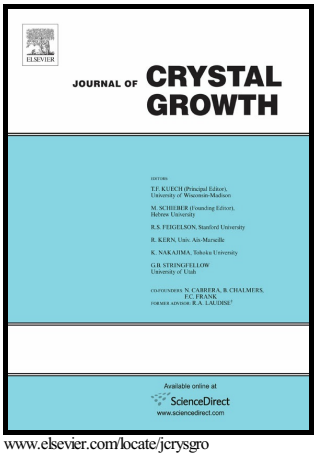

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Growth of Bi_2Te_3 films and other phases of Bi-Te system by MOVPE

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Abstract

We have deposited films of Bi-Te system by atmospheric pressure MOVPE on (0001) Al_2O_3 substrates with thin ZnTe or thick GaN buffer layers at different temperatures and Te/Bi ratio in the vapor phase. As-grown films were studied by X-ray diffractometry, SEM microscopy and Raman spectroscopy. To determine the elemental composition of the films, an energy dispersive spectrometer was used. Single-phase films of Bi_2Te_3, Bi_4Te_5, BiTe, $Bi_{10}Te_9$, Bi_4Te_3, Bi_3Te_2 have been grown and growth parameter ranges for obtaining different phases were defined. It was found that under the same growth condition different phases of the Bi-Te system realize depending on the film's thickness. Thus, when growing of Bi_2Te_3 films by MOCVD method the careful control of the phase composition is required.

Keywords: A1. Solid solutions, A1. X-ray diffraction, A3. Metalorganic vapor phase epitaxy, B1. Bismuth compounds, B2. Topological insulators

1. Introduction

Recently thin films of bismuth telluride have been intensively investigated as a topological insulator (TI), a new material of condensed matter physics [1]. Moreover, versatile TI saturable absorbers, including those on the base of Bi_2Te_3 nanoparticles, have been employed to passively mode-lock the fiber lasers at telecommunication wavelength regime [2, 3, 4]. For the latter application, thin films are needed and the high bulk resistance of TI is likely not required. Various deposition techniques, such as sputtering [5], thermal evaporation [6], electrodeposition [7], pulsed laser deposition [8], molecular beam epitaxy [9, 10] and metalorganic chemical vapor epitaxy [11, 12] have been developed to grow thin Bi_2Te_3 films on different substrates.

Today to best of our knowledge there is no good quality phase diagram of the Bi-Te system, which would include different phases of the homologous series $m\mathrm{Bi}_2{\cdot}n\mathrm{Bi}_2\mathrm{Te}_3$, where m and n are numbers of Bi_2 and Bi_2Te_3 blocks per unit cell [13, 14, 15]. When depositing thin films of Bi_2Te_3 other phases of the system Bi-Te may appear. The authors of the paper [16] have grown films with Bi_4Te_3 phase in MBE system at the flows ratio of Te/Bi lower than 17. Caha *et.al* [17] observed the growth of BiTe phase on BaF_2 substrates.

In this paper we report the observation of many transition phases from Bi_2Te_3 to Bi_2 when the growth temperature and the Te/Bi ratio in vapor phase are varied upon deposition of thin films in $BiMe_3$ -Et_2Te -H_2 system. We have found that the phases Bi_2Te_3 (m=0, n=3,) Bi_4Te_5 (m=1, n=5), $Bi_{10}Te_9$ (m=6, n=9), BiTe (m=1, n=2), Bi_4Te_3 (m=3, n=3), Bi_3Te_2 (m=5, n=4) and Bi_2 (m=3, n=0) of infinitive adaptive series $m\mathrm{Bi}_2{\cdot}n\mathrm{Bi}_2\mathrm{Te}_3$ may be obtained. The formation of Bi_4Te_5, BiTe, Bi_4Te_3 and Bi_3Te_2 phases occurs over a wide range of Te/Bi ratio in the vapor phase at low temperatures. Thus, it is essential to identify and control the emergence of other phases of bismuth telluride when growing Bi_2Te_3. One should use with caution such a technological method as a low temperature deposition of films to suppress the free bonds of the substrate.

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