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Converting Waste Plastics into Carbon for 2D-MXene-Based Triboelectric Nanogenerators in Sustainable Gas Sensing

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The increasing accumulation of plastics in the environment is a serious threat today. Soil and water bodies are significantly affected, as microplastics can form a layer in soil that inhibits water infiltration, reducing groundwater recharge and contributing to depletion. In water bodies, microplastic contamination is associated with the release of phenols, which are hazardous to aquatic and terrestrial organisms. This highlights the urgent need for effective waste management and remediation strategies.

To address this, the aim is to collect plastic waste and convert it into valuable carbon materials, which can then be used to build MXene-based 2D materials for detecting atmospheric CO_2 and methane. Several 2D materials, including graphene, MoS_2, and MXene, have already been explored for gas sensing, typically using commercial activated carbon. However, many sensors struggle to detect multiple gases at once, and the carbon sources are often not sustainable.

This work proposes integrating plastic-derived carbon into MXene-based 2D materials and applying them in a triboelectric nanogenerator (TENG) platform. TENGs convert small mechanical motions like airflow or vibrations into electrical signals. Gas adsorption on the sensing surface can influence the triboelectric output, enabling self-powered sensing and possible IoT-based monitoring.

The novelty of this study lies in attempting plastic conversion at or near room temperature using thermodynamic driving forces (Gibbs free energy considerations), with the goal of minimising harmful gas emissions that are common in high-temperature conversion methods. Using NiO, Al_2O_3, and plastic-derived carbon, MAX-phase-related structures will be designed and etched to obtain MXene. The device targets low-temperature conversion and self-powered operation. With atmospheric CO_2 at ~0.042% (400–430 ppm) and slightly higher near industrial areas, the sensor is expected to work in a ~50–800 ppm range at 50–80°C, linking plastic upcycling with sustainable gas monitoring.

Keywords: Plastics, carbon material, MXene-based 2D material, CO_2 and methane detection