Determination of polarity orientation in polar metals *via* nonlinear Hall response

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In typical ferroelectrics, which are polar insulators, switching of polarity is immediately manifested in a polarization switching current. By contrast, in a polar metal or semimetal, a corresponding experimental response is missing. In this work, we theoretically propose that the nonlinear Hall effect can offer a way to detect the polarization direction and polarization switching in polar metals and semimetals, as well as in narrow bandgap ferroelectric semiconductors, which often show conducting behavior due to the presence of defects and impurities. We particularly focus on T_d-$MoTe_2$, which is a non-centrosymmetric Weyl semimetal with multiple type-II Weyl nodes near the Fermi level. These type-II Weyl nodes inherit large sources of asymmetric Berry curvature, which yield a non-vanishing Berry curvature dipole moment (BCDM) tensor as first proposed by Sodemann and Fu [Phys. Rev. Lett. 115, 216806 (2015)], and calculated for the case of bulk T_d-$MoTe_2$ by Zhang, Sun, and Yan [Phys. Rev. B 97, 041101 (2018)]. Building upon these previous works, here we investigate the BCDM and the resulting nonlinear Hall response in T_d-$MoTe_2$ as well as in some other polar (semi)metals and narrow bandgap semiconductors, and show that the reversal of polarity is always manifested through the reversal of the nonlinear Hall current, which can be experimentally detected. We hope that our theoretical proposal sparks experimental efforts to use the nonlinear Hall effect for the detection of polarization switching in polar metals and semimetals.