Anisotropic charge transport in $Ti_3C_2T_x$ flakes probed by C-AFM

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MXenes are a family of two-dimensional carbides and nitrides, synthesized for the first time in 2011. Their high conductivity and high surface area makes them attractive for applications such as EMI shielding or gas sensing. For now, the electronic transport in MXenes has been mostly studied in films consisting of randomly stacked monocrystalline flakes with various thicknesses. It becomes clear that the intra-flake and inter-flake transport phenomena should be understood separately [1]. In this context, the present work investigates charge transport in single flakes of $Ti_3C_2T_x$, the most known MXene to date. More specifically, the goal is to measure the resistivity of single crystal flakes. We first used the method of Lim et al. developed for monolayer graphene, based on conductive AFM (C-AFM) [2]. For this purpose, we choose individual flakes overlapping both Au electrodes and Si/SiO_2 substrate, as illustrated in Fig. 1a. By applying a voltage between the tip and the electrode, an image of the current measured while scanning the flake is obtained, from which it is possible to extract resistivity values. However, as in all lamellar materials, one can anticipate that transport is anisotropic so that in-plane and out-of-plane resistivity are most likely different. For this reason, we performed complementary measurements in a configuration where current flows perpendicular to the MXene planes, i.e. with the flakes fully deposited on the Au substrate, as illustrated on Fig. 1c. Local I-V curves have also been acquired on the surface of single flakes. From this dataset, the anisotropy between the in-plane and out-of-plane resistivity of $Ti_3C_2T_x$ will be discussed, as well as the variation of resistivity as a function of the number of layers in the flakes. An electrical equivalent model is developed to understand the contribution of the contact resistances.

References

[1] Michel W. Barsoum, and Yury Gogotsi, Ceramics International, 14 (2022) 24112-24122
[2] Lim, Soomook, Hyunsoo Park, Go Yamamoto, Changgu Lee, and Ji Won Suk, Nanomaterials, 11 (2021) 2575

Figures

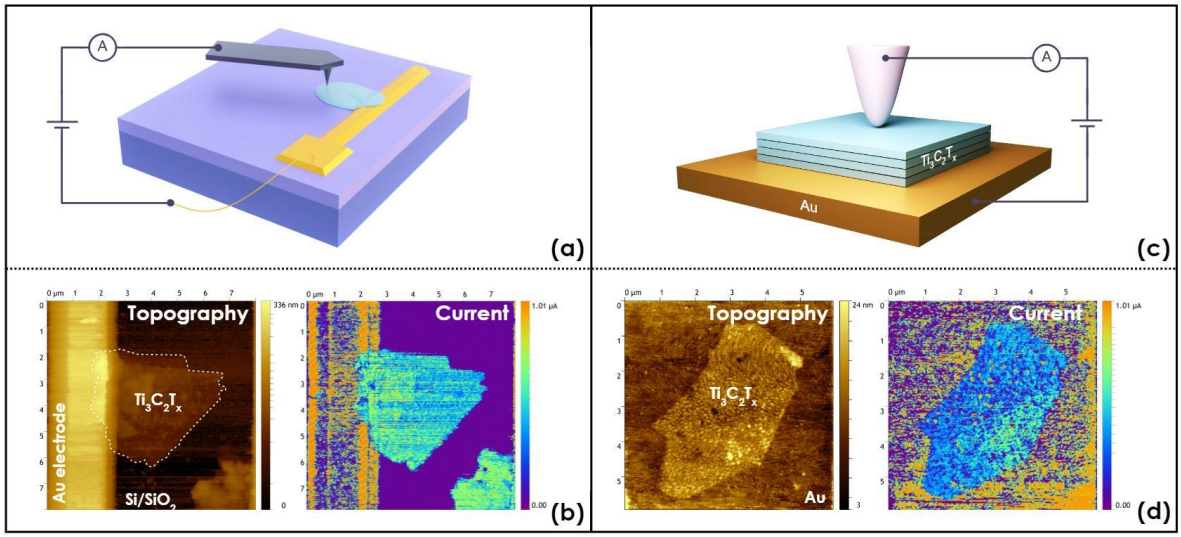

Figure 1: Illustration of C-AFM setup and obtained results of single (a),(b) $Ti_3C_2T_x$ flake on electrode and (c),(d) $Ti_3C_2T_x$ flake on Au substrate.