State the objective of the project

The Ni-Mn-Ga alloys are characterized by martensitic transformation and comparably easy motion of twin boundaries under a magnetic field. Recent studies carried out in the field of Ni-Mn-Ga alloys have shown a huge magnetic field-induced strain of about 12%. Due to these advantages they are mostly chosen as a potential candidate for practical application especially promising for actuators, pumps and sensors since they are showing the largest magnetic field-induced strain so far. Due to a low crystal symmetry of the modulated phases different types of twin boundaries may exist in Ni-Mn-Ga martensite. They also differ in twinning stress and show typically a hierarchy in twin boundary formation. For example type I twin boundaries exhibit a strongly temperature-dependent twinning stress typically of about 0.5 – 1 MPa at room temperature while type II twin boundaries show a much lower stress of about 0.05 – 0.3 MPa which is almost temperature independent. However, so far detailed experimental as well as theoretical studies on twinning in Ni-Mn-Ga alloys are still scarce. Therefore, the main goal of the present research is to define the role of different twin boundaries including periodic atom displacements called modulation and inverting stacking faults on the crystal structure and magnetic field induced strain in single crystalline five-layered 10M and seven-layered 14M Ni-Mn-Ga alloys. A close examination of the microstructure will also help to show the particular contribution of each boundary to the twinning stress level and as a consequence to optimize the effect. Using a proper magneto-mechanical treatment should lead to a single-variant state which significantly simplifies the investigations on electron and crystal structure of this material. Such an approach will confirm or exclude the so-called adaptive concept of martensite. Concurrently, the issue presented here will form part of a broader topic related to the so-called twin boundary engineering. It is based on design, creation of a twin configuration for particular application. Depending on the twin configuration (parallel, perpendicular or mixed) different effects can be observed such as magneto-elasticity, magneto-plasticity, and magnetically induced pseudoelasticity.

Research plan

The research plan assumes a thoughtful examination of the microstructure of Ni-Mn-Ga monocrystalline alloys with five-layered and seven-layered martensite. To achieve this goal a numerous advanced techniques such as transmission and scanning electron microscopy will be applied. This study will be supported by a synchrotron radiation measurements which provide information from the bulk. Training process will be apllied as the last step in the preparation procedure of Ni-Mn-Ga alloys. It consists of multi-axis compressions finally leading to a single-variant state. Moreover, interaction between different types of twin boundaries will be studied. As a consequence a better understanding and control of particular twin configurations will be achieved. This will allow for more efficient use of the programing functions of this material.

Reason for choosing the research topic

The research program attempts to explain and expand the knowledge of the fundamental issues but also leads to practical applications. It will demonstrate the coupling between the microstructure, crystal structure and easy twin boundary motion in Ni-Mn-Ga modulated martensite. It will also help to answer the question about the adaptive phase martensite which is still very controversial. From more particle point of view it will optimize both the magnetic field induced strain and other related effects such as magneto-elasticity, magneto-plasticity, magnetically induced pseudoelasticity which have a very large application potential especially for a large number of technological applications like actuators, sensors or pumps.