Metallurgy Exploration of Cores in Fluxgate Magnetometers

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Problem

Since 1968 [1], ring-core Fluxgate Magnetometers have mostly used a ferromagnetic core of 6% Mo, 81% Ni, and some Fe. Using research from [4] and [3], we strive to produce better magnetic sensing, lower magnetic noise and lower power consumption instrument. The best performing cores will be integrated in the fluxgate magnetometer for a graduate student led sounding rocket mission launching in 2026 which aims to observe the space physics of the Earth's ionosphere and cusp.

Metal Selection

Alloys of ~43% Cu and ~52% Ni and Fe lie on the magnetorestriction line [Fig. 1], which mean they are better at keeping their characteristics when introduced to magnetization. The properties we will measure are resistivity, Curie temperature, coercivity, saturation, magnetic noise, and power consumption.

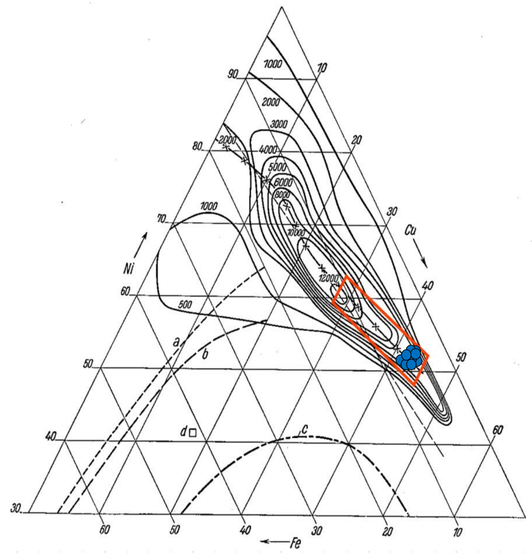
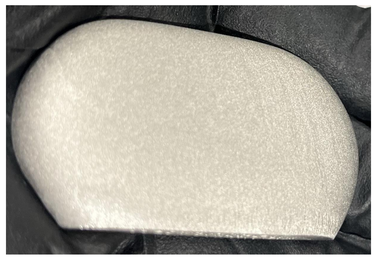


Figure 1. *The range of copper permalloy compositions in this research shown with blue dots. The research from [3] is outlined in red and superimposed on the figure from [4], with their contour plot of initial permeabilities.*

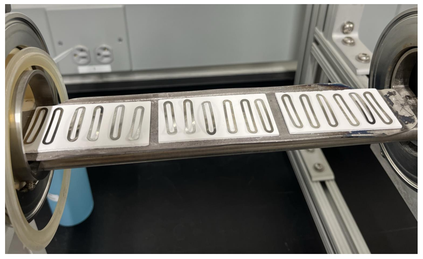
Permalloy Compositions		
42Cu52.5Ni	43.5Cu51Ni	44Cu51Ni
42.5Cu52Ni	43Cu52Ni	44Cu51.5Ni
42.5Cu53Ni	43.5Cu53Ni	43.5Cu52Ni

Core Manufacturing

A



C



B

D

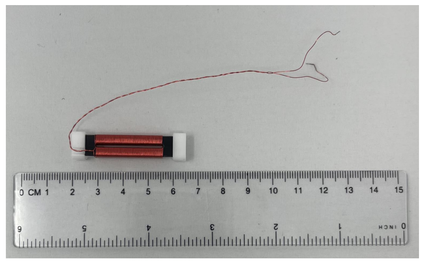


Figure 2. A) *Ingot made of copper, nickel and iron powder.* ***B)*** *Portion of cold-rolled foil of 50 micron thickness created from the ingot.* ***C)*** *Eighteen washers laid out before closing the furnace for heat treatment.* ***D)*** *Sealed bobbin with six permalloy washers layered inside between kapton washers. Copper wire (red) is hand wound in a quasi-toroid shape as the drive winding for induction. These bobbins are placed in an oven at 100C for 100 hours to age the core for better magnetic performance.*

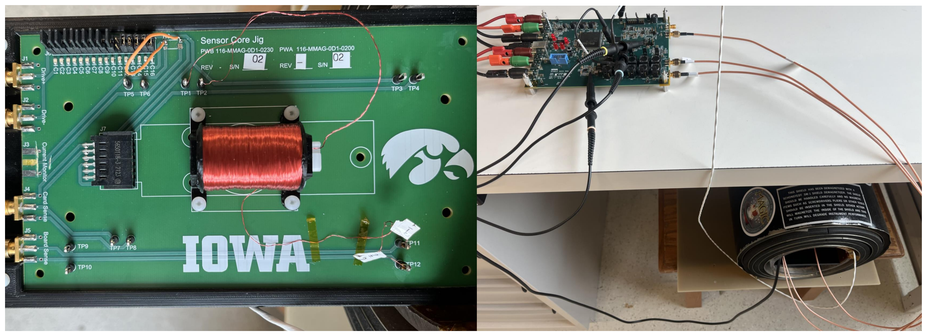


Figure 3. *Magnetic characterization setup, measuring the magnetic properties listed in metal selection section. A bobbin is placed in a magnetically quiet environment and induced current is sent through the drive winding, generating a small magnetic field.*

Core Characterization

- **Power Spectral Density (PSD):** The magnetic noise generated by the core is measured by comparing the frequency to the PSD. For the Mini-Tesseract, PSD is 3pT/√Hz. The PSD for the Tesseract is 20pT/√Hz [2]. **The core in [Fig. 4] has a noise floor of 2.82 pT at 1 Hz**

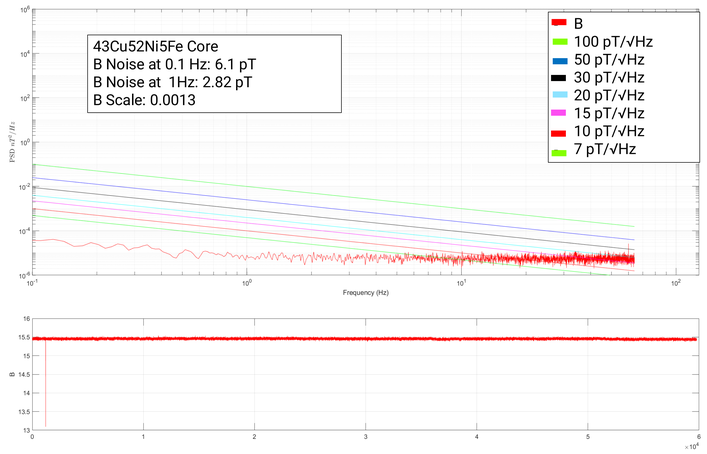


Figure 4. *PSD graph with the noise slope best matching ~2-3 pT at 1 Hz. The lower the slope, the better. The detrended magnetic field remains centered on 15.5 as the coil generates a magnetic null.*

Sounding Rocket Mission

Six of the best performing cores will be included in the Mini Tesseract instrument onboard the Observing Cusp High-altitude Reconnection and Electrodynamics mission sounding rocket.

Acknowledgments

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References

To view the sources cited in this research project, scan the QR code