Strain and Raman Spectroscopy Experiments on Synthetic Polymer and Hard Biological Materials

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Motivation

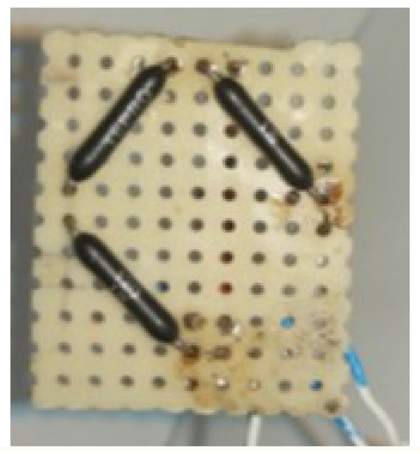
The motivation behind our research is to conduct a study regarding the physical properties of non- biological materials and compare them to human bone. Studying these properties allows examination into materials that may be candidates for bone implants/prosthetics.

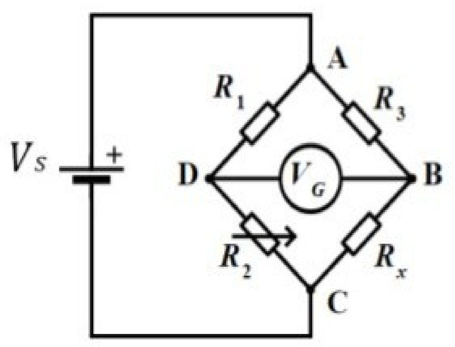
• Stress and strain measurements will be taken to determine mechanical properties

• Raman Spectroscopic experiments will be done on the materials to determine biocompatibility

Strain Measurements Experimental Design

- Samples of Acrylonitrile butadiene styrene (ABS) Plastic, Chicken Bone, and Aluminum were used in the experiments
- Laboratory weights were used to apply strain to the chosen materials
- A banded metallic strain gauge was used to measure the strain the weights put on the materials
- A quarter wave Wheatstone bridge constructed using three 120Ω metal film resistors and the 120Ω strain gauge. This bridge allows measurement of the unbalance created by the changing resistance of the strain gauge. This measurement is preferred to measuring the change in resistance directly as the change in resistance is much harder to measure accurately.
- A 9V battery was used as our power supply





$$\frac{R_x}{R_3} = \frac{R_2}{R_1}$$

$$R_x = R_3 \frac{R_2}{R_1}$$

$$V_G = \left(\frac{R_1}{R_1 + R_2} - \frac{R_x}{R_x + R_3}\right) V_S$$

Figure 1: Quarter Wave Wheatstone Bridge

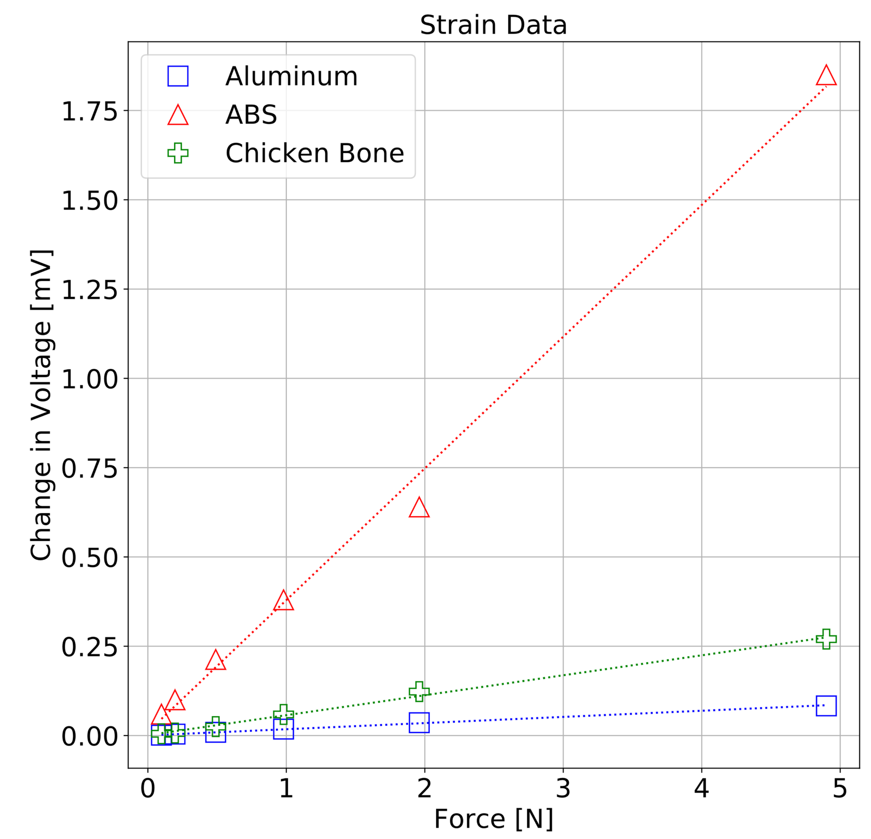


Figure 2: Strain data of the materials tested

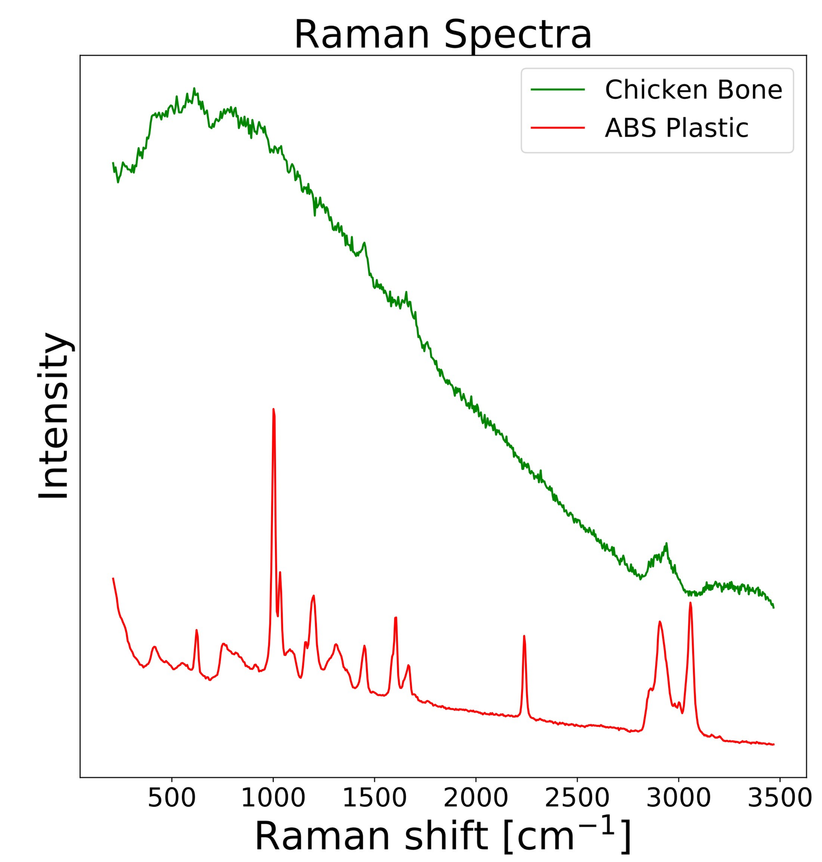


Figure 3: Raman spectra of Chicken Bone compared to ABS Plastic

Strain Measurements

We can see from the above plot that the force applied to the materials is linearly correlated to the change in Voltage. We will use the formula

where is the strain, GF is the Gauge Factor, is the change in voltage, and is the source voltage. The Gauge Factor is a number inherent to the strain gauge and is given by the manufacturer.

Experiment Set up

Figure 4: The experiment setup with Aluminum being tested

Raman Spectroscopy

Raman Scattering is a form of inelastic light scattering. It probes molecular vibrational modes, and it is sensitive to chemical bonding. Raman spectroscopy helps us link between the chemical and mechanical properties of the sample.

- We observe that the bone has broader bands which implies a more disordered structure.
- In Fig. 5, there is an additional peak near 3050 . This peak corresponds to aromatic C-H stretch vibrations.

Young's Modulus

Young's Modulus describes the elastic properties of a material. It conveys the ability to withstand deformation under stress. It can be used to compare the mechanical properties of materials in the elastic region. It is calculated using:

where M is a constant of the sample called the sectional modulus. We calculated Young's Modulus for our materials using Aluminum to calibrate our measurements. We found that our calculation for aluminum was higher than the standard value. This error can be attributed to the uneven cross section of our sample.

- Aluminum (measured): 250 GPa
- Aluminum (standard value): 69 GPa
- ABS: 52 GPa
- Chicken Bone: 4 Gpa
- Human Bone (Known Value): 20GPa

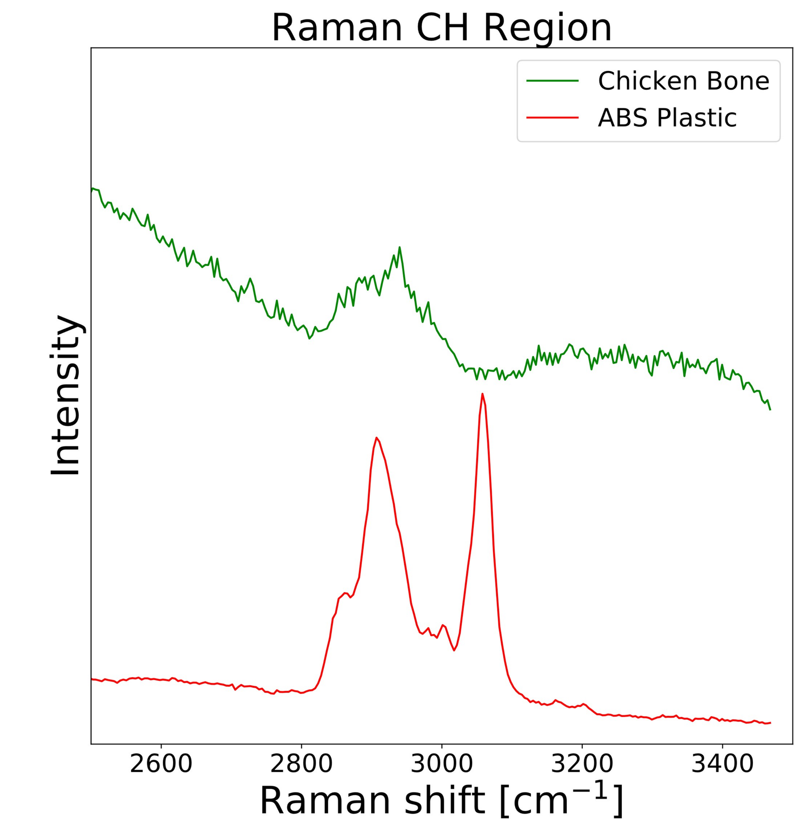


Figure 5: Raman Spectra in C-H Region

Conclusion

- We devised a strain gauge setup to measure elastic properties of materials
- Using aluminum, we concluded that its linear nature confirms the reliability of our experiment.
- We conclude that of the tested materials, ABS is the closest to chicken bone with respect to Young's Modulus
- Vibrational molecular structure was probed with Raman spectroscopy. ABS contains more aromatic C-H which could be related to its elastic properties.

Future Plans

- Conduct other similar experiments using more suitable materials with anatomically correct dimensions.
- In addition, we also want to see what kinds of materials companies use for prosthetics and if these materials are more useful for our purposes.

References

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