Negative refraction in Cr doped Indium Oxide in the mid-infrared region

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The magnetic semiconductor , Indium Oxide doped with Chromium ($In_{2-x}Cr_xO_{3-\delta}$), is fabricated on Si substrate by DC-RF magnetron sputtering deposition technique at room temperature with low stoichiometric oxygen deficiency, δ [10^{-4}-10^{-2}] , a carrier concentration of $10^{22}cm^{-3}$,and doping concentration of x=3% . These isotropic films are uniformly homogenous and ferromagnetic at room temperature. The sputtered samples are grown using two targets - a d.c. magnetron sputtering gun for the Cr and an r.f. magnetron gun for the In_2O_3. The sputtering is performed in an Ar atmosphere of around 24 mT, while the oxygen concentration can be enhanced by the inclusion of a small partial pressure of oxygen at around ~$0.3x10^{-3}$ mT. The structural study of the films were done by using the X-ray diffraction, Energy Dispersive Spectroscopy. The magnetic characterization was performed by Quantum Design Superconducting Quantum Interference Device (SQUID) magnetometer (MPSM XL and SVSM), and the optical properties of the films were investigated by measuring the relative transmission using Fourier Transformation Infrared Spectroscopy (FTIR) VERTEX 70-BRUKER. Based on the method of the transmitted beam shifting, the films were shown, experimentally, to demonstrate negative refraction in the mid-infrared region by measuring. Here, we introduced the blade method as it is described in A. Boltasseva's paper [Proc. Natl. Acad. Sci. USA 5 June 2012: 8834-8838.] and measured the relative transmission for the angles 5 to 35 degrees.