XMCD, STM/STS, and AFM/KPFM study on layered ferromagnet Fe_3GeTe_2 surface

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Atomic and molecular magnets are gaining attention as new solid-state quantum bit materials. It is desirable to have a substrate that electronically decouples from the conducting electrons to stabilize quantum spins while maintaining magnetic coupling. Therefore, we focused on the atomic layer ferromagnet of Fe_3GeTe_2 (FGT), in which chalcogen layers sandwich one honeycomb lattice Fe monolayer, leading to the cleavage between Te layers via weak van der Waals interaction. FGT atomic layer ferromagnets have the highest Curie temperature (approximately 200 K), and the detached surface is expected to weaken chemical bonding with adsorbates [1].

In this study, we evaluated FGT substrates using (1) X-ray magnetic circular dichroism (XMCD), (2) scanning tunneling microscopy/scanning tunneling spectroscopy (STM/STS), and (3) atomic force microscopy/Kelvin probe force microscopy (AFM/KPFM). We investigated the usefulness of FGT substrates for quantum bit substrates using these three research methods.

(1) FGT samples cleaved in an ultrahigh vacuum (UHV) condition (4.7×10^{-7} Pa) were subjected to XMCD measurements at low temperature (T_{sample} = 6.5 K). While applying a magnetic field within the sample plane and perpendicular to the sample surface using a superconducting coil (maximum magnetic field ±5 T), soft X-rays were irradiated to match the absorption edges of Fe, Ge, and Te. We report the magnetic properties of FGT samples.

(2) STM/STS measurements were conducted at a temperature of T_{sample} = 78 K on FGT samples cleaved under UHV. We report atomic images of the cleaved FGT surface and STS measurements.

(3) The FGT samples cleaved in air using Scotch tape were observed using AFM. A wide atomic terrace exceeding 3000 nm was confirmed. However, it was also confirmed that there are terraces with a diameter of approximately 100 nm with a depth of 2-3 nm, which seems to be a large step, but this could indicate only a few atomic steps since the thickness of FGT monolayer is approximately 0.9 nm. From the KPFM images, it was found that the terraces have a work function of about 0.6 eV lower than the flat FGT surface. There was no difference in work function between the terraces.

[1] Yang et al., 2D Mater. 9, (2022) 025022.