PLD 法による CaF_2 と BaF_2 基板における Bi_2Te_3 薄膜成長

Investigation on the growth of Bi_2Te_3 thin films on CaF_2 and BaF_2 substrates by pulsed laser deposition

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Topological superconductivity and half integer quantum Hall states are just a few examples of topological states that can be studied on the surface of topological insulators. Owing to proximity effects between TIs and superconductors or ferromagnets, these effects have been studied for $Bi_2Se_3/Bi_2Sr_2CaCu_2O_{8+\delta}$ or Bi_2Te_3/YIG. [1, 2]. High-quality Bi_2Te_3 thin film are therefore of utmost importance though their availability is limited due to difficulties in materials synthesis. In this study, we have investigated the thermodynamic growth conditions of Bi_2Te_3 thin films on the alkaline earth fluoride substrate using pulsed laser deposition.

For the growth of Bi_2Te_3 thin films, we used (111) CaF_2 and BaF_2 substrates. As a target material, we used commercially available $BiTe_{10}$, sintered into a pellet. In order to maintain reproducibility, we mechanically polished the pellet surface after every 30th deposition. Lattice constants and stoichiometries of the grown Bi_2Te_3 films are characterized by using x-ray diffraction, inductivity coupled plasma analysis, and transmission electron microscopy. Using a KrF excimer laser with a wavelength of 248 nm and an energy density of 1.0 J/cm^2 we deposited Bi_2Te_3 thin films at 20 Hz repetition rate. In order to improve the crystal quality of the Bi_2Te_3 thin films, a series of films were deposited at temperatures ranging from 220 to 500℃. The ablation was performed under Ar pressure ranging from 1 mTorr to 5 Torr. We find optimal synthesis temperatures for Bi_2Te_3 thin films on CaF_2 and BaF_2 are 320℃ and 360℃, respectively. Minimizing the influence by loss of tellurium while maintaining sufficiently high synthesis temperatures is the utmost requirement for the synthesis of Bi_2Te_3 thin films. We approached this problem by monotonically varying the synthesis temperature from a lower to a higher value during the synthesis process. We find a significant enhancement of crystalline quality when the starting and end temperatures are 320/440℃ for Bi_2Te_3 thin films on CaF_2 and 380/440℃ for BaF_2 substrates. While this result indicates superior crystalline quality of Bi_2Te_3 thin films over constant temperature growth methods, further investigations are required in order to minimize the droplet densities driven by excessive Te precipitates.

This work was supported by JSPS KAKENHI Grant Numbers JP20H02563 and JP20H05670.

[1] E. Wang *et al.*, Nature phys. **9**, 621 (2013). [2] V. M. Pereira *et al.*, Phys. Rev. Mater. **4**, 064202 (2020).