Engineering n-type $Ti_3C_2T_X$ MXene-based heterostructures for enhanced ammonia sensing performance

Elmehdi Ould Maina [1,2], Adam Hassan Denawi [2], Alessio Teruzzi [1,2], Ran Li [2], Inass El Hajj [1,2], Kassiogé Dembélé [2,3], Holger Vach [2], Fatima Z. Bouanis [1,2]*

[1] COSYS-IMSE, Université Gustave Eiffel, F-77454 Marne-la-Vallée, France

[2] LPICM, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, 91128 Palaiseau, France

[3] Centre interdisciplinaire de microscopie électronique, Ecole Polytechnique, 91120 Palaiseau, France

Abstract:

Among 2D nanomaterials, $Ti_3C_2T_x$ MXene has attracted attention for gas sensing thanks to its high electrical conductivity, mechanical strength, and abundant surfaceactive terminations (–O, –OH, –F), which promote strong room-temperature interactions with NH_3 [1]. However, pristine $Ti_3C_2T_x$ sensors still suffer from limited sensitivity, slow response/recovery, and poor long-term stability.

To overcome these limitations, $Ti_3C_2T_x$ was combined with graphene, MoS_2, and WS_2 to form Ti_3C_2@graphene, Ti_3C_2@MoS_2, and Ti_3C_2@WS_2 heterostructures.

Ultra-thin sensing layers (<15 nm) were fabricated through a one-step interfacial self-assembly method [2,3], enabling reproducible integration of multiple 2D materials and formation of hybrid interfaces with enhanced sensing properties [4]. Structural, morphological, and optical analyses confirmed the successful formation of high quality heterostructures. All devices exhibited an n-type chemiresistive response, attributed to charge transport dominated by interflake junctions in the ultra-thin films. Among them, the Ti_3C_2@graphene sensor showed the best NH_3 sensing performance, with the response improving from –0.76% for pristine $Ti_3C_2T_x$ to –1.33% at 0.5 ppm NH_3, together with a lower LOD (34 ppb vs 89 ppb). While pristine $Ti_3C_2T_x$ sensors degraded significantly within 14 days, the $Ti_3C_2T_x$@graphene heterostructure maintained stable and reproducible performance for over 30 days. Selectivity tests also demonstrated superior selectivity toward NH_3 compared to other interfering gases and VOCs.

Overall, this work demonstrates a scalable strategy for engineering solution-processed 2D heterostructures for high-performance room-temperature gas sensing and environmental monitoring applications.

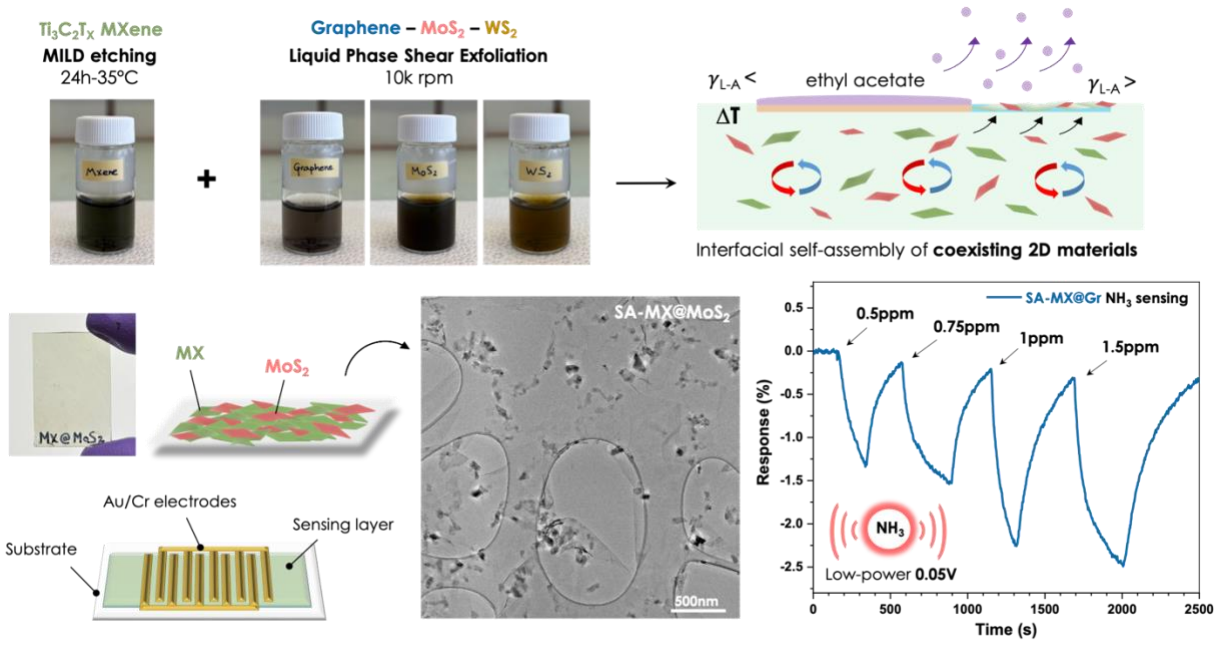


Figure 1: General schematic of the one-step interfacial self-assembly of two coexisting 2D materials approach for MXene-based heterostructures fabrication, and gas sensing performance towards NH_3 gas.

References:

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