Electronic Supplementary Information

Intrinsic Quantum Spin Hall and Anomalous Hall Effect in $h$-Sb/Bi Epitaxial Growth on Ferromagnetic MnO$_2$ Monolayer

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Figure S1. Spin polarized band structure of (a) $h$-Sb@MnO$_2$ and (b) $h$-Bi@MnO$_2$ with blue and red colors representing spin up and spin down channels, respectively. The Fermi level is shifted to 0 eV. One clearly sees that Dirac points at the K (–K) decrease from 0.96 and 0.74 eV, respectively.

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Figure S2. Variation of formation energy (see main text) with respect to absorbing H atoms.

Figure S3. Band structure (with SOC) of $h$-Sb@MnO$_2$-4H with circle size denoting Sb-$p_x$,$p_y$ contribution.
Figure S4. Band structure calculated using the tight binding model (see main text for the Hamiltonian). (a) Only hopping integral. $t = 0.91 \text{ eV}$, $M_{\text{ex}} = \lambda_{\text{in}} = \lambda_{\text{R}} = 0$. (b) Hopping integral and magnetic exchange. $t = 0.91 \text{ eV}$, $M_{\text{ex}} = 0.03 \text{ eV}$, $\lambda_{\text{in}} = \lambda_{\text{R}} = 0$. (c) Hopping integral, magnetic exchange, and intrinsic SOC. $t = 0.91 \text{ eV}$, $M_{\text{ex}} = 0.03 \text{ eV}$, $\lambda_{\text{in}} = 0.016 \text{ eV}$, $\lambda_{\text{R}} = 0$. (d) Hopping integral, magnetic exchange, intrinsic and Rashba SOC. $t = 0.91 \text{ eV}$, $M_{\text{ex}} = 0.03 \text{ eV}$, $\lambda_{\text{in}} = 0.016 \text{ eV}$, $\lambda_{\text{R}} = 0.027 \text{ eV}$. Different colors in (b)-(d) represent $\langle \hat{s}_z \rangle$. (e) In-plane spin texture of four bands. We observe that the spin textures at the K (and $-\text{K}$) calculated from the tight binding model have similar behavior with those calculated from DFT, validating our tight binding model.
Figure S5. (a) Berry curvature and (b) spin Berry curvature between CB and CB+1 [denoted as $\Omega_{CB}(k)$ and $\Omega^s_{CB}(k)$] of $h$-Sb@MnO$_2$-4H.

Figure S6. (a) $\Omega_{CB}(k)$ and (b) $\Omega^s_{CB}(k)$ of $h$-Bi@MnO$_2$-4H.