Heat and Current Annealing Effects on Magnetic Properties of Fe-rich Glass-Coated Amorphous Microwires with Different Radius

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Resume

Álvaro González Villegas

- Studies:
  - *Bachelor's degree on Physics.*
  - *Master's degree on Material's Science and Technology.*
  - *Presently studying a PhD on Physics of Nanostructures and Advanced Materials.*
- Areas of Expertise:
  - *Magnetocaloric and Magnetostrictive materials.*
  - *Magnetic alloys and composites.*

Workgroup

Advanced Polymers and Materials: Physics, Chemistry and Technology.
Department of Physics, University of the Basque Country, San Sebastián.

- Main focus on Glass-Coated Amorphous Microwires:
  - Fabrication.
  - Treatments.
  - Experimentation.
- Applications:
  - Security devices.
  - Computing.
  - Stress monitoring.
  - Geolocation.

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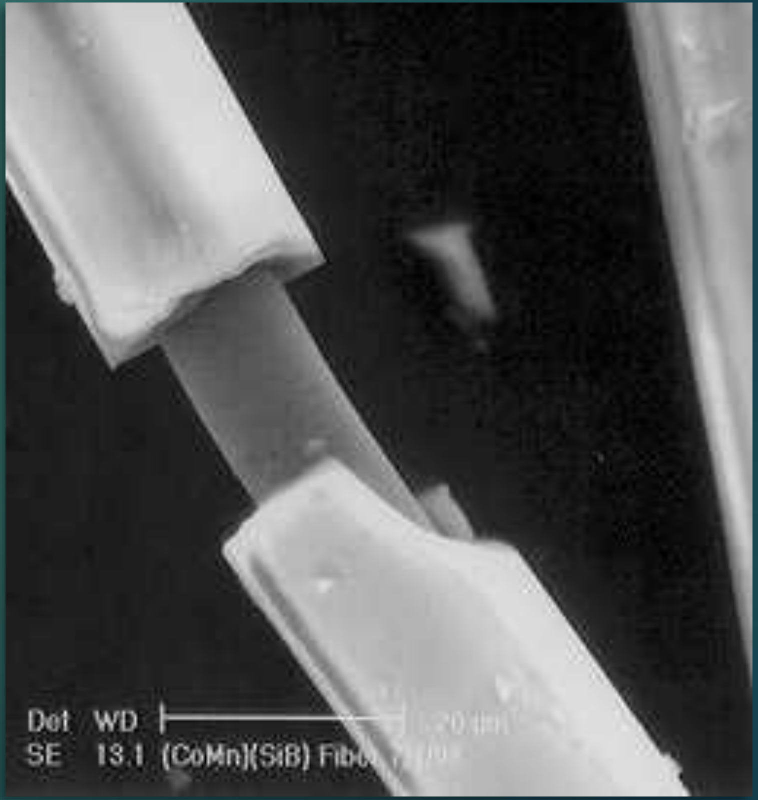
Introduction to Glass-Coated Microwires

- Characteristics
  - Metal core enveloped by glass coating, µm radius.
  - Amorphous alloy, no structural ordering.
  - Magnetic structure depending on core-coating interaction.
- Magnetic Properties:
  - Bi-stability.
  - Ultra fast switching.
  - High magnetic softness.
  - Giant Magneto-Impedance (GMI) effect.
  - Tuning of previous properties by annealing.



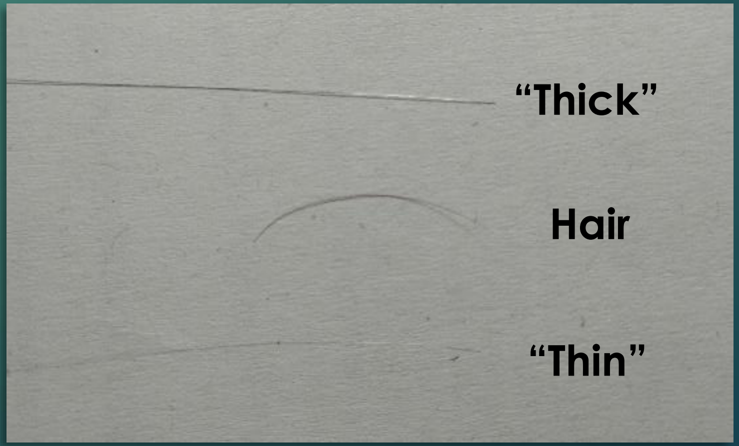
Experimental

Fabrication and parameters

Fabrication:

Taylor-Ulitovsky Technique. [1]

Sample name	*Composition*	*Inner diameter d (μm)*	*Total Diameter D (μm)*	*d/D*
"Thick"	$Fe_{71.8}B_{13.27}Si_{11.02}Nb_{2.99}Ni_{0.92}$	47.9	53.2	0.9
"Thin"	$Fe_{74.87}B_{9.06}Si_{11.99}C_{4.08}$	15.2	17.2	0.88



Experimental

Characterization

- Hysteresis:
  - Fluxmetric method at 114 Hz.
  - 13 cm inductive coil, 2 cm pickup and compensator coils.
- Domain Wall (DW) dynamics:
  - Modified Sixtus-Tonks method. [2]
- Giant Magneto-Impedance:
  - Network vector analyzer. [3]
  - GMI efficiency [4]

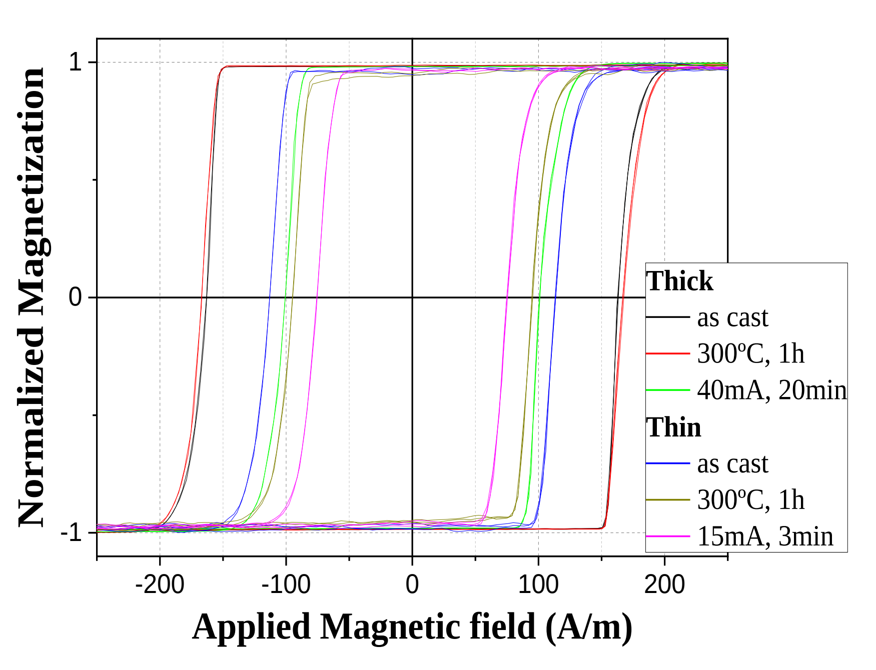
$$\frac{\Delta Z}{Z} = \frac{Z(H) - Z(H_{max})}{Z(H_{max})}$$

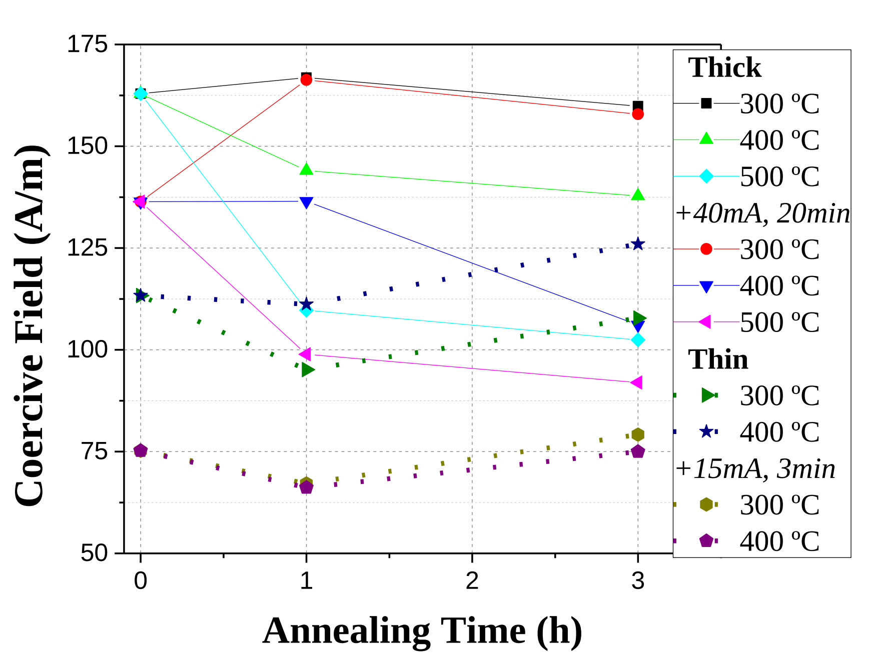
Annealing

- 24 cm samples.
- "Conventional" furnace annealing:
  - At 300, 400 and 500 ˚C.
  - For 1 and 3 hours.
- Current annealing [5]:
  - "Thick" samples: 40 mA for 20 minutes.
  - "Thin" samples: 15 mA for 3min.

Results

Magnetic hysteresis



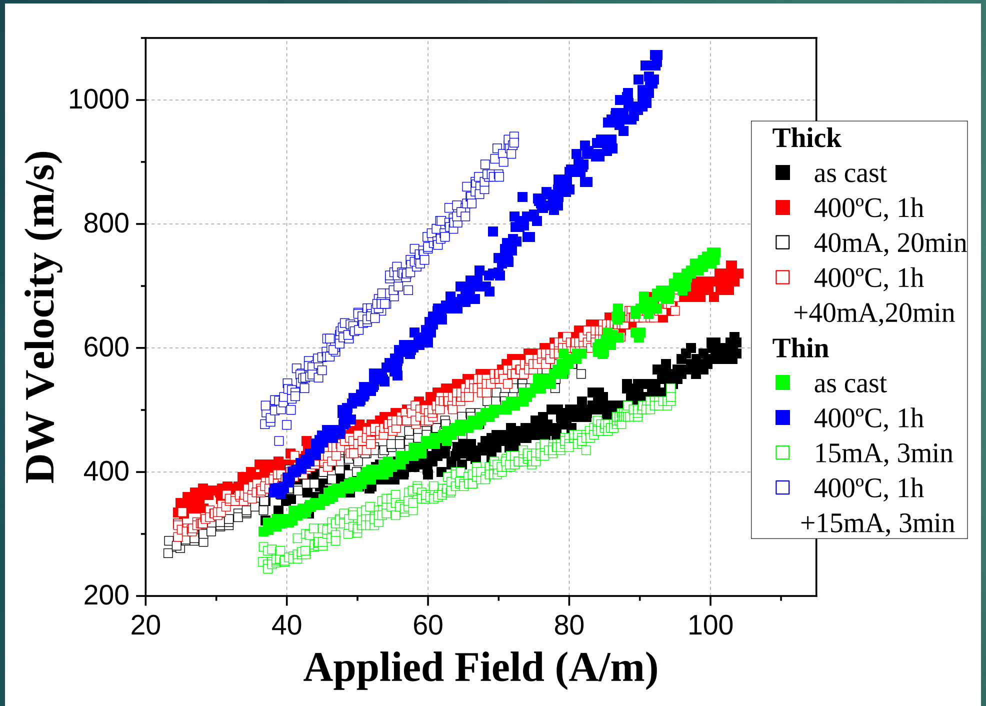


- Magnetic bi-stability.
- Thicker microwire -> bigger H_C
- Current annealing further reduces H_C

- "Thick" H_C reduction with T -> stress relaxation
- "Thin" H_c rises with T -> crystallization

Results

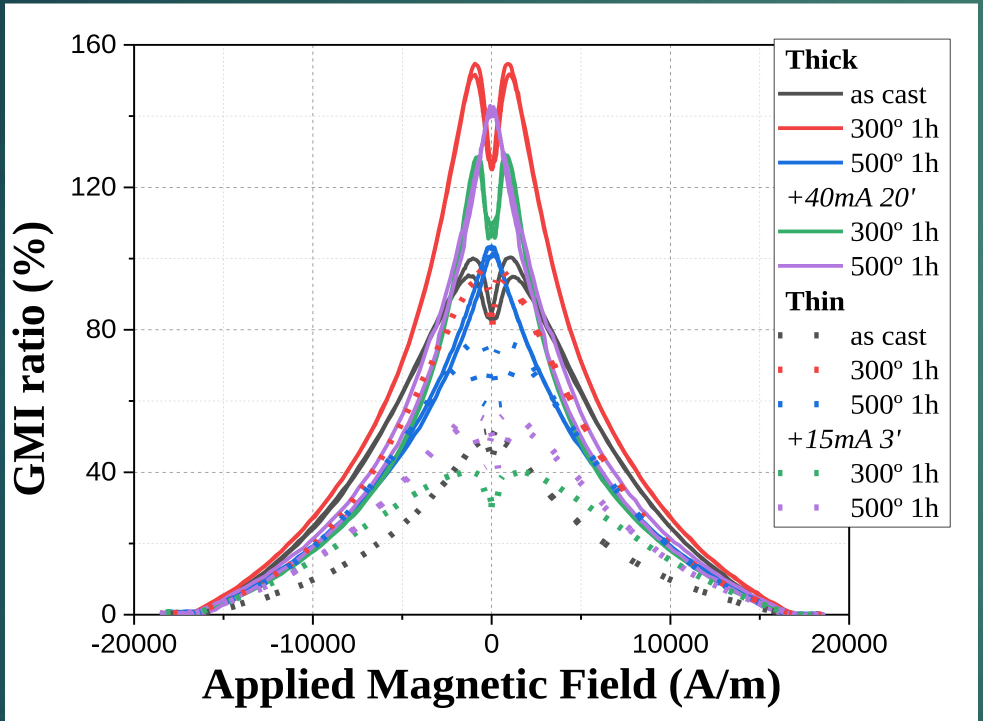
Domain Wall (DW) dynamics



- Thinner microwire -> faster DWs.
- Conventional annealing enhances velocity and movility.
- Current annealing shows small, even negative results.
- Combination of annealings:
- "Thick" -> almost no effect
- "Thin" -> further enhancement of DW velocity

Results

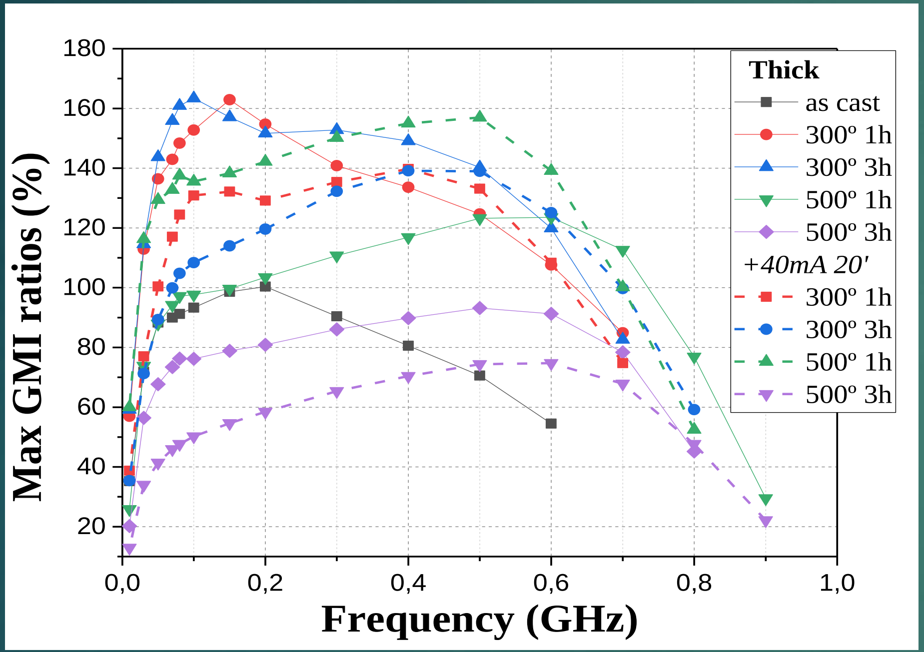
Giant Magneto-Impedance (GMI)

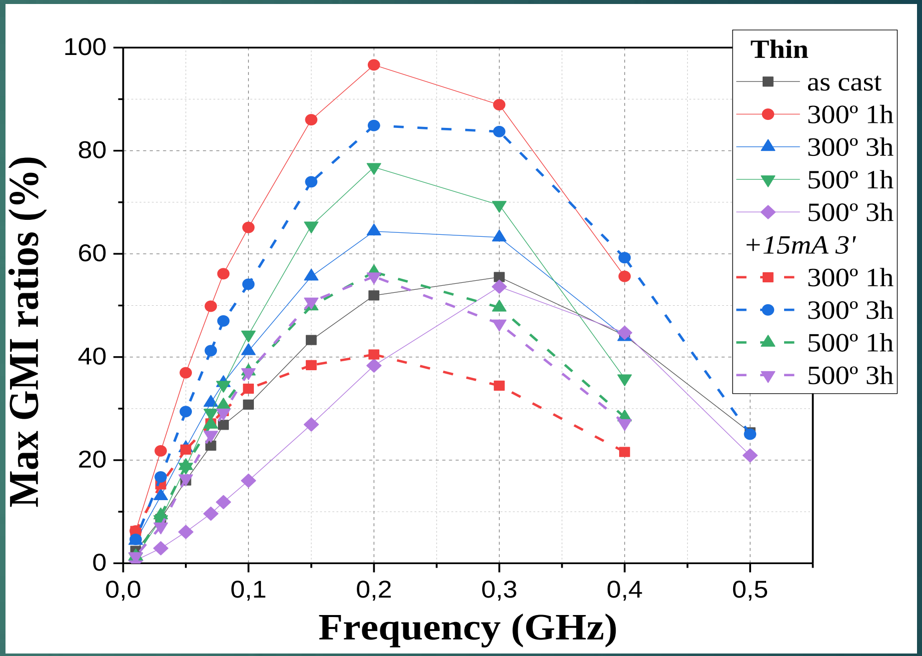


- Thicker microwire -> Higher GMI values.
- Annealing enhances values, but excessive annealing is detrimental.
- "Thin" microwires are more sensitive to annealing.

Results

Giant Magneto-Impedance (GMI)





- Annealing shifts frequency for max GMI effect.
- Excessive anneling reduces GMI, but current annealing can recover efficiency.
- Frequency shift almost not pressent.
- Lower resistance to and recovery from excessive annealing.

Conclusions

- Thinner microwires are magnetically softer and present higher DW velocity and movility, but show lower GMI efficiency and resistance to long exposure to high temperatures.
  - Better suited for computation related and lower scale technologies.
- Thicker microwires posses higher GMI effect, with the posibilty of recovering efficiency losses from heat exposure by aplying current annealing.
  - Better suited for magnetic and stress sensing and composite designs.
- Conventional furnace annealing at 300 ˚C for 1 hour yields the best GMI performance enhancement for both types of microwires. Tuning of other properties require might require different temperatures and times.
- Aplication of current annealing after conventional annealing seems to be a viable option to further tune specific properties of microwires for applications outside GMI related ones.

References

1. A.V. Ulitovsky, I.M. Maianski, and A. I. Avramenco, “Method of continuous casting of glass coated microwire”, Patent No128427 (USSR), 15.05.60, Bulletin, 10, p. 14.
2. V. Zhukova et al., “Domain wall propagation in micrometric wires: limits of single domain wall regime”, J. Appl. Phys. 111, pp 07E311-1 - 07E311-3, 2012.
3. M. Ipatov, V. Zhukova and A. Zhukov. “Low-field hysteresis in the magnetoimpedance of amorphous microwires”. Phys. Rev. B 81, pp 134421-1 - 134421-8, 2010.
4. P. Corte-Leon, V. Zhukova and A. Chizhik. “Magnetic Microwires with Unique Combination of Magnetic Properties Suitable for Various Magnetic Sensor Applications”. Sensors 20, pp 7203-1 – 7203-21. 2020
5. A. Gonzalez et al., “Effect of Joule heating on GMI and magnetic properties of Fe-rich glass-coated microwires”, AIP Adv. 12, pp 035021-1 - 035021-4, 2022.