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Development of lead-free perovskite ceramics with tunable optical and magnetic properties at room temperature

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In recent days, there have been extensive interests in developing transparent lead free ceramics as the alternatives to toxic lead-based ceramics. Transparent ceramics are fundamental to applications in lasers, sensors, IR optics, and transducers. In this work, La doped sodium potassium niobate based perovskite (ABO_3) ceramics, more specifically [{(1-x)($K_{0.5}Na_{0.5}$)xLa} $Nb_{(1-2x/5)}O_3$] ($0 < x < 0.1$) have been developed. Among these, the material at 5 mol% La doping appears with an unusually high density up to 99% of its theoretical value, while densities of the parent $K_{0.5}N_{0.5}NbO_3$ (KNN) ceramics typically only reach ~ 70 to 89% of the theoretical limit. The obtained ceramics display distinctive properties. The developed ceramics in their circular disk form with thickness 0.8 mm show certain transparency and most importantly, this transparency is electrically tunable up to 52%, which is quite remarkable and makes it suitable for optical device applications such as optical filters, sensors and smart windows. Moreover, under UV illumination, the ceramics display a photo-darkening which is reported for the first time for KNN based ceramics. The photodarkening phenomenon is reversible and is time-temperature-transformation phenomena. Additionally, the material shows extraordinary sensitivity of its magnetic and optical properties to UV irradiation. These materials transform to a metastable and reversible state that exhibits graded color change from clear to deep blue and shows considerable increase of magnetization under UV exposure. This feature makes the developed ceramics attractive for the fabrication of new generation devices; e.g. powerless UV detectors as well as protectors, since it absorbs UV completely. Based on first-principles calculations, we developed a model that attributes these observations to the occupancy of La fxyz orbitals induced by UV excitations. The model also indicates that UV induced absorption in the visible range and magnetism are related.

Biography

Santiranjan Shannigrahi is currently working as a senior scientist in the Institute of Materials Research and Engineering, A*STAR (Agency for Science, Technology and Research), Singapore. He is also associated with National University of Singapore as an adjunct Assoc. professor. His research expertise include design, fabrication and characterization of different types of advanced smart materials (mainly oxide electric and magnetic ceramics in their various form factor) for UV, electro-optic, magneto-optic sensing as well as high frequency electromagnetic interference (EMI) shielding applications. He has published more than 95 papers in referred international journals and 10 patents among which 4 technologies have been licensed. He is a regular reviewer of University Ph.D. thesis as well as several international journals including Nature Nanotechnology, Jl. of Appl. Phys., Appl. Phys. Lett., Ceramics International, etc. He is a member of Materials Research Society-Singapore (MRS-S) and served as one of the symposium chairperson in the International Conference on Materials for Advanced technologies (ICMAT) 2017.

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