Pulsed Laser and Sputtering Deposition of Optical Materials

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We used Pulsed Laser Deposition and Sputtering to synthesize advanced materials in the form of thin films with tailored properties. In this presentation, we will mainly focus on two materials, namely calcium-barium niobate (CBN) that show excellent electro-optical properties and vanadium dioxide (VO_2) that presents a reversible insulator-to-metal transition. Capitalizing on our in-depth characterization of such films, we were able to optimize their properties and to explore their use for various applications, including high performance electro-optical waveguide modulators based on CBN films and smart radiator device (SRD) based on VO_2 films for the passive thermal control of microsatellites.

1. Introduction

Innovation in materials science and engineering resides in our ability to design new materials with tailored properties (electrical, optical, magnetic, etc.) by controlling their microstructure. One of the most powerful means to uniquely arrange matter at such scale is to use plasmas due to their unique ability to provide simultaneously a variety of particles such as ions, neutral atoms and radicals. In this presentation, we will focus on the synthesis of two specific materials in the form of thin films, namely calcium-barium niobate (CBN) and vanadium dioxide (VO_2) using Pulsed Laser Deposition (PLD) and sputtering.

2. Results

Calcium barium niobate ($Ca_xBa_{1-x}Nb_2O_6$) in the form of thin film is a promising material for integrated electro-optical (EO) device applications, due to its unique EO properties (EO coefficient of 130 pm/V) and high Curie temperature (above 250°C). We successfully used PLD to grow high quality CBN epitaxial thin films on various substrates (MgO and NSTO). These films show both low surface roughness and out-of-plane lattice parameters comparable to that of CBN bulk material. An advanced patterning method using a nickel hard mask and a chlorine inductively coupled plasma was also developed. Combining PLD grown films and patterning, waveguides with smooth and nearly vertical sidewalls were fabricated and characterized. In addition, highly (001)-oriented CBN thin films were grown on MgO by Radio-Frequency magnetron sputtering. Close-to-bulk film stoichiometry ($Ca_{0.28}Ba_{0.72}Nb_2O_6$) was obtained for an O_2 fraction of 5% in the deposition chamber. At the annealing temperature of 1000ºC, (001) oriented thin films were achieved with lattice parameter in the c-direction and a chemical composition very close to that of the bulk. The refractive index of the films is 2.21 at λ = 630 nm and a strong second harmonic signal can be generated nonlinearly in the films [1]. This overall work represents a significant step towards the integration and the potential use of CBN films for high performance electro-optical waveguide modulators.

Vanadium dioxide (VO_2) is a “smart” material that undergoes a reversible insulator-to-metal transition (IMT), characterized by a dramatic increase of both its conductivity and reflectivity in infrared and terahertz (THz) ranges of wavelengths when the temperature is increased above 68°C. In a series of studies, our group has investigated the physics governing the IMT of VO_2 thin films [2] and explored new application opportunities [3-4]. For example, we demonstrated that by incorporating VO_2 films in an appropriate multilayer structure, it was possible to achieve VO_2-based smart coatings responding to the temperature by adapting their thermal emittance to radiate more heat at high temperature and less at low temperature. This behavior is quite interesting for application as smart radiator device (SRD) for the passive thermal control of microsatellites.

3. References

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