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Ferroelectric thin film nanostructures by laser ablation

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Multiferroic composite materials are of great interest for technological applications due to the magnetoelectric coupling effect, by which an electric (magnetic) field may be used to control the magnetization (polarization). Being insulators, these materials find application in low power energy efficient electronics, due to their low joule heating effect. In the form of thin films the magnetoelectric coupling can be considerably increased by strain engineering, by controlling the mechanical interaction and lattice mismatch across the substrate/film interface. Different deposition methods are available to produce the composite structures, with pulsed laser ablation in a background gas being noteworthy for its simplicity and precise control of the deposition parameters, namely the target-substrate distance. However, the optimization of the deposition parameters to obtain films with the desired microstructure is still performed on a trial and error basis, justifying the modelling of the ablation plume dynamics with the background gas in order to try and predict the resulting film structure. In this study, multiferroic composite systems were produced by pulsed laser ablation. The systems studied consisted of lithium niobate ($LiNbO_3$, ferroelectric) thin films deposited on Si and Si\Pt substrates, and bi-layer $LiNbO_3$ \ $CoFe_2O_4$ (cobalt ferrite, ferromagnetic) thin films deposited on Si\Pt substrates. $LiNbO_3$ possesses high piezoelectric and electro-optic properties while $CoFe_2O_4$ has high magnetostriction, saturation magnetization, coercivity and magnetocrystalline anisotropy. The films were deposited at 650 ºC and at room temperature, with the latter submitted to an annealing procedure post-deposition. Different combinations of pressure and target-substrate distance were used. The resulting films were studied using scanning electron microscopy and focused ion beam. The film thickness and grain size generally increased with deposition time. The ablation plume dynamics in a background gas were modelled according to a blast wave model [1], providing an equation for the propagation of the shock front and allowing the determination of a pressure-distance relationship [2]. A phase diagram of the zones of Thornton's diagram [3] was built for both deposition temperatures, predicting the resulting zone structure for a given pressure and distance. The Thornton's zones observed in the samples indicate the existence of an optimal value of deposition parameters, striking a balance between film crystallinity and adequate microstructure, but without increasing the thickness to the extent of inhibiting surface diffusion or inducing structure relaxation in the films.

Scientific Area

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