Abstract

Shape memory alloys are the promising candidate materials for sensing and actuator-based applications. Amongst a variety of shape memory alloys, NiMnGa based magnetic shape memory alloys are technologically most important owing to their superior properties such as large recoverable strain, low field actuation and fast response. In the present study, a systematic study has been performed to understand the effect of growth conditions and substrate selection on the texture, microstructure and magnetic properties of sputter deposited NiMnGa thin films.

The film deposited in Zone T condition (500 °C) on Silicon (100) are polycrystalline with preferred out of plane orientation. A gradual transition of crystallographic texture from (220) to (400) fiber with increase in sputtering power has been observed and is correlated with the minimization of surface and strain energies in the films. The higher grain size and better packing density in the film deposited at higher sputtering power have led to superior magnetic properties in terms of lower value saturation field and coercivity. The films deposited under Zone 2 condition (650 °C) on silicon (100) substrate showed the development of a bi-axial texture with both out-of-plane and in-plane preferred orientation. In-depth structural investigations reveal excellent crystal quality in these films with rocking curve measurements. The cube on cube orientation relationship films and the substrate further confirms the bi-axial alignment of unit cell due to imperfect epitaxial growth of the film. Three levels of microstructural hierarchy and formation of epitaxial Ni-Si at the interface are some of the key results from high resolution transmission electron microscopy studies. For the first time, a four-step phase transformation sequence 'austenite → pre-martensite → martensite → intermediate martensite' has been observed by temperature dependent magnetization and in-situ high/low temperature X-ray diffraction studies.

NiMnGa films deposited on Al_2O_3 $(11\bar{2}0)$ substrate under Zone T condition shows bi-axially oriented film with multiple variants. The TEM investigations reveals the presence of secondary nano-twins formed by adaptive modulation within the primary martensitic twins. The presence of six satellite spots within the main diffraction spots confirms the presence of seven modulated orthorhombic martensite phase in the as-deposited film. Overall development of bi-axial texture and epitaxial like growth in the films has been attributed to optimum growth conditions and suitable selection of substrate with low lattice mismatch with the film (0.7%).

The last part of the work is dedicated to the epitaxially grown films on Al_2O_3 $(11\bar{2}0)$ and MgO (100) substrates under Zone 2 condition. The minimization of lattice strain due to lower lattice mismatch between film and substrate and higher mobility of ad-atoms led to the development of such high-quality films. The coexistence of non-modulated and seven modulated martensite phases observed with TEM imaging provides a clear evidence of adaptive modulation of martensite in the as-deposited film. The magnetic field induced reorientation of martensitic variants (MIR) has been observed as an abrupt change in the slope of magnetic hysteresis.