Control of Chemical Composition of Rare-earth Substituted Iron Garnets using Biased Target Deposition

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Abstract: Rare earth cerium substituted europium iron garnets $(CeEu)_3(FeGa)_5O_{12}$ (Ce:EIG) as well as the elemental oxides were deposited on fused quartz substrates using Biased Target Deposition (BTD). The Ce:EIG films are prepared at low temperature (80-120ºC) by sputtering four metallic targets simultaneously using a low energy ion beam. This method provides control over the material composition in a predictable way by controlling the bias duty cycle on individual targets.

1 Introduction: Rare earth substituted iron garnets are well known for their magneto-optical properties that make them well suited for the applications such as optical isolators, high speed temporal modulators, lightwave polarisation controllers etc. The cerium substituted europium iron garnets (Ce:EIG) have potential applications in the visible spectrum of between 400 and 700nm and in the infrared spectrum around 1550nm for optical communications.

The garnet materials can be prepared using various techniques such as Liquid Phase Epitaxy, Pulsed Laser Deposition, Solgel and Reactive Ion Beam deposition. In this paper, we present BTD as an effective method to prepare Ce:EIG films as well as Ce, Eu, Fe and Ga oxides. The unique feature of this method is the controllability of the thin film composition by varying the duty cycle of four metal targets that are sputtered simultaneously [1]. Another important feature of this system is that the Cerium Oxide can be deposited as Ce_2O_3 and rather than CeO_2.

2 Experimental Procedure:

2.1 Sample Preparation: The Ce:EIG films are deposited on fused quartz substrates by BTD as shown conceptually in Figure 1.

A low energy ion source is directed at negatively biased sputtering targets. A plasma sheath develops at the surface of the targets that accelerates positive ions entering the sheath toward the target to produce sputtering. Sputtering is performed by illuminating up to four individual metal targets in mixed Argon / Oxygen atmosphere by applying -800V (ON) and +5V (OFF) DC supply. The targets are pulsed using a bi-polar waveform of 71.43KHz (14 μs full cycle). The material that is deposited depends on the relative ON time or duty cycle of the targets. The sample reached a maximum temperature of around 80 – 120ºC during the deposition. The Ce:EIG and the individual metal oxides namely Cerium oxide (Ce_2O_3), Europium oxide (Eu_2O_3), Iron oxide (Fe_2O_3) and Gallium oxide (Ga_2O_3) are deposited under these conditions.

The material composition of the as-

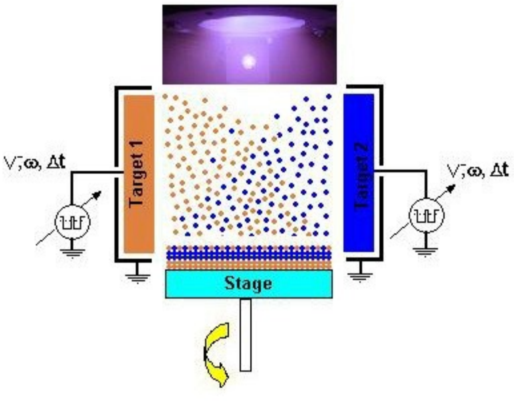

Figure 1. Biased Target Deposition system concept showing two target depositions. In this work, simultaneous sputtering was done from four targets. (Courtesy: 4Wave Inc, VA).

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Table 1: Variation in material composition with respect to target pulse width.

ON time Pulsewidth (in µs, full cycle = 14µs)				**Material Composition**
Ce	Eu	Fe	Ga	
3	5.2	4.9	2	$Ce_{1.3}Eu_{1.7}Fe_3Ga_{1.6}O_{12}$
3	5.2	5.5	1.6	$Ce_1Eu_{2.2}Fe_{3.8}Ga_{0.6}O_{12}$
2	5.5	6	0	$Ce_{0.9}Eu_{2.3}Fe_{4.5}O_{12}$
2	0	0	0	Ce_2O_3
0	12	0	0	Eu_2O_3
0	0	7	0	Fe_2O_3
0	0	0	12	Ga_2O_3

deposited films are analysed by Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) and the individual metal oxides are identified by the X-Ray Diffraction (XRD) patterns and Electron Probe Micro Analysis (EPMA), which was also used to verify the oxygen level in the Ce:EIG.

3 Results and Discussion:

3.1 Chemical Analysis: Table 1 shows the variation in material composition with respect to change in the target ON pulses analysed using LA-ICP-MS. It has been observed that the results are repeatable when deposited under the same conditions and the chemical composition of the films can be altered easily in a predictable way. As a comparison, to vary the film composition using conventional RF sputtering would require different targets.

3.2 X-Ray Diffractions: Figure 2 shows the XRD patterns of the grown films, where it can be observed that the Ce:EIG films deposited using BTD are amorphous while the XRD patterns for the oxides of Cerium, Europium, Iron and Gallium indicate microcrystalline thin film structure [2-5].

3 Conclusion: We have demonstrated BTD to be an effective method to prepare $(CeEu)_3(FeGa)_5O_{12}$ on fused quartz substrates. The LA-ICP-MS results show that the material composition of the samples can be controlled by pulsing targets. The as-deposited individual metal oxide films are microcrystalline and as-deposited Ce:EIG films are amorphous. Currently we are working on a post growth crystallisation procedure of the Ce:EIG films deposited using Biased Target Deposition system.

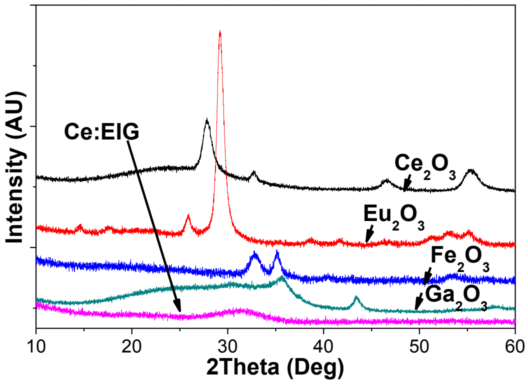

Figure 2. XRD patterns of as-deposited Ce:EIG and the individual metal oxides.

Acknowledgements

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