$(Ba_{1-x}Ca_x)(Zr_yTi_{1-y})O_3$ processing by PLD and LIFT

Adrian-Ionut Bercea

National Institute for Laser, Plasma and Radiation Physics, 409 Atomistilor St, RO-077125, Magurele, Romania

Piezoelectric and ferroelectric materials are of great interest to thin film based technologies (few example micro components used in electronics), due to their high dielectric constant and strong piezoelectric response. The most popular piezoelectric material is lead zirconium titanate (PZT) but the high toxicity of lead gives rise to the need for developing new lead-free materials with comparable proprieties.

The studies [1-3] demonstrated the possibility to obtain lead-free $(Ba_{1-x}Ca_x)(Zr_yTi_{1-y})O_3$ or (xBCT- BZT) named (BCTZ) ferroelectric materials with very high dielectric permittivity and piezoelectric coefficients, thus opening the way to competitive devices free of toxic elements.

In the first part of this work, BCTZ thin films with different compositions (x= 45%, x = 50% and x = 55%), were deposited using pulsed laser deposition (PLD) with an ArF excimer laser, on platinum coated silicon substrates in a reactive environment (oxygen). The properties of the BCTZ thin films i.e. the optical and electrical properties, thickness, roughness, and dielectric constant were investigated by X-ray diffraction, atomic force microscopy (AFM), scanning electron microscopy (SEM) and spectroscopic ellipsometry (SE).

The films deposited on Pt/Si substrates are polycrystalline and show a (110) and (111) orientation. AFM evidenced a uniform surface microstructure with small roughness.

Using SE, the optical behavior and band gap characteristics were determined. A high refractive index and low extinction coefficient for a large spectrum of wavelength ($n>2$ and $k<10^{-4}$ for near UV-VIS-near IR) was found. The thickness and roughness of samples determined by SE were in good agreement with the SEM and AFM results.

Dielectric spectroscopy measurements were carried out at room temperature and at different frequency values. The measured dielectric values of the BCTZ samples (relative permittivity of about 2000 and tangent loss ~ 3% at a frequency of 10 KHz) were comparable with the values reported for the PZT thin films.

In the second part of this work, BCTZ thin films were also deposited by PLD on a quartz substrate with the aim of producing donor layers for laser induced forward transfer (LIFT) experiments, further expanding the possible applications of this material in electronics.

LIFT is a technique that allows the transfer of a material on a receiver, with high precision, in the desired place and with the shape of the pixel depending only on the shape of the irradiated area. The BCTZ pixels were transferred on a platinum coated receiver substrate by using an ArF excimer laser. During the LIFT experiments the donor layer and the receiver were placed in contact. The best results were obtained when using a laser fluence of 0.1 J/cm^2 corresponding to a thickness of approximately 400 nm of the BCTZ layer, as confirmed by AFM and SEM.

In conclusion, BCTZ thin films show great potential in replacing PZT in applications where materials with high dielectric values are needed. Although the deposition of BCTZ thin films by PLD and LIFT is at its infancy and further investigation are still needed until it can fully replace PZT, first results obtained in this work are very promising and make it a good candidate.

References:

[1] W. Liu and X. Ren, Phys. Rev. Lett. 103, 257602 (2009).

[2] M. C. Ehmke, S. N. Ehrlich, J. E. Blendell and K. J. Bowman, J. Appl. Phys. 111, 124110 (2012).

[3] D. Damjanovic, A. Biancoli, L. Batooli, A. Vahabzadeh and J. Trodahl, Appl. Phys. Lett. 100, 192907 (2012).