# Circular dichroism in $Cr_2Ge_2Te_6$ valence bands

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2D magnetism is an active field of research because of its wide range of potential applications. Most studies deal with magneto optical properties, magnetic imaging or magnetic and electrical transport [1]. We focus on understanding the underlying mechanism of magnetism through circular dichroic angle resolved photoemission (CD-ARPES). CD-ARPES can also be used to understand additional details in band structure due to its relation with orbital angular momentum (OAM) through the dipole selection rules ($\Delta m_l = \pm 1$).

$Cr_2Ge_2Te_6$ (CGT) is a ferromagnetic semiconductor with an indirect band gap of 0.4 eV. The bulk Curie temperature ($T_C$) is 65 K [2]. CGT contains large Te atoms (Z=52), therefore spin momentum locked splittings, Weyl nodes and anticrossings are expected due to the combination of ferromagnetism and spin orbit coupling. We performed light polarization dependent, photon energy dependent, and temperature dependent ARPES on cleaved bulk samples of CGT. We observed rich photon energy dependent CD textures as shown in Fig.1 (a) and (b). We could also see a clear change in intensity below and above Cr 3p edge, which is likely related to the combination of matrix element effects and perpendicular momentum dispersion. In agreement with [2], we observed CD intensity redistribution above and below $T_C$ (shown in Figure 1 (b) and (c)), even though we were averaging signals from both spin up and spin down domains. These measurements were taken at the PHELIX beamline at SOLARIS synchrotron.

These results can be understood by analyzing the angular part of the transition matrix element, which has a light polarization dependence [3], $\langle f|P_\alpha^q|i\rangle = \delta(m_s m_{s'})\langle R_{n'l'}|r|R_{nl}\rangle \sum_{l,l',p} e_\alpha^q \langle l', m_{l'}|C_p|l, m_l\rangle$. The circular light, used for the dichroic measurements, couple with the OAM of the bands and only the allowed dipole transitions occur. At an intermediate level, one can consider the scattering state for the final state [4], while the full description of the process can be done within the one-step model, where multiple scattering is considered [5]. It is important to consider the details of experimental geometry, such as the sample orientation with respect to the light incident direction, to meaningfully compare the experimental results with calculated intensities. Our results can be further used for understanding Berry curvature of the bands [6], which enters the quantum transport equation and controls the topological properties.

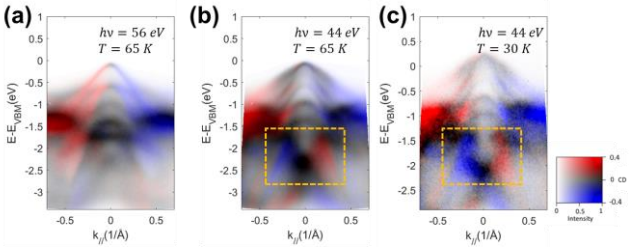


Fig. 1. CD spectra from cleaved bulk CGT. Special colormap used is shown at the right bottom. Each map is made from two spectra measured with LCP and RCP light and CD is calculated as $(C_+-C_-)/(C_++C_-)$.

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