INTERFACE, MISFIT AND BULK MAGNETOELASTIC COUPLINGS IN RARE EARTH (Dy, Ho, Er)/Y, Lu, Tm SUPERLATTICES

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9.7 cm

We review our researches on the *magnetoelastic* (MEL) *coupling* (MEL-C) in a wide range of MBE grown Rare Earth (RE = Ho, Dy, Er) superlattices (SL), spaced by Y, Lu and T-m (SP), of formula $\mathrm{RE}_n/\mathrm{SP}_m$. The epitaxy is $[11\overline{2}0]Al_2O_3\|[110]Nb\|[0001]RE/[110]Nb$, and RE blocks are hcp pseudomorphic. We performed MEL stress (MEL-S) measurements up to 12 T fields, **B**, between 10-300K. MEL-S $\widetilde{\sigma}(\mathbf{a},\mathbf{a})$ and $\widetilde{\sigma}(\mathbf{a},\mathbf{b})$, were measured on basal plane (b.p.), with $\mathbf{B} \parallel$ easy **a**-direction (Dy, Er), **b**(Ho), using a capacitive *cantilever* technique. We determined the *irreducible* $\mathbf{M}^\gamma$ MEL-S, breaking the b.p. hexagonal symmetry. The series are: **Ho/Lu** (n=8–85; m=15), **Ho/Y** (10; 10–40, 6; 6), **Dy/Y** (5-25; 15); **Er/Lu** (10-30; 10); **Ho/Tm** (8-60; 16). MEL-S for thick (10^4 Å) RE films gave close values to the bulk. The MEL-S in RE's SL are rather *different* as in bulk. We found three contributions to $\mathbf{M}^\gamma$: RE volume ($\mathbf{M}^{\gamma}_{v0}$), *interface* (IF) ($\mathbf{M}^{\gamma}_{s}$) and RE/SP a(or b)–lattice constant *misfit* (MF) strain ϵ^{γ}_{mf}, i.e. we observed *second-order* MEL effects. They compose as: $\mathbf{M}^\gamma = \mathbf{M}^{\gamma}_{v0} + 2\mathbf{M}^{\gamma}_{s}/\mathrm{t}_{RE} + \mathbf{D}^{\gamma}_{v}\epsilon^{\gamma}_{mf}$, for *elastic* regime ($\epsilon^{\gamma}_{mf} = \mathrm{e}(\mathrm{t}_{SP}/(\alpha\ \mathrm{t}_{RE}+\mathrm{t}_{SP}))$), and bulk mismatch e= $(\mathrm{a}^{b}_{SP} - \mathrm{a}^{b}_{RE})/\mathrm{a}^{b}_{SP}$= -1.7%; in **Ho/Lu SL, Ho** is under *compression*. Edge dislocation effects could also be present. The main results, e.g. in the $\mathbf{Ho}_n/\mathbf{Lu}_{15}$ SL, are:

i) the *IF* and *MF* MEL-S are strong, -6 and 5.5 times $\mathbf{M}^{\gamma}_{v0}$ (n=8), with MEL-S (in GPa and at 0K) $\mathbf{M}^{\gamma}_{v0}$ =+0.275, $\mathbf{M}^{\gamma}_{s}/(c/2)$ =-7.0 and $\mathbf{D}^{\gamma}_{v}$ =-116;

ii) MEL-S are of *single–ion* crystal-field (CEF) origin, as concluded from: a) scalings with reduced magnetisation, m(T), are as $\widehat{I}_{5/2}(\mathrm{L}^{-1}(\mathrm{m}))$ for $\mathbf{M}^{\gamma}_{v0}$ and $\mathbf{D}^{\gamma}_{v}$, and as m^4 for $\mathbf{M}^{\gamma}_{s}$, i.e. RE-IF behaves as $2d-spin$; b) the MEL-S signs agree with Stevens parameter α_J. We also studied $\mathbf{Ho}_{10}/\mathbf{Y}_n$ SL to single out the MF MEL-S; $\mathbf{M}^\gamma/(c/2)$ changes sign at n $\cong$ 14, because of the opposite signs of $\mathbf{M}^{\gamma}_{v0}$=0.27 GPa and $\mathbf{M}^{\gamma}_{s}/(c/2)$ = 2.16 GPa relative to $\mathbf{D}^{\gamma}_{v}$ = -56 GPa. In Ho/Y SL e=+2.3%, so Ho is under *tension*. In $\mathbf{Ho}_n/\mathbf{Tm}_{16}$ SL, with *competing* anisotropies ions, $\mathbf{Ho}^{3+}$ and $\mathbf{Tm}^{3+}$,we found a sign inversion of $\mathbf{M}^\gamma$ relative to $\mathbf{Ho}_n/\mathbf{Lu}_{15}$ SL. A developed *model* shows that the strong and of opposite sign relative to $\mathbf{M}^{\gamma}_{v0}$, $\mathbf{M}^{\gamma}_{s}$ comes out from *localised* conduction band states at IF, screening the IF distorted CEF differently as in the volume.

For revealing the $\alpha - mode$ MEL-S (of volume $\mathbf{M}^{\alpha}_{12}$ and of c/a distortion, $\mathbf{M}^{\alpha}_{22}$) we studied the *thermal variation* (4.2K-300K) of **a** and **c** parameters for $\mathbf{Er}_n/\mathbf{Lu}_{10}$ SL, using a triple-axis X-ray spectrometer. Noticeably, besides the exchange $\alpha - mode$, we found *strong* IF and MF *CEF* contributions. Finally, accurate magnetic phase diagrams in ($\mathbf{H}_C$,T) plane were traced from our MEL-S and magnetization measurements.

13.4 cm

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Subject category :

2. Magnetic Films, Surfaces and Multilayers

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