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XXXVI Cycle

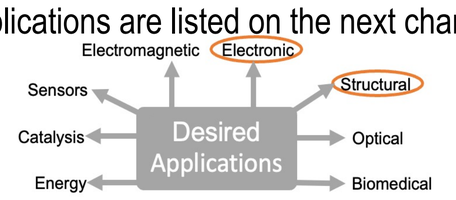
3D Photo-printable Mxene/composites towards electronic applications

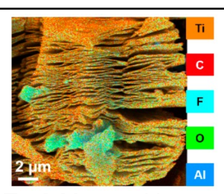
Alejandra Salas

Supervisor: Prof. Candido Fabrizio Pirri & Prof. Matteo Cocuzza

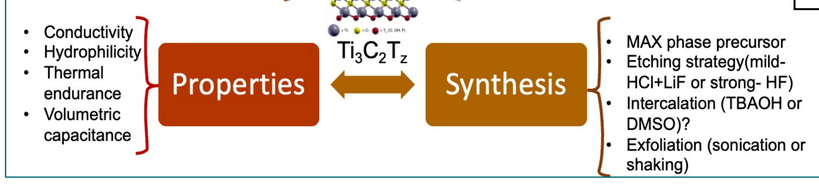
Research context and motivation

- The development of **3D printable inks** via photopolymerization including **MXenes ($Ti_3C_2T_Z$)** as additives to deliver conductive applications on polymeric nanocomposites.
- **MXenes** are a family of electrically conductive, hydrophilic, two-dimensional (2D) nanomaterial made of transition metal carbides, nitrides or carbonitrides with a range of aspect ratios & a few atomic layer thicknesses. Their synthesis and MAX phase precursor can vary the quality and efficiency of their given properties.
- Making them an innovative new material with various properties that give them **functional dye potential** in Additive Manufacturing, in the case of the **$Ti_3C_2T_Z$** the colour is **black**. It has been proven in literature, that they can improve the electrical, mechanical and thermal characteristics of polymers. Thus, the motivation for using them as additives for building potential devices in the electronic field.
- The applications are listed on the next chart:





- $M_{n+1}X_nT_Z$ → M: transition metal, X: C and/or N and T: -O, -OH F & Cl)
- Layered structure & processability.



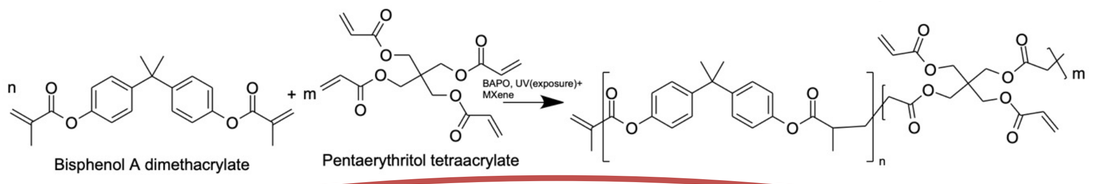
Addressed research problems

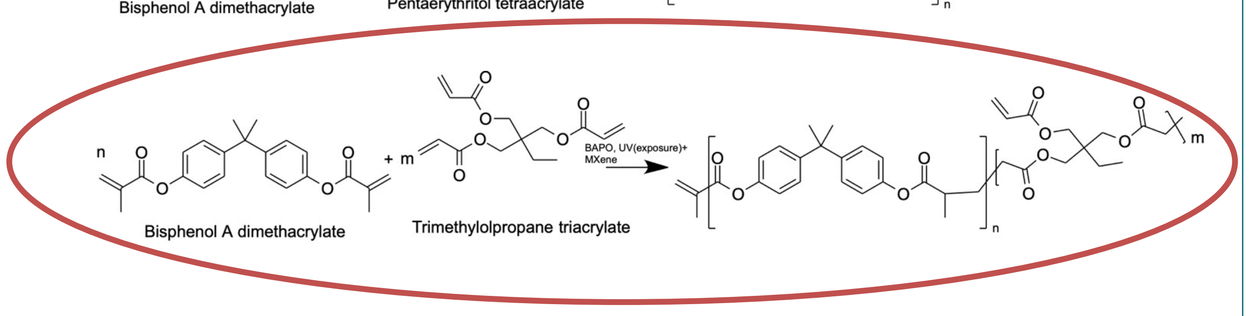
The aim of the research is to 3D print functional devices with polymeric **MXene/composites** that have suitable conductive properties for them to be used on specific electronic applications. For which, the next milestones were established:

- The formulation of 3D printable inks that can:

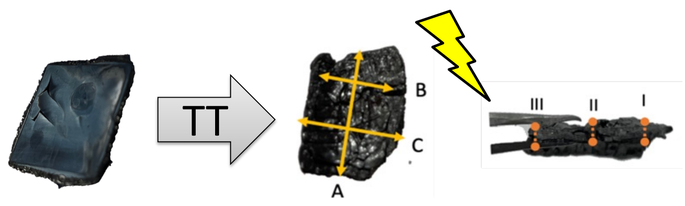
-Dispersed directly the MXene on the resin -Have simpler processes & less polymerization time -Achieve complex architectures & Higher Resolutions.	-However, fillers affect viscosity and light absorption. Therefore, the amount should be managed (%).

- The selection & characterization of the formulations for the nanocomposites.





- The characterization & enhancement of the conductive properties on the 3D printed nanocomposites in order to get optimized conductivity on the material for the "future device".



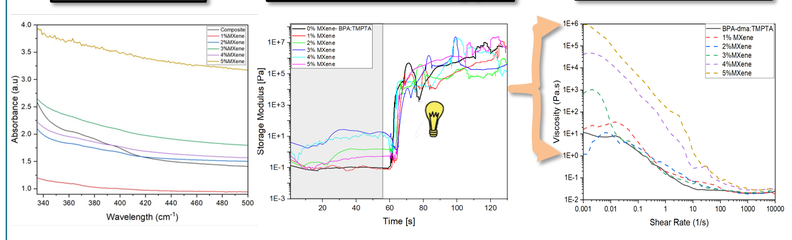
Things to consider:
- Shrinkage
- Deformation
- Orientation

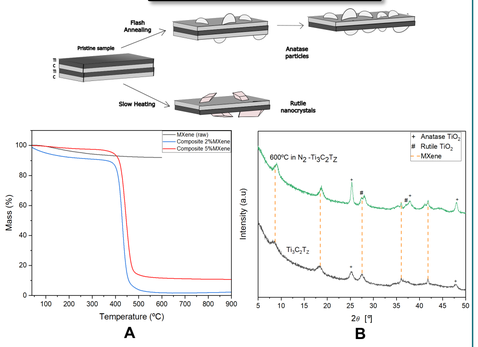
Submitted and published works

- Author 1, A. , Author 2, A., and Author 3, C., "*Title of the work*", Name of the Journal, vol. V, no. N, 2016, pp. 123-125

Novel contributions

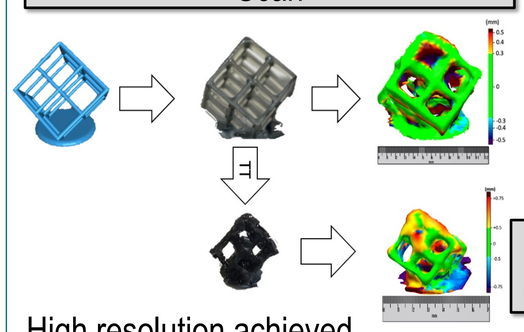
UV-Vis | Photorheology | Flow Curve | TGA & XRD





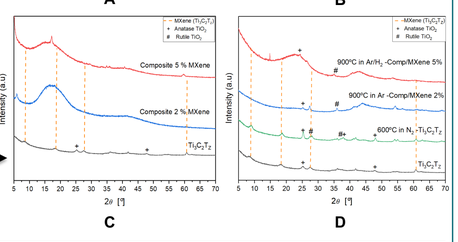
Increased light absorption, viscosity & photopolymerization time with higher MXene content.

3D printed composites & Heatmap Scan



High resolution achieved

$Ti_3C_2T_Z$ oxidation profile after photopolymerization & TT.



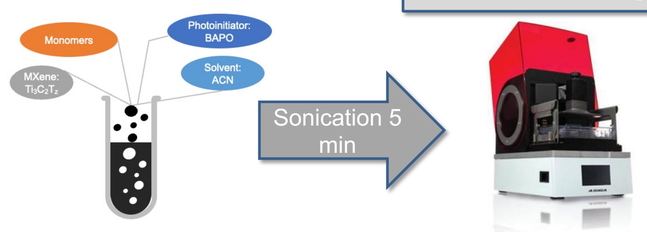
Resistance measurements

Section	Resistance [Ω]	Length [mm]	Resistivity [Ω.m]
A (x)	6	12	$4.5x\ 10^{-3}$
B (y)	4.1	5	$9.84x\ 10^{-3}$
C (y)	7.2	9	$9.6x\ 10^{-3}$
I (z)	3.6	>1	$4.3x\ 10^{-2}$
II (z)	3.1	>1	$3.7x\ 10^{-2}$
III(z)	4.3	>1	$5.1x\ 10^{-2}$

Adopted methodologies

One-pot formulation was introduced on the DLP printer, which has already been uploaded with the CAD.

DLP- 3D Printing



Ranges	Printing Parameters	
Burn-in	Print Range (mm)	0-1.02
	Layer Thickness (µm)	60
	Light intensity (mW.cm-2)	35
	Exposure Time (s)	21
	Slices (n)	17
1	Print Range (mm)	1.02-9.9
	Layer Thickness (µm)	70
	Light intensity (mW.cm-2)	35
	Exposure Time (s)	20
	Slices (n)	127

Optimization of the printing parameters according to the chosen formulation → 5% $Ti_3C_2T_Z$ - 2:1 TMPTA: BPA-dma.

Acetone washed

12 mW.cm-2x 2 min

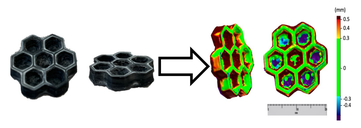
Post- Curing

5 hrs-900ºC
- Ar (Inert atm)
- Ar+H_2 (Reductive atm)

Thermal Treatment (TT)

Future work

- Increased MXene content on the printed structures to increase conductivity on the material.
- Improve the thermal treatment process to decrease MXene oxidation in order to enhance conductivity.
- Measure and predict shrinkage of the printed nanocomposite structures after thermal treatment.
- Design and 3D print electrodes for further application development.



List of attended classes

- SHORT 3rd LEVEL COURSES ON ELECTROCHEMISTRY– (30/06/2022)
- 01NDLRV – Lingua italiana I livello (25/01/2022, 3 CFU)
- 01UNTRV – Managing conflict: negotiation and communication (18/03/2022, 1 CFU)
- 08IXTRV – Project management (04/05/2022, 1 CFU)
- 01SYBRV – Research Integrity (01/02/2022, 1 CFU)
- 01DVTRV – SDG7- Affordable and clean energy (18/08/2022, 1 CFU)
- 02RHORV – The new Internet Society: entering the black-box of digital innovations (24/02/2022, 1 CFU)

Politecnico di Torino

PhD program in
Electrical, Electronics and Communications Engineering