Electron Transfer Mediated Antibacterial Property of 2D Materials: From Graphene to MXene

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Abstract
The novel antimicrobial concept “bacteria starvation therapy” is developed to empower extraction of extracellular electrons from bacterial membrane respiration chain and interruption of energy metabolism of bacteria. The antimicrobial behaviours of large-area graphene film on Cu conductor, Ge semiconductor and SiO_2 insulator show a strong dependence on the band structure of substrate, in the order of graphene-Cu > graphene-Ge > graphene-SiO_2.[1] Moreover, increase of electrical conductivity of graphene-Ge heterojunction by improving graphene crystallinity can enhance the antimicrobial ability.[2] To further verify the antimicrobial correlation with band structure, cobalt doped TiO_2 coatings are designed with tunable bandgap (3.10 eV to 1.55 eV) and the results reveal that narrowing TiO_2 bandgap can remarkably boost the antimicrobial capacity.[3] Recently, through in-situ oxidation of $Ti_3C_2T_x$ MXene, TiO_2-$Ti_3C_2T_x$ heterojunction is fabricated to tailor the band structure (Figure 1). Under light irradiation, the heterojunction can exhibit favourable antibacterial activity. In summary, semiconductor-based materials with tailored band structure are able to act as extracellular electron acceptors, which can disturb the electron transfer and energy metabolism of bacteria, thereby leading to bacteria starvation and death. The “bacteria starvation therapy” can provide new insight into the interactions between bacteria and 2D materials and contribute to the design of novel antimicrobial agents based on 2D nanomaterials.

References

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Figures

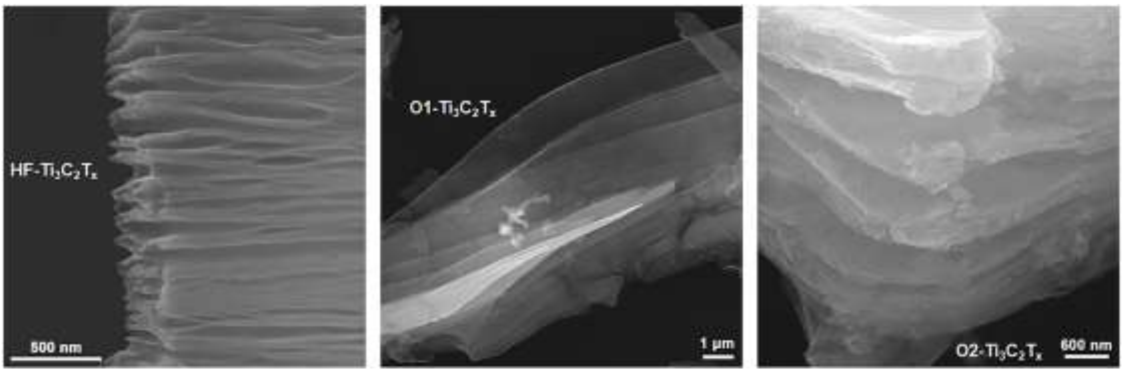

Figure 1: SEM images of pristine $Ti_3C_2T_x$ MXene sample (left) and different oxidation degrees of TiO_2-$Ti_3C_2T_x$ heterojunction samples including lightly oxidized O1-$Ti_3C_2T_x$ (middle) and heavily oxidized O2-$Ti_3C_2T_x$ (right).