

# Formation and Mechanics of High-Tesla Neutron Stars

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# What is a Magnetar?

Definition:



**Figure:** Artistic depiction of a magnetar

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- neutron star



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- massive magnetic field ( $\geq 10^{13}$  G)



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# Distinctions

Detection

Sample

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- 2-12s period X-Ray bursts
- large spin-down rates imply massive magnetic fields

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## Sample

- Piezoelectric Suspension
- Indium-Tin Oxide coated PET plastic (0.01" thickness)

# Kinds of Magnetars

## Bi-modal

- Persistent Magnetars

## Cross-species



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- Magnetar Pulsar

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## Bi-modal

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## Cross-species

- Magnetar Pulsar
- Theoretically: neutron star switch between magnetar, pulsar, and magnetar pulsar

# Budgeting

Materials

Per Sample

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- BaTiO<sub>3</sub> nanoparticles - \$30/25g

## Per Sample

- 0.04g BaTiO<sub>3</sub> nanoparticles

# Budgeting

## Materials

- BaTiO<sub>3</sub> nanoparticles - \$30/25g
- Flexible Photopolymer - \$90/1kg

## Per Sample

- 0.04g BaTiO<sub>3</sub> nanoparticles
- .2g Flexible Photopolymer

# Budgeting

## Materials

- BaTiO<sub>3</sub> nanoparticles - \$30/25g
- Flexible Photopolymer - \$90/1kg
- Indium Tin Oxide PET - \$5/(32 sq.in. sheet)

## Per Sample

- 0.04g BaTiO<sub>3</sub> nanoparticles
- .2g Flexible Photopolymer
- 1.5 sq.in. Indium Tin Oxide PET

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## Per Sample

- 0.04g BaTiO<sub>3</sub> nanoparticles
- .2g Flexible Photopolymer
- 1.5 sq.in. Indium Tin Oxide PET
  
- Total Cost per sample: \$0.30



# Standards

- 176-1987 - IEEE Standard on Piezoelectricity (withdrawn)
- No other applicable standards were found

# Typical Response (Plucking)

Control Test:

# Typical Response (Plucking)

6 wt% Test:

# Typical Response (Plucking)

11 wt% Test:

# Typical Response (Plucking)

20 wt% Test:

# Sources of Uncertainty

- Force measurement
- Unknown polymer structure
- Noisy Environment

# Summary and Conclusions

## Successes

## Further Study

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## Further Study

- Better understand the polymer
- Explore other piezoelectric ceramic nanoparticles.
- Determine how to use suspension in 3D printing.

# Resources

- Project Files: <https://github.com/mflibby/FlexPiezo>
- Samples Request: [mackenzieflibby@gmail.com](mailto:mackenzieflibby@gmail.com)

# References

- Cui, H., Hensleigh, R., Yao, D., Maurya, D., Kumar, P., Kang, M. G., Zheng, X. (R. (2019). Three-dimensional printing of piezoelectric materials with designed anisotropy and directional response. *Nature Materials*, 18(3), 234-241. doi: 10.1038/s41563-018-0268-1
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- Yang, Y., Pan, H., Xie, G., Jiang, Y., Chen, C., Su, Y., Tai, H. (2020). Flexible piezoelectric pressure sensor based on polydopamine-modified BaTiO<sub>3</sub>/PVDF composite film for human motion monitoring. *Sensors and Actuators A: Physical*, 301, 111789. doi: 10.1016/j.sna.2019.111789