Elastic and Magnetic Properties of Tb-MnO Based Thin Films

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Introduction
- Ferroelasticity and ferromagnetism are primary ferroic orders that can be utilized to study the potential of materials that can deliver in the next-generation memory storage technology.
- Elasticity and magnetism are mediated by phonons (vibrational lattice waves) and magnons (magnetic spin waves), respectively.
- Multiferroic refers to the existence of two or more ferroic orders (ferroelastic, ferroelectric, ferromagnetic, ferrotoroidic, etc.) in the same material and can be coupled via mechanical stress (σ), strain (ε), electric field (E), polarization (P), magnetization (M), or magnetic field (H) [1].

Methodology
Growth of Tb-MnO thin films
- Energetic Ar⁺ ions eject materials from the target via knock-on effect and deposits them onto the substrate.
- The film deposition was carried out using RF magnetron sputter system.

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X-ray reflectivity (XRR)
- A non-destructive X-ray technique to determine thickness, mass density and roughness of thin films.
- Principle of total external reflection of X-rays from surfaces and interfaces.
- Periodicity of the Kikuchi fringes correlate with film thickness, and onset of decay in oscillation to the mass density, θ — ρ [2].

Surface Brillouin scattering (SBS)
- Inelastic scattering of light (λ=532 nm) by phonons using back scattering geometry (Fig. 4).
- Surface phonons probed by momentum conservation (Eqn.1), while the phase velocities obtained using Eqn. 2.

\[ v = \frac{\omega}{k} \]

\[ k = \frac{\omega}{v} \]

where \( k = 2 \pi \sin \theta \).

Results and Discussions

Elastic Properties
- (λ=532 nm) Determined using mass density, wave-vector – thickness product of the films, and Brillouin shift of the SBS spectra. The Brillouin shift of the films is shown in Fig. 7.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Magnitude</th>
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<tbody>
<tr>
<td>C11</td>
<td>1.6±0.6 GPa</td>
</tr>
<tr>
<td>C14</td>
<td>3.5±0.6 GPa</td>
</tr>
<tr>
<td>C21</td>
<td>1.5±0.6 GPa</td>
</tr>
<tr>
<td>Young’s modulus (E)</td>
<td>43 GPa</td>
</tr>
<tr>
<td>Shear modulus (G)</td>
<td>43 GPa</td>
</tr>
<tr>
<td>Bulk modulus (K)</td>
<td>123 GPa</td>
</tr>
<tr>
<td>Poisson’s ratio (ν)</td>
<td>0.34</td>
</tr>
<tr>
<td>Pugh’s ratio (E/G)</td>
<td>2.85</td>
</tr>
</tbody>
</table>

Conclusions
- The independent elastic constants of Tb-MnO films at ambient temperature have been determined as: C11 = 1.6±0.6 GPa, and C14 = 3.5±0.6 GPa.
- The derived elastic constants suggest that the films are ductile.
- The films show ferromagnetic properties at T≤150 K, with competing magnetic interactions at 75–100 K.

Bibliography

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