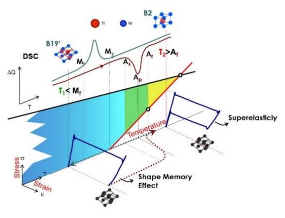

Additive Fabrication of Anepectic Meshes controlled by a NiTi alloy

Workshop on Shape Memory Alloys
Processing, Properties and Applications
CENIMAT, FCT/UNL, 19/02/2020

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ABSTRACT

An anepectic material is a metamaterial which simultaneously exhibits a negative coefficient of thermal expansion (CTE) and a negative Poisson coefficient. These meshes may be applied in situations where a response to a thermal stimulus is desired, such as in the aerospace and medical fields. In the current work, anepectic composite meshes, made from ABS and NiTi alloys, were fabricated with the aid of an additive manufacturing technique and subsequently characterized. Seven different mesh designs or material combinations were tested. In every case, a common passive part consists of ABS. A complementary active part, consisting of NiTi wire, differed from case to case, whether in terms of the particular behavior demonstrated (shape memory effect [SME] an/or superelasticity [SE]), the temperature of the relevant phase transformation, the geometry adopted, or the diameter used. All meshes were tested in a silicone bath, and their CTE was measured. The results showed that, under careful parameter selection it is possible to achieve an anepectic effect by combining ABS with SME or SE wires. The mesh that showed to have a more negative CTE (-3008 x 10-6 °C-1) combined SME wires with SE wires. With such combination, it was possible to activate the mesh bellow the glass transition of the polymer, at 38ºC. For one of the seven fabricated meshes, cyclic tests of three heating and cooling were performed. But only during the first cycle could the anepectic behavior be preserved, the CTE becoming positive on the remaining cycles. Finite element simulation was also performed, where both positive and negative mesh displacements were verified.

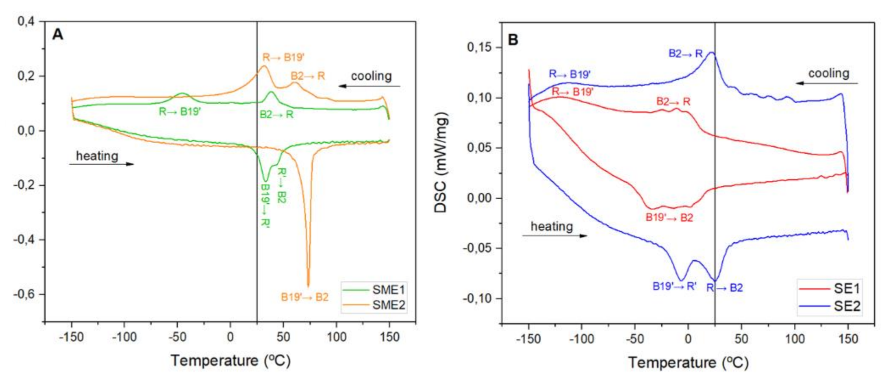
MATERIALS AND METHODS

Glass transition temperatures

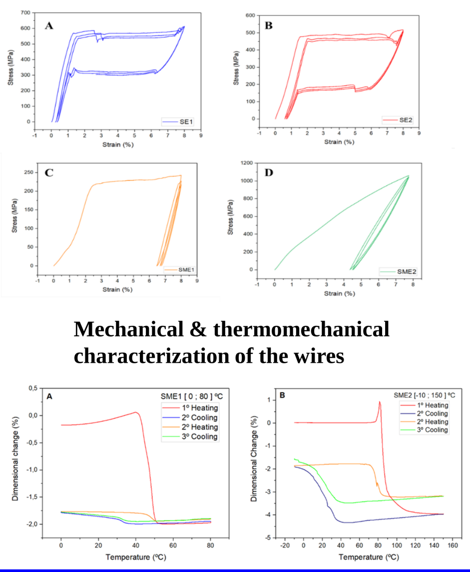
Material	T_g (ºC)
ABS	87
CPE+	105 [2]

Specifications of the wires

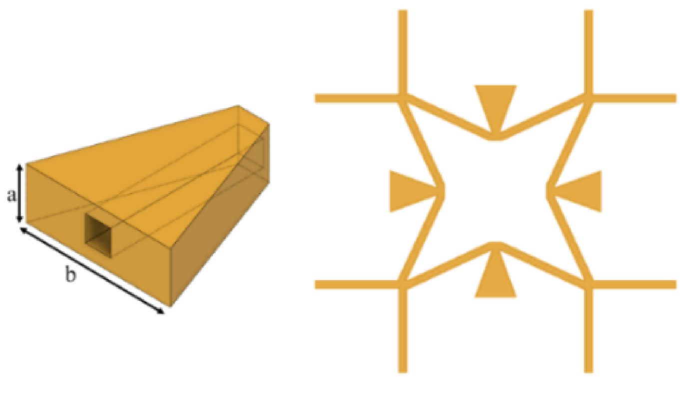
Designation	Description	Diameter (mm)	Alloy Type	Lot	Provider
SE1	Superelastic at room temperature	0.24	S	7711	Euroflex
SE2	Superelastic at room temperature	0.38	S	IC #2508	Memry Nitinol +
SME1	Shape memory effect above room temperature	0.80	Memory metal	-	Educational Innovations, Inc.
SME2	Shape memory effect above room temperature	0.38	DY90	IC #0017	Memory-Metalle



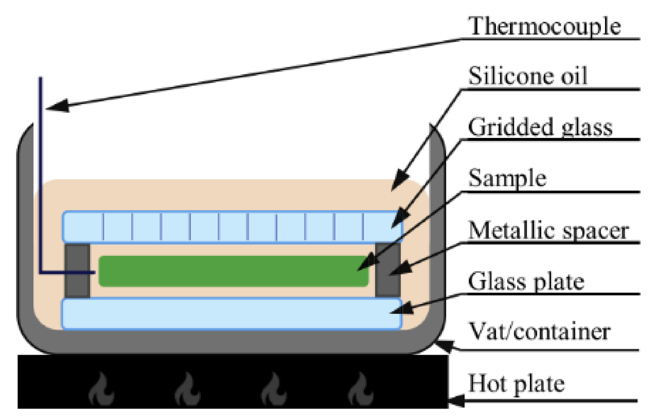
DSC of NiTi alloys: SME1, SME2, SE1 and SE2 (vertical line represents room temperature).



Mechanical & thermomechanical characterization of the wires

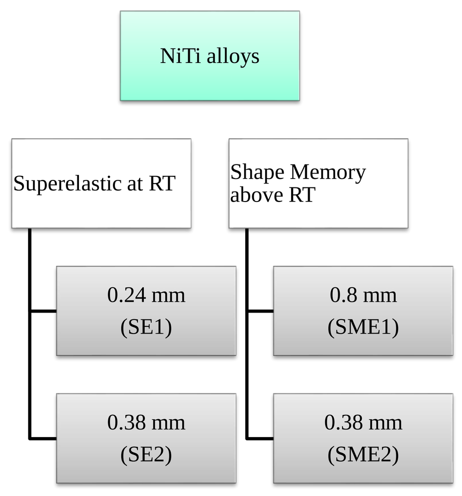


Unit cell with sleeves and sleeve detail

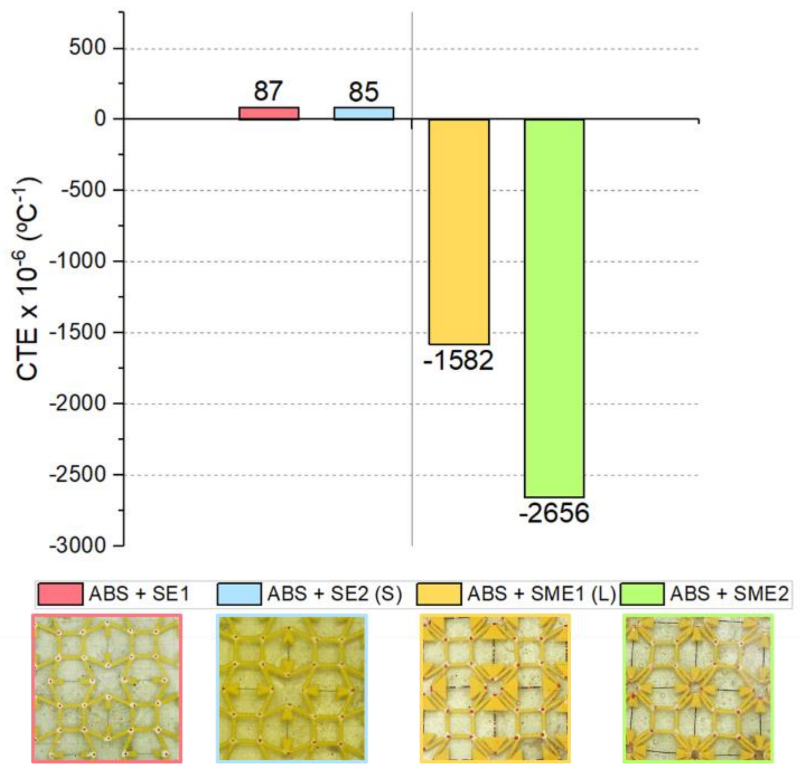


Schematic of the CTE mesh testing setup

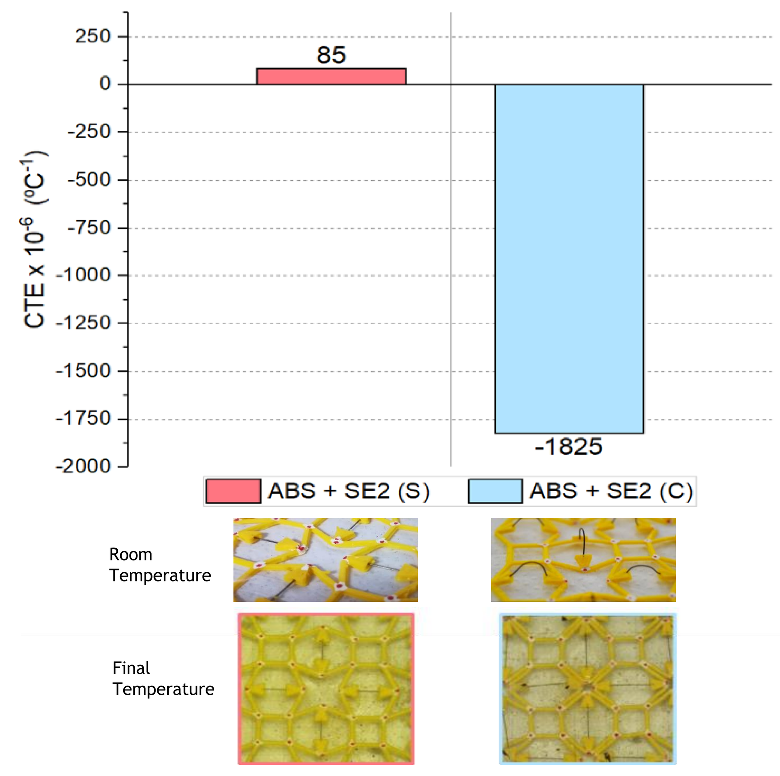
RESULTS AND DISCUSSION



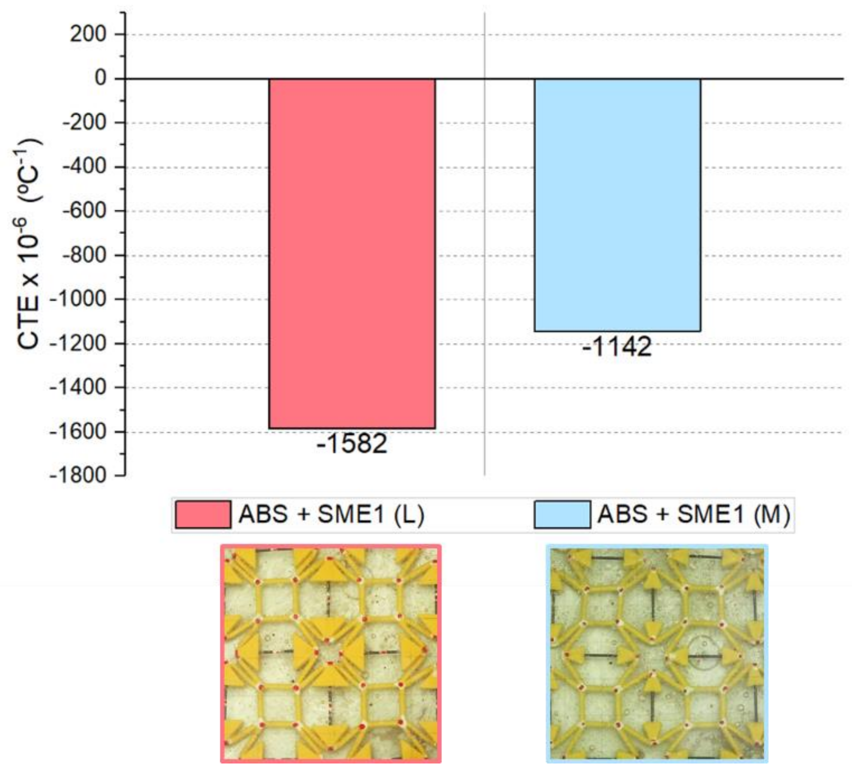
Effect of the wire diameter



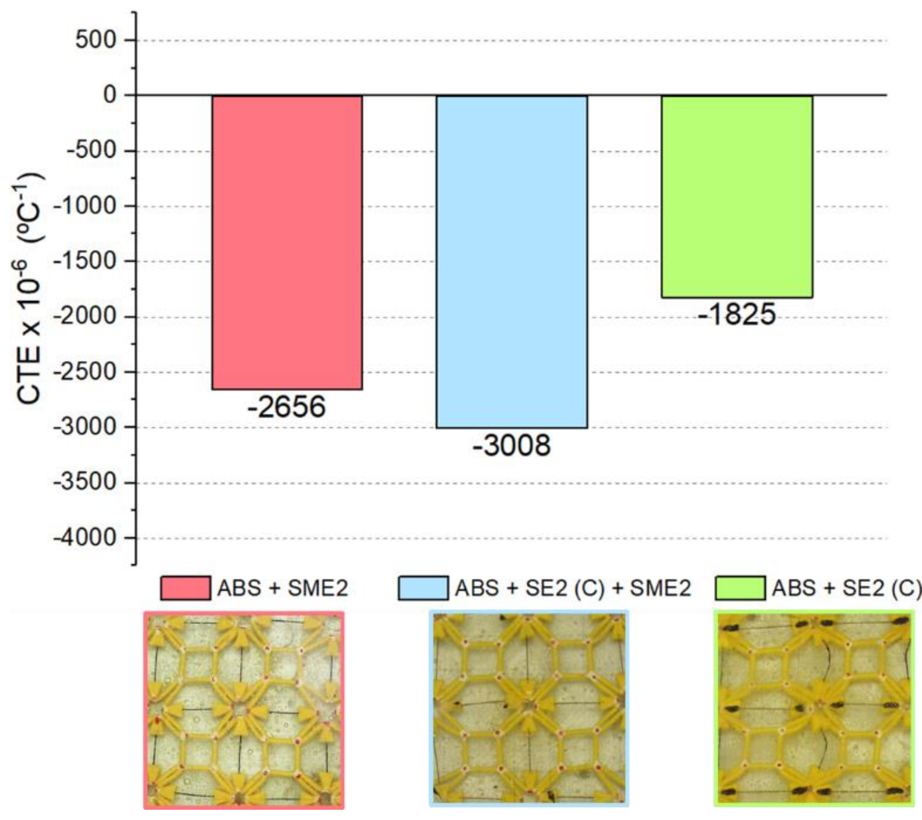
Effect of the wire configuration



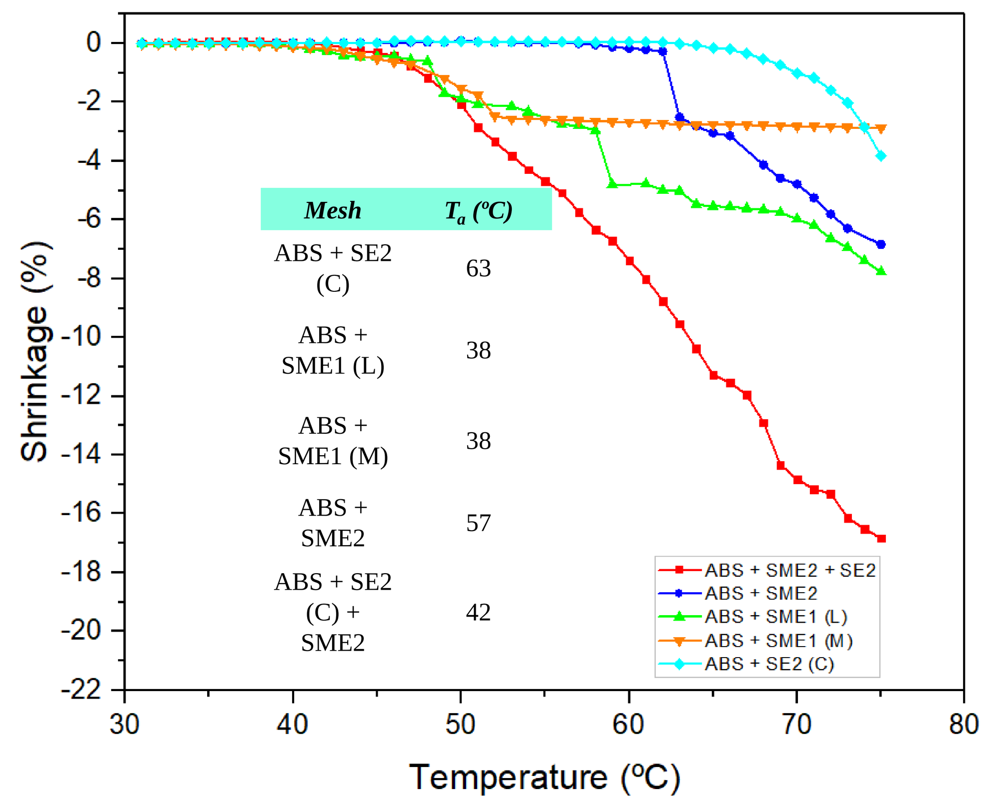
Effect of sleeve geometry



Separated and combined effects of SE and SME

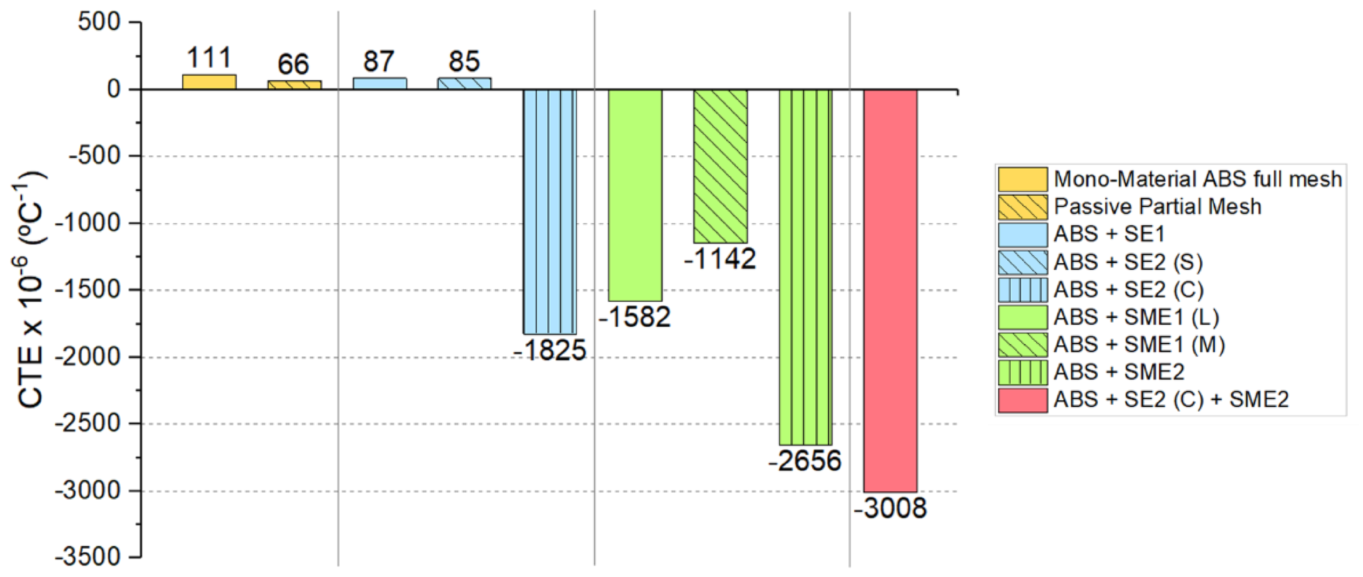


Activation temperatures



CONCLUSIONS

CTE of the most relevant meshes on this work



- The meshes with the wires placed in a curved configuration have NTE – big influence of the wire configuration
- Extreme NTE result of -3008 x 10-6 °C-1 on the mesh with simultaneously wires showing SE and SME
- Earliest activation temperatures at 38 °C.

REFERENCES

[1] J. S. Raminhos, J. P. Borges, and A. Velhinho, "Development of polymeric anepectic meshes: auxetic metamaterials with negative thermal expansion", Smart Mater. Struct., 2019.
[2] Inês Marcelino. "Additive Fabrication of Anepectic Meshes controlled by a NiTi alloy". MSc thesis in Materials Engineering, Faculdade de Ciências e Tecnologia, UNL, 20/11/2019.

ACKNOWLEDGMENTS

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