# 2017 PhD Thesis Research Topic (2)

**Title**: Multi-scale patterns and nonlinear performance of multi-physics coupling materials

**Subfield**: Mechanics, Applied Physics and Materials Science.

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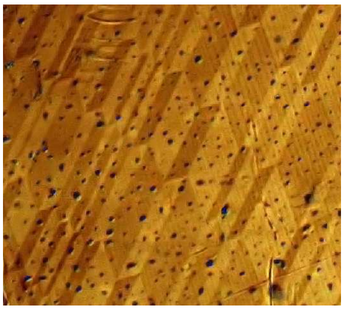
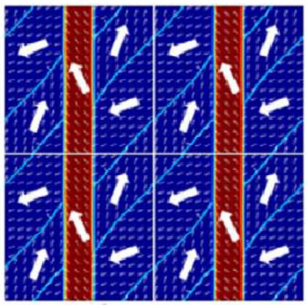
Multi-physics coupling materials (or smart materials) are sensitive to multiple physical fields (stress fields, thermal field and electric/magnetic fields) and have many applications such as actuators, sensors, energy harvesting (mechanical/thermal energy to magnetic/electric energy) and magneto-caloric/elasto-caloric cooling systems. In contrast to the traditional smart materials (with small linear coupling such as piezoelectricity and magnetostriction), the recent advanced coupling materials have much larger strain, more heat release/adsorption, and/or stronger magnetization/polarization (like ferroelasticity, ferromagnetism and ferroelectricity) and these strong couplings trigger the formation of various patterns/domains in the materials, leading to nonlinear global performances. For example the following two figures show the patterns from experimental observations and theoretical simulation on a magnetic shape memory alloy (a material combining ferromagnetism and ferroelasticity). Preliminary studies[1-5] revealed that the patterns governing the global performance are sensitive to the external conditions such as the loading frequency/rate and heat-transfer environment. In this thesis, based on microstructure observations, macro-response measurement and multi-scale modelling, we will derive the pattern evolution laws, particularly, the kinetics of the various interfaces (magnetic domain walls, twin boundaries, etc.) and their relations with the material's global performance.



Experimental observed patterns



Simulated magnetic domains in twin structures [5]

**Representative publications on the research topic:**


[1] **Y.J. He**, X. Chen, Z. Moumni, "Reversible-strain criteria of ferromagnetic shape memory alloys under cyclic 3D magneto-mechanical loadings". *Journal of Applied Physics* 112, 033902 (2012).

[2] X. Chen, **Y. J. He**, and Z. Moumni, "Twin boundary motion in Ni-Mn-Ga single crystals under biaxial compression". *Materials Letters* 90, 72-75 (2013).

[3] X. Chen, Z. Moumni, **Y. J. He**, W. Zhang, "A three-dimensional model of magneto-mechanical behaviors of martensite reorientation in ferromagnetic shape memory alloys", *Journal of the Mechanics and Physics of Solids* 64, 249–286 (2014).

[4] O.-Z. Pascan, **Y.J. He**, Z. Moumni and W.H. Zhang "Temperature rise of high-frequency martensite reorientation via Type II twin boundary motion in NiMnGa Ferromagnetic Shape Memory Alloy" *Scripta Materialia* 104, 71–74 (2015).

[5] Q. Peng, **Y.J. He** and Z. Moumni "A phase-field model on the hysteretic magneto-mechanical behaviours of ferromagnetic shape memory alloy" *Acta Materialia* 88, 13–24 (2015).