Growth of ultrathin MnTe monolayer films on Fe(001) utilizing STM/STS combined with DFT

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Low-dimensional metallic materials epitaxially grown exhibit distinct properties from bulk materials. It is widely known that Mn deposited on Fe(001) exhibits interlayer antiferromagnetism, and recently, it has been predicted that MnTe thin films also demonstrate a magnetic phenomenon called Altermagnetism [1][2]. In this study, we explored the possibility of realizing Mn monolayers without alloying or mixing using the chalcogen element Te. Te and Mn monolayer films were stacked on Fe(001) substrates, and atomic structures were investigated using ultrahigh vacuum scanning tunneling microscopy (UHV-STM). Electron structure measurements were conducted using scanning tunneling spectroscopy (STS) to identify the alloying between Mn, Te, and Fe.

When Te (purity 99.9999%) was deposited to a thickness of 134 pm on a cleaned bcc-Fe(001) whisker at room temperature, monolayer-height Te nanoislands were observed on the Fe(001) surface. The deposited samples were subsequently post-annealed at temperatures ~611 K. STM measurements revealed island growth with increasing post-annealing temperature. The observed Te islands had a height of approximately 160 pm and were found to have a bcc structure. STS measurements showed local density of states (LDOS) peaks of the Te film at positions near the Fermi level at -1.1 eV, -0.3 eV, +0.7 eV, and +1.3 eV.

From these results, it was determined how much Te needed to be deposited on the Fe surface to form a certain number of layers. Accordingly, Te was deposited to a thickness of 240 pm and post-annealed at 611 K, resulting in the creation of exactly one monolayer (1 ML) of Te film on the Fe(001) surface. Subsequently, Mn was deposited onto the Te film at room temperature to a thickness of 46 pm, without thermal diffusion, resulting in numerous islands of Mn being observed (approximately 0.35 MLs of Mn). From the height histogram of the STM shape image, it was found that about 80% of Mn showed heterogeneous alloying. The remaining 20% of Mn formed Mn islands (approximately 160 pm) on the Te monolayer. The Te terraces and Mn islands showed differences in dI/dV maps. Normalized dI/dV curves showed an LDOS peak at +1.3 eV for both Te regions and Mn islands on Te, with Te exhibiting higher intensity.

References:

[1] Yamada, et al., Surf. Sci. 516, 179–190 (2002). [2] Šmejkal, *et al.*,. Phys. Rev. X 12, 040501 (2022).