of SMM
- Used for healing of crack deformations
- Comprised of 3 components:
  - shape memory component
  - healing agent
  - matrix

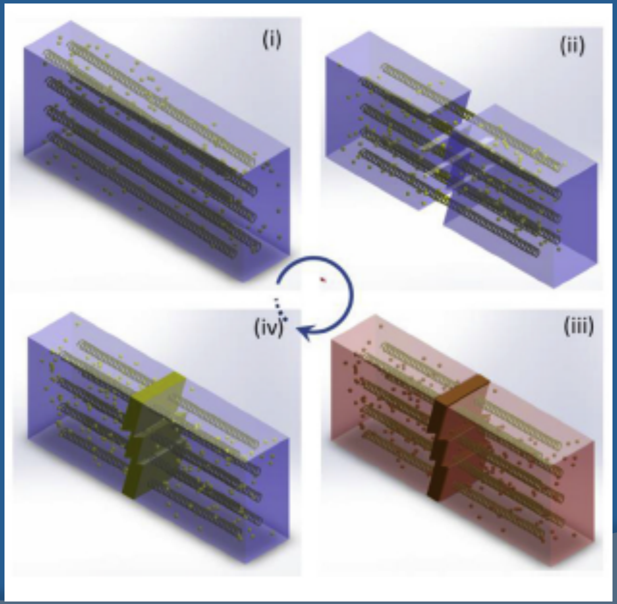


Background

Improved self healing composite

- Utilizes artificial muscles
- Achieves macro scale crack healing
- Achieves repeatable actuation





Purpose of research

- To improve the artificial muscle self healing composites by:
  - creating improved artificial muscle actuators
  - testing new polymer fibers
  - finding a fiber with more desirable shape memory properties

Materials

Polymer fibers tested:

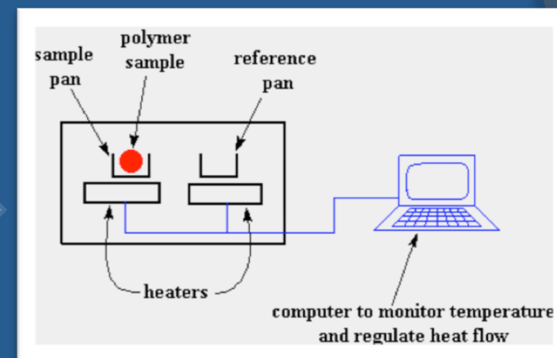
- Polyethelyne (PE) copolymer fishing line
- Nylon 6 based fishing line
- Nylon 6,6 based fishing line

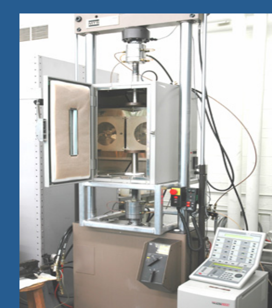
Methods for testing

FTIR Spectral Ananalysis

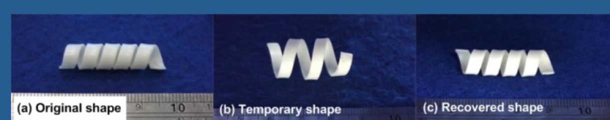
MTS Tensile Testing

DSC Testing

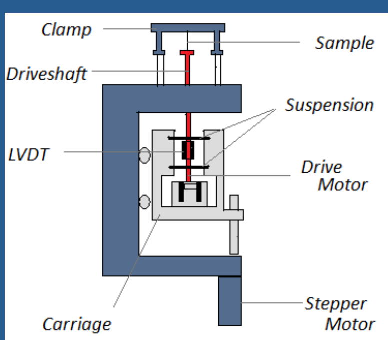




Hot Programming



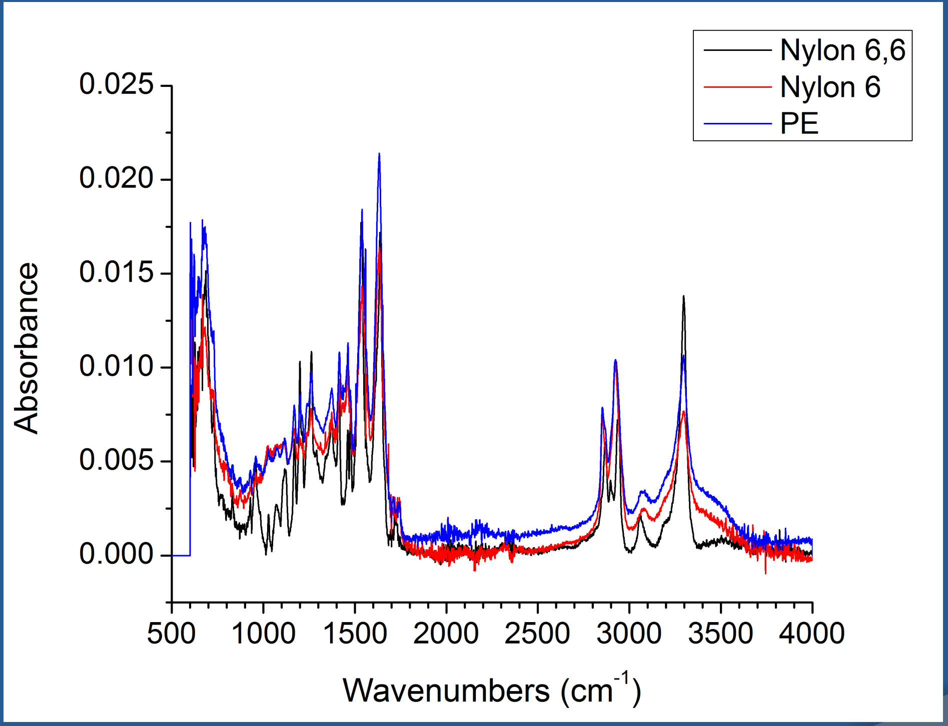
Free Shape Recovery Test



DMA Fixed Stress Recovery

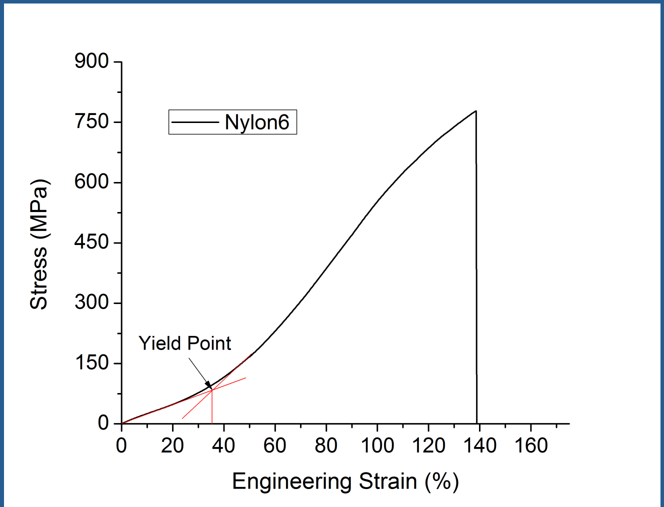
FTIR Spectrum Results

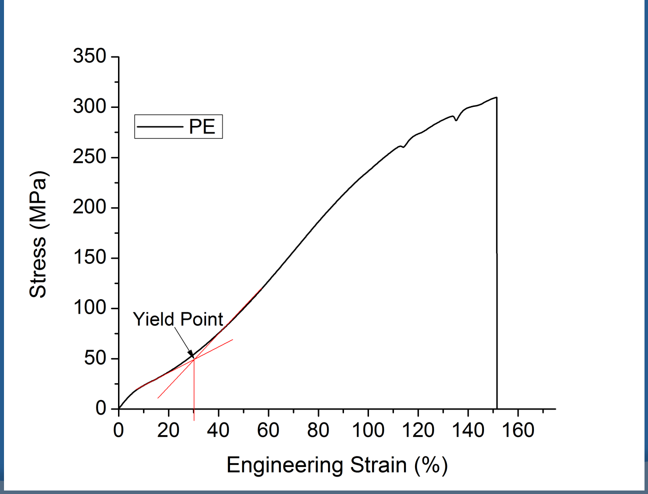
- Peaks distinguish molecular bonds
- Intensities distinguish abundance of bonds
- Large resemblance between Nylon 6 and PE

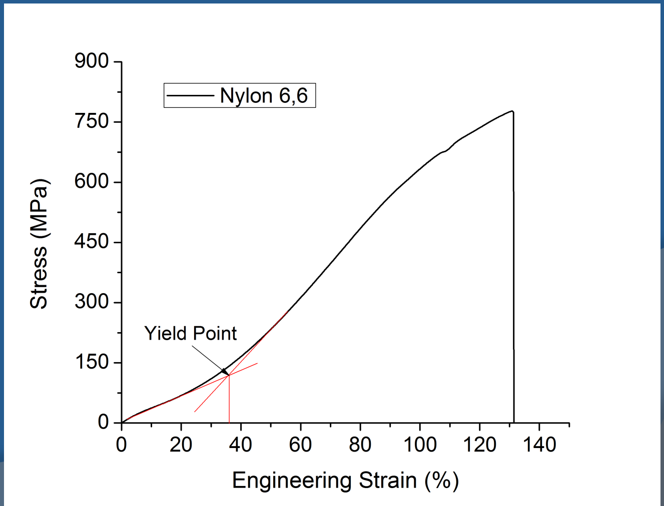


Tensile Test Plots

- Fibers were tested until break
- Nylon fibers had higher stress strengths ≈ 800Mpa
- Yield points were found for hot programming purposes



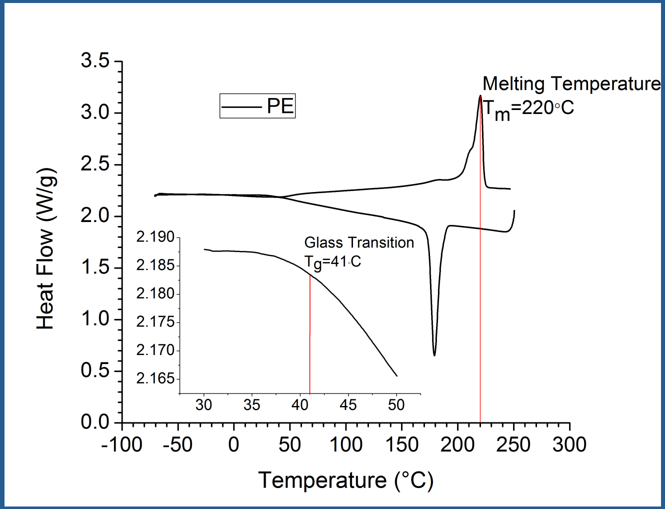


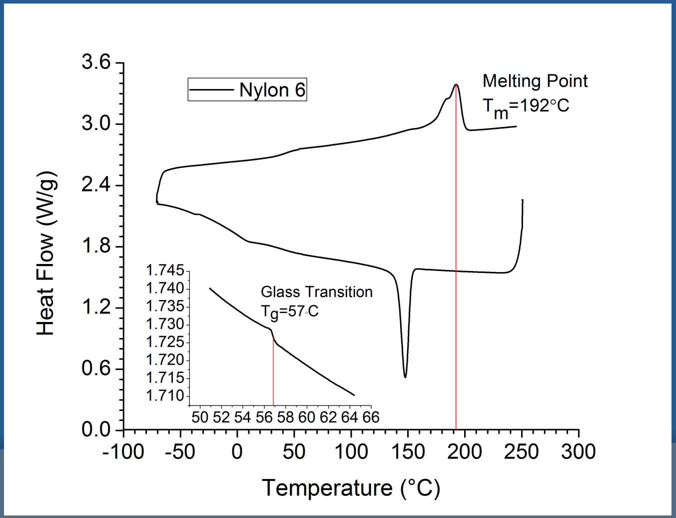


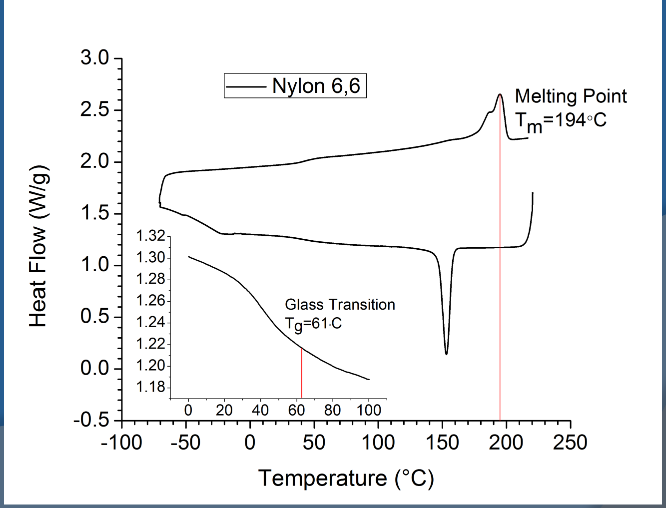
DSC Heat Flow Charts

- Glass transition temperatures (T_g) and melting temperatures (T_m) for each polymer were found

- Shape memory effects occur between temperatures T_g and T_m







Shape Fixity and Shape Recovery

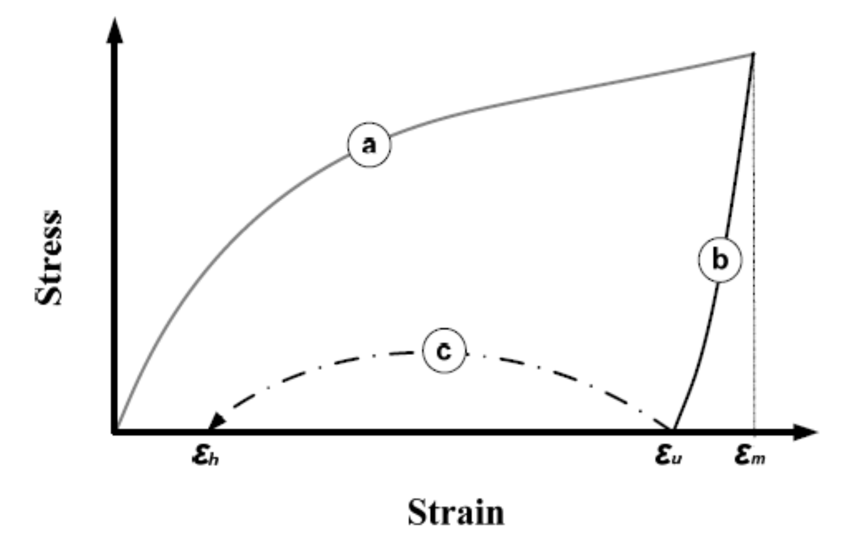
After hot programming :

- Shape fixity ratio (R_f) was calculated using

$$R_f = \frac{\varepsilon_u}{\varepsilon_m}$$

- Shape recovery ratio (R_r) was calculated using

$$R_r = \frac{\varepsilon_u - \varepsilon_h}{\varepsilon_u}$$



Step a) : fibers are programmed to a desired strain

Step b) : fibers are cooled down

Step c): fiber is heated

Shape Recover Results

- Larger shape fixity and shape recovery ratios are desired
- Data suggest Nylon 6,6 could be a viable replacement for PE
- More trials need to be conducted to verify these results

Material	Programmed Strain	Shape Fixity Ratio (%)	Shape Recovery Ratio (%)
Nylon 6,6	40%	62.5	31.25
	60%	59.0	31.65
	80%	67.7	17.86
	100%	70.8	15.24
Nylon 6	20%	52.1	34.72
	40%	52.1	18.38
	60%	55.5	25
PE	20%	41.7	39.06
	40%	67.7	14.88
	60%	69.4	21.55

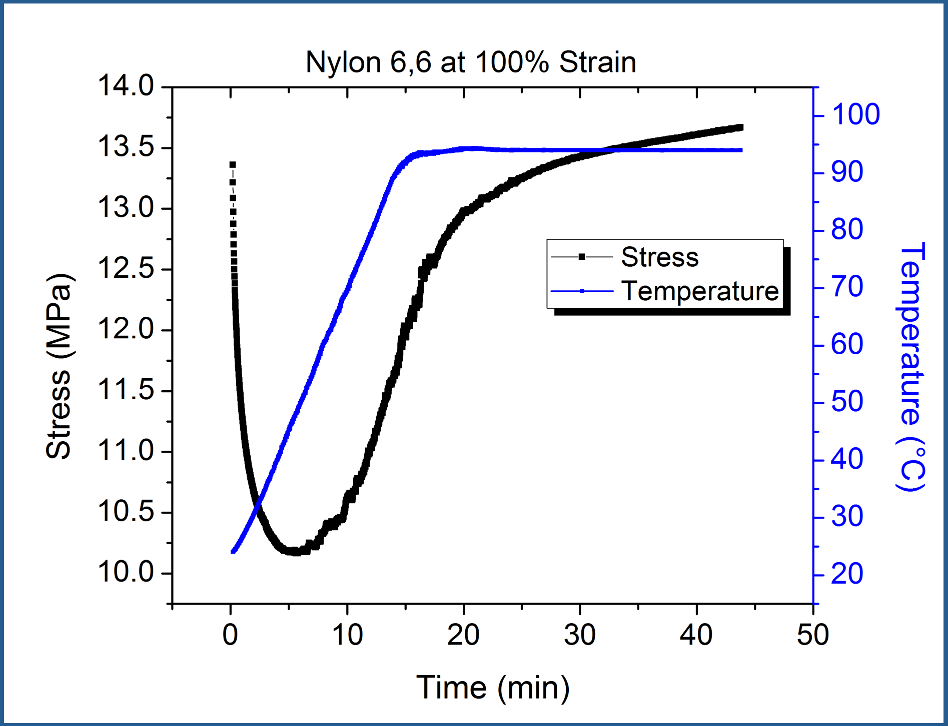
Stress Recovery

- Blue data shows the temperature ramp rate (T_{set}=94°C)

- The black data shows the stress recovery as time progresses

- The stress recovery strength of this sample peaks around 13.75Mpa

- Further stress recovery tests are being conducted



Conclusion

- Goal:
  - To find a new polymer fiber with improved mechanical & shape memory properties
- Found:
  - Nylon 6 and Nylon 6,6 had greater tensile strengths then PE
  - Nylon 6,6 had shape fixity and shape recovery comparable to PE
  - Nylon 6 and PE had similar chemical compositions

Future Studies

- Conduct more trials to find more conclusive shape fixity and shape recovery ratios
- Finish gathering stress recovery test results
- Construct artificial muscles using our materials, and test actuation stress
- Incorporate theses muscle into our self healing composites

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Questions?

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