I. POLARIZED NEUTRON REFLECTOMETRY

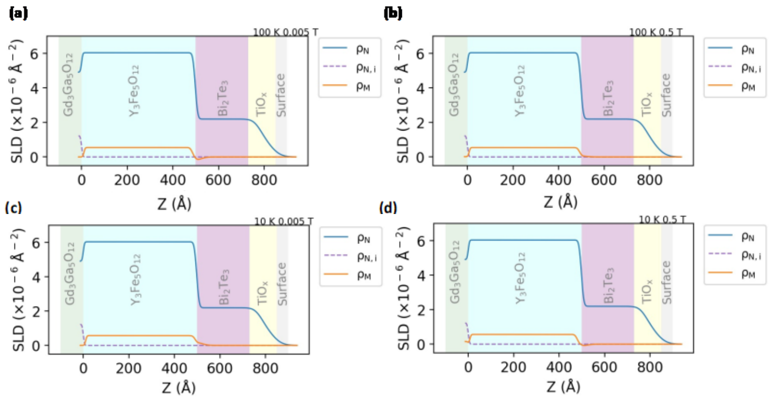

FIG 1. Displayed are the model profile for nuclear and magnetic scattering length density for measurements taken at 10 K and 100 K with an in-plane bias field (a) 100 K & 0.005 T, (b) 100 K & 0.5 T, (c) 10 K & 0.005 T, and (d) 10 K & 0.5 T.

To investigate the quality of the BT/YIG interface and the presence of a possible magnetic proximity effect, we performed PNR using the Magnetism Reflectometer at the Spallation Neutron Source at Oak Ridge National Laboratory. The depth profiles of the nuclear (real ρ_N and imaginary $\rho_{N,i}$) and magnetic (ρ_M) scattering length densities (furthermore referred to as the nuclear SLD and magnetic SLD respectively) of the heterostructure at remanence (0.005 T) and saturation (0.5 T) are shown in Figure 1. The nuclear SLD is determined by the density and composition of the scattering material, while the magnetic SLD is directly related to the net in-plane magnetization. The sharp transition in the nuclear SLD at the YIG/Bi_2Te_3 interface confirms the bilayer's high-quality interface. The modeled proximity-induced magnetization at the YIG/Bi_2Te_3 interface from magnetic SLD shows the induced magnetization in the interfacial TI is confined to an extremely thin layer (< 1.5 nm) with very low magnetization.

II. LOW TEMPERATURE MAGNETOTRANSPORT MEASUREMENTS

We conducted comprehensive transport property investigations on Bi_2Te_3 using temperature and magnetic field-dependent measurements in a BT/YIG bilayer with van der Pauw electrode geometry. The ordinary Hall effect demonstrated n-type transport, evidenced by decreasing electron carrier concentration at lower temperatures, suggestive of defect states near the Fermi level, likely caused by Te vacancies and TeBi antisite defects (Figure 3(b)). Enhanced mobility at reduced temperatures may result from diminished electron-phonon scattering and multi-band conduction effects. The longitudinal sheet resistivity displayed typical metallic characteristics of a highly doped degenerate semiconductor, increasing at low temperatures possibly due to electron-electron interactions in two dimensions (Figure 2(d)). Magnetoresistance measurements between 3.5 K and 20 K (Figure 2(e)) revealed quantum interference effects such as weak-antilocalization (WAL) cusps below 15 K, transitioning to a quadratic-like dependence at higher temperatures. Below 15 K the magnetoresistance curves show a linear, non-saturating magnetic

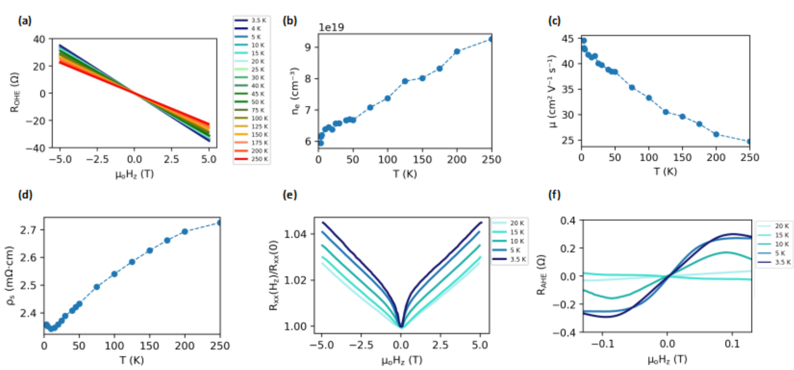

FIG 2. Magnetotransport measurements for the 250°C grown Bi_2Te_3 on YIG/GGG. a) Ordinary Hall effect component of the transverse resistance with an out-of-plane magnetic field. (b) Extracted electron carrier concentration as a function of temperature. (c) Calculated carrier mobility as a function of temperature. (d) Longitudinal sheet resistivity in the absence of applied magnetic field. (e) Longitudinal magnetoresistance. (f) Transverse resistance with the ordinary Hall effect contribution removed.

field dependence above ~0.5 T. These WAL cusps, indicative of high conductivity and helical polarization of the topological surface states (TSS), confirm the presence of TSS in Bi_2Te_3 films.

The study further identified ordinary and anomalous Hall effects (OHE and AHE). At low temperatures, a distinct, saturating transverse resistance suggestive of AHE was observed below 15 K, intensifying as temperature decreased (Figure 2(f)). This behavior typically correlates with the perpendicular component of the YIG magnetization. The anomalous Hall effect magnitude in our $Bi_2Te_3/Y_3Fe_5O_{12}$ bilayer, R_{AHE} = 0.30 Ω, significantly exceeded previous R_{AHE} ~0.015 Ω reported for MBE-grown Bi_2Te_3 on YIG/GGG, highlighting potential differences in interfacial and contact quality or growth conditions. This investigation provides crucial insights into the magnetic and electronic interplays in TI materials, advancing the understanding of complex transport phenomena in Bi_2Te_3 films on YIG.

III. LOW TEMPERATURE MAGNETIZATION DYNAMICS

We conducted temperature-dependent ferromagnetic resonance (FMR) measurements at 8 GHz on both crystalline BT/YIG (BT T_{growth}=250°C) and amorphous BT/YIG (BT T_{growth}=25°C) bilayers. At low temperatures, the FMR lin ewidth significantly broadened, particularly evident at 10 K where it was approximately tenfold greater in BT/YIG than in the reference YIG film (Figures 3(a) and (b)). This broadening, indicative of dominant spin pumping, was influenced by the topological surface states (TSS) in the TI. Additionally, we observed a substantial induced in-plane magnetic anisotropy in the BT/YIG bilayer, demonstrated by a uniform shift of the FMR mode to a lower resonance field (Figures 3(a), (c), and (d)). This finding contrasts with previously reported mixed anisotropies and supports the hypothesis that spins pumped into the TSS via FMR are constrained to the plane when TSS dominate. The exchange coupling across the YIG/TI interface compels YIG spins to align with those in the TI, enhancing damping and creating in-plane anisotropy. Furthermore, the differential resonance field curve between YIG/Bi_2Te_3 and the reference YIG film displayed a significant negative shift with a strong temperature dependence below ~30 K. This shift is linked to the suppression of TI bulk conduction and the strong presence of TSS, elucidating the observed enhancement in damping at low temperatures. Previous studies, such as those involving YIG/Bi_2Se_3, did not report such pronounced temperature-dependent shifts in resonance fields. In summary, our findings demonstrate significant alterations in YIG magnetization dynamics, driven by proximity to the TI film free from confounding interfacial effects. These include enhanced spin pumping at low temperatures and pronounced in-plane anisotropy with a marked temperature dependency.

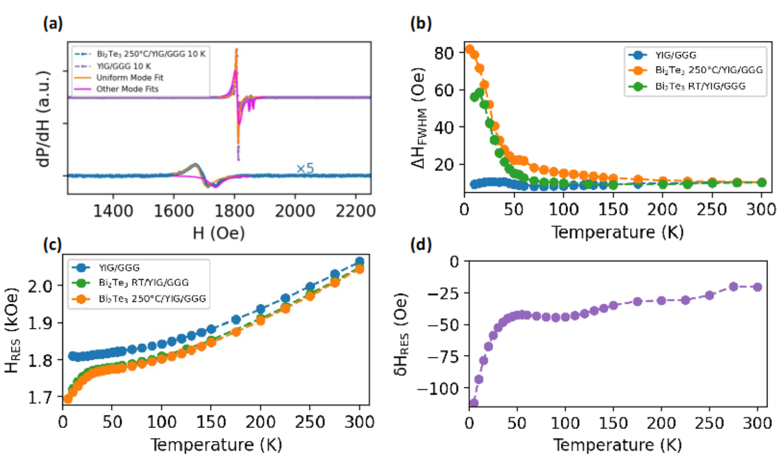

FIG 3. (a) Representative FMR spectra at 8 GHz at 10 K of the 250°C grown BT/YIG/GGG film and YIG/GGG reference sample. The uniform mode and additional spin wave modes are both fitted with a Lorentzian. (b) The uniform FMR mode full-width half-maximum linewidth at 8 GHz as a function of temperature and (c) The uniform FMR mode resonance field at 8 GHz as a function of temperature for YIG/GGG reference film and sputtered Bi_2Te_3 films deposited at 250°C or room temperature on the YIG/GGG substrate. (d) The difference curve of the uniform FMR mode resonance field at 8 GHz for the YIG film/GGG reference sample and BT/YIG /GGG substrate deposited at 250°C.