MXene Based Conductive Transparent Films (CTFs) Towards Printed Electronics Applications

Laila Balobaid[1,3], Joseph Nielson[1], Dahnan Spurling[2], Valeria Nicolosi[2], Jonthan Coleman[1*]

[1] School of Physics, Trinity College Dublin, Dublin 2, D02 PN40, Ireland, [2] School of Chemistry, Trinity College Dublin, Dublin 2, D02 PN40, Ireland,

[3] Department of Science and Technology, University College at Nairiyah, University of Hafr Al Batin, Nairiyah 31981, Saudi Arabia,

*Corresponding author. E-mail address: COLEMAJ@tcd.ie

Abstract

MXene 2D materials attracted researchers due to their unique properties and tuneability ranging from metallic to semiconductor. In particular, $Ti_3C_2T_x$ became the focus of research efforts lately pertaining to its high conductivity. This work applies liquid-liquid interface deposition (LLID) to synthesize CTFs whilst reporting the measured conductivity for the MXene-based CTFs to be 3.3 x 10^5 S/m at 11.7 nm thickness.

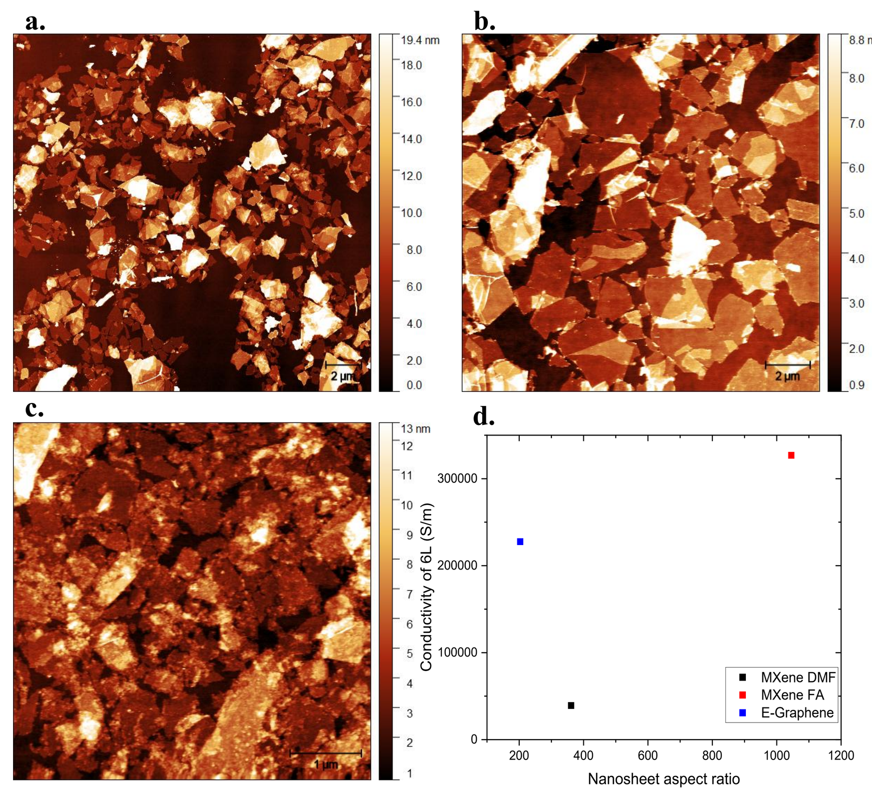

Figure 1. AFM drop-cast of MXene DMF in ***a***, MXene FA in ***b*** and E-graphene in ***c.*** The aspect ratios of the three materials are illustrated in ***d.***

Introduction

The adoption of solution-based techniques enables sustainable innovation within the printed electronics industry. Recently, liquid-liquid interface deposition (LLID) offered conformal coatings of graphene, MoS_2 and Ag NS [1]. Titanium carbides and nitrides known as MXene are well-studied in the recent years since their discovery in 2011[2]. These materials are synthesized through the selective etching of the “A” layer from a MAX phase precursor, where M represents a transition metal, A denotes an A-group element, and X corresponds to carbon and/or nitrogen.

Methodology

1. Film Synthesis

- Inks of MXenes dissolved in DMF and FA were prepared by further dilution in IPA and FA, respectively.
- Two immiscible liquids, DI water and Hexane are set into a glass beaker, a syringe pump and a substrate holder all were set to a dip coater apparatus (Ossila) according to Fig. 2.
- A set of microscope glass of size 2.5 cm x 2.5 cm were cut, followed by cleaning protocol and used for film formation.

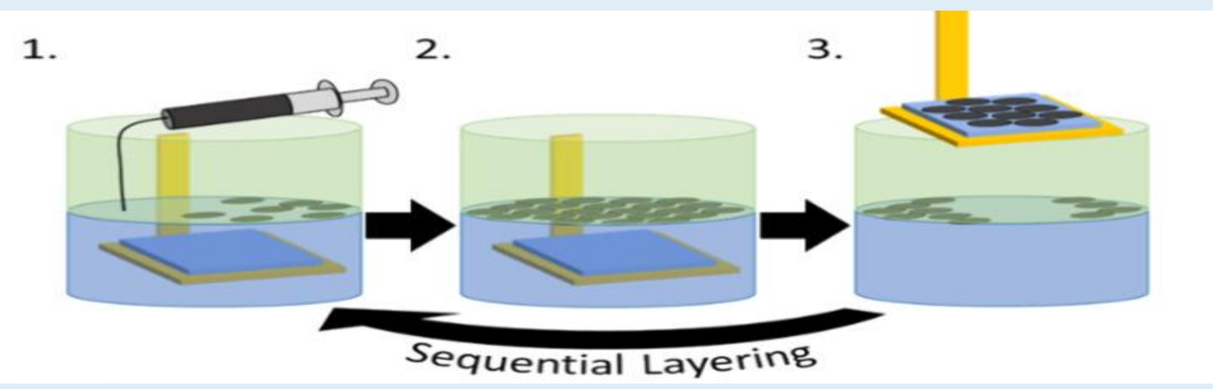

Figure 2. Schematics showing the steps of LLID [2]

- A set of CTFs at layer number ranging from 1 to 6 and 1 to 5 were fabricated and tested against Sixonia E-Graphene thin films.
- Annealing was performed after each layer at continuous vacuum at temperature 80 ◦C for 1 hr.

2. Film Characterisation

Drop cast on Si substrate was used to study nanosheets sizes and thickness, see Fig.1. Morphology was studied via SEM whereas film thickness was studied using Multimode AFM Bruker. Electrical measurements are performed using 4PointProbe and optical measurements are done using UV Vis spectrometry and optical scanner.

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Analysis And Results

1. Morphological Properties

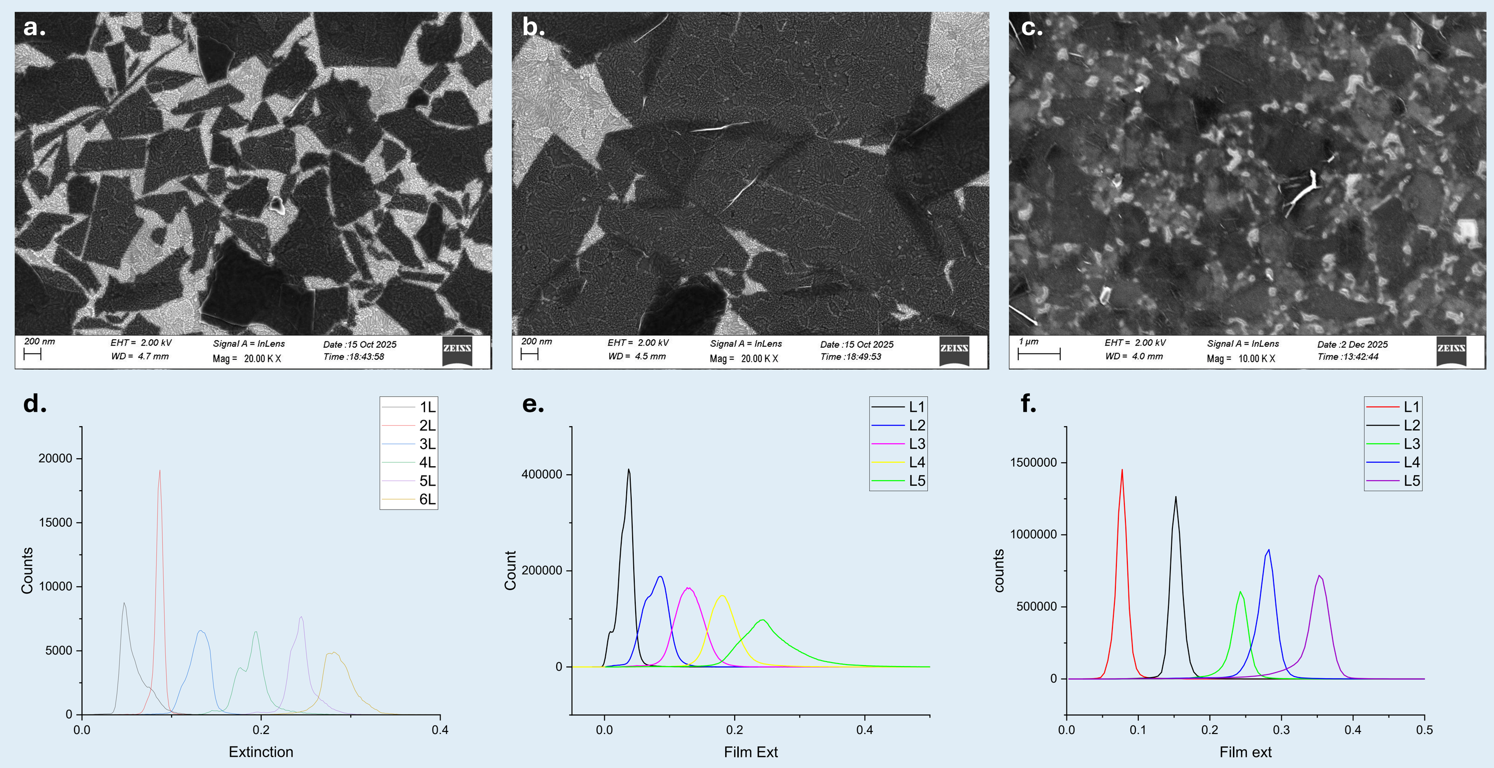
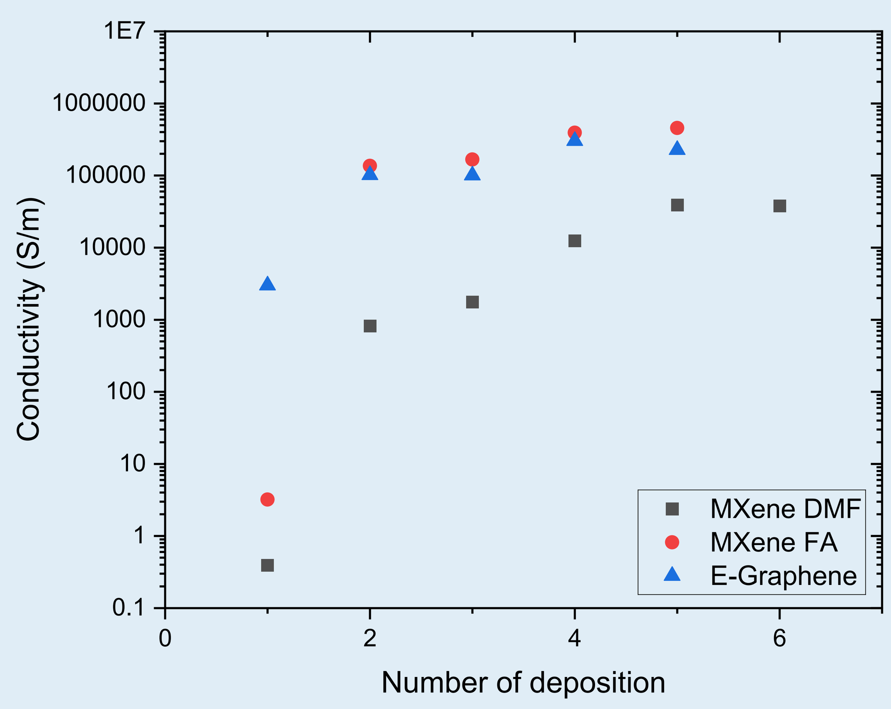
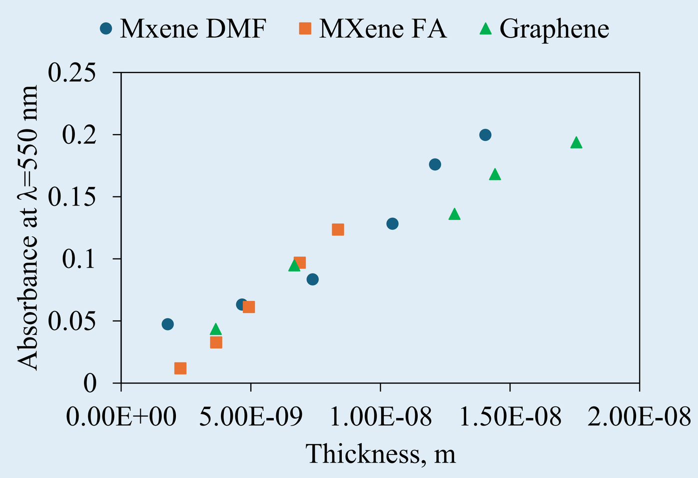


Figure 3. SEM images of 1 layer of MXene DMF in ***a***, MXene FA in ***b*** and E-graphene in ***c.*** Extinction distribution for CTFs of MXene DMF in ***d***, MXene FA in ***e*** and E-graphene in ***f.***

2. Electrical and Optical Properties



2D Material	Conductivity [S/m]	Nanosheet thickness [nm]	Nanosheet size [nm]
MXene DMF	3.8x10^4	2.04	662.69
MXene FA	3.3x10^5	1.65	1712.24
E-Graphene	2.3x10^5	2.83	535.93



Zhang et al., in 2020, reported σ = 15.1x10^5 S/m for a 214 nm thick MXene using blade-coating method [3], while Zeraati et al., in 2021, showed σ = 2.4 x10^6 S/m for a 200 nm thick films using vacuum filtration method [4]. However, Echols et al., in 2022, reported σ = 0.9 x10^5 S/m for MXene ($Ti_3C_2T_z$/f-$Ti_3C_2T_z$) layer by layer assembly as thick as 63 nm with nanosheet thickness 2.5 nm [5]. This current research results in σ = 3.3 x10^5 S/m for film thickness = 11.7 nm with nanosheet thickness 1.65 nm.

Future work

- Apply MXene FA as electrodes in Metal-Semiconductor-Metal (MSM) heterostructure and measure out-of-plane current with the range of TMDs such as MoS_2 and WS_2 to take the place of the semiconductor.
- Study the properties of MXene nanosheets and as network treated with size selection using Liquid Cascade Centrifugation (LCC).

References

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