Electronic and spin structure of the topological insulator $Bi_2Te_{2.4}Se_{0.6}$

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High-resolution spin- and angle-resolved photoemission spectroscopy measurements were performed on the three-dimensional topological insulator $Bi_2Te_{2.4}Se_{0.6}$, which is characterized by enhanced thermoelectric properties. The Fermi level position is found to be located in the bulk energy gap independent of temperature and it is stable over a long time. Spin textures in the Dirac-cone state at energies above and below the Dirac point as well as in the Rashba-type valence band surface state are observed in agreement with theoretical prediction. The calculations of the surface electronic structure demonstrate that the fractional stoichiometry induced disorder within the Te/Se sublattice does not influence the Dirac-cone state dispersion. In spite of relatively high resistivity, temperature dependence of conductivity shows a weak metallic behavior that could explain the effective thermoelectric properties of the $Bi_2Te_{2.4}Se_{0.6}$ compound with the in-plane Seebeck coefficient reaching $-330\ \mu V/K$ at room temperature.

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I. INTRODUCTION

Rapid development of spintronics aimed at creation of spin-current devices stimulates intense investigations of systems where nondissipative spin transport, spin-current control, and separation of electrons with different spin orientation are possible. The very promising materials in this respect are topological insulators with unique spin electronic structure. Topological insulators (TIs) are characterized by an insulating energy gap in the bulk and the gapless spin-polarized metallic surface states with linear Dirac-cone-like dispersion in the energy-momentum space with spin of electron locked perpendicular to its momentum (see, for instance, Refs. [1–9]). Owing to the opposite spin orientation for opposite sign of momentum, the topological surface states (TSSs) are protected from backscattering resulting in spin currents with reduced dissipation.

The electronic and spin structures of the surface states for a wide class of TIs are well studied by spin- and angle-resolved photoemission spectroscopy (SARPES), in the first instance, for the Bi_2Se_3 and Bi_2Te_3 compounds [5–7]. These prototypical compounds are characterized by a relatively wide bulk energy gap (∼0.3 eV for Bi_2Se_3 and ∼0.15 eV for Bi_2Te_3) and a single Dirac cone of the topological surface state at the $\bar{\Gamma}$ point. Typically, they are *n*-type compounds with the Dirac point located inside the bulk energy gap at energies of 0.1–0.4 eV below the Fermi level [1,5–7,10]. Such features of the electronic structure are mainly determined by the Se vacancies in Bi_2Se_3 and Bi-Te antisite defects in Bi_2Te_3 [7,11]. Investigations of the Dirac-cone spin structure in these topological insulators confirmed its antisymmetric spin polarization with respect to $k_\parallel$ [7,12,13].

Recently, it was demonstrated that ternary compounds based on binary TIs show a rich variety of TSSs [3,8,9,14–17] including buried TSSs [3,8] and occupied and unoccupied TSSs in local energy gaps [8,18,19]. Some of these compounds possess extraordinary wide fundamental energy gaps and nearly ideal Dirac cones [8,15]. It was also shown that the modification of such features of the electronic structure as the position of the Dirac point relative to the Fermi level and to the bulk valence band edge, the absence of bulk conduction band states at the Fermi level, etc., can be efficiently controlled by means of a variation of the third component concentration [1,5–7,9,20] or by diluted metal atom doping [7].

The ternary topological compounds Bi_2Se_2Te and Bi_2Te_2Se were studied by SARPES [20], ARPES with circular light polarization [21], and angle-resolved two-photon photoemission [18] with analysis of their spin texture. In contrast to the binary compounds, Bi_2Te_2Se is characterized by a higher insulating gap resistivity [11,22]. In such compounds, the central Te (Se) layer in Bi_2Te_3 (Bi_2Se_3) is substituted for the Se (Te) layer. It was shown [9] that the change of the concentration of Bi and Se in ternary Bi-Te-Se TIs leads to the shift of both the Fermi level position into the bulk energy gap and the position of the Dirac point relative to the valence band, which result in the change of the surface-state contribution to the conductivity. Ternary Bi-Te-Se TIs exhibit a temperature-dependent

