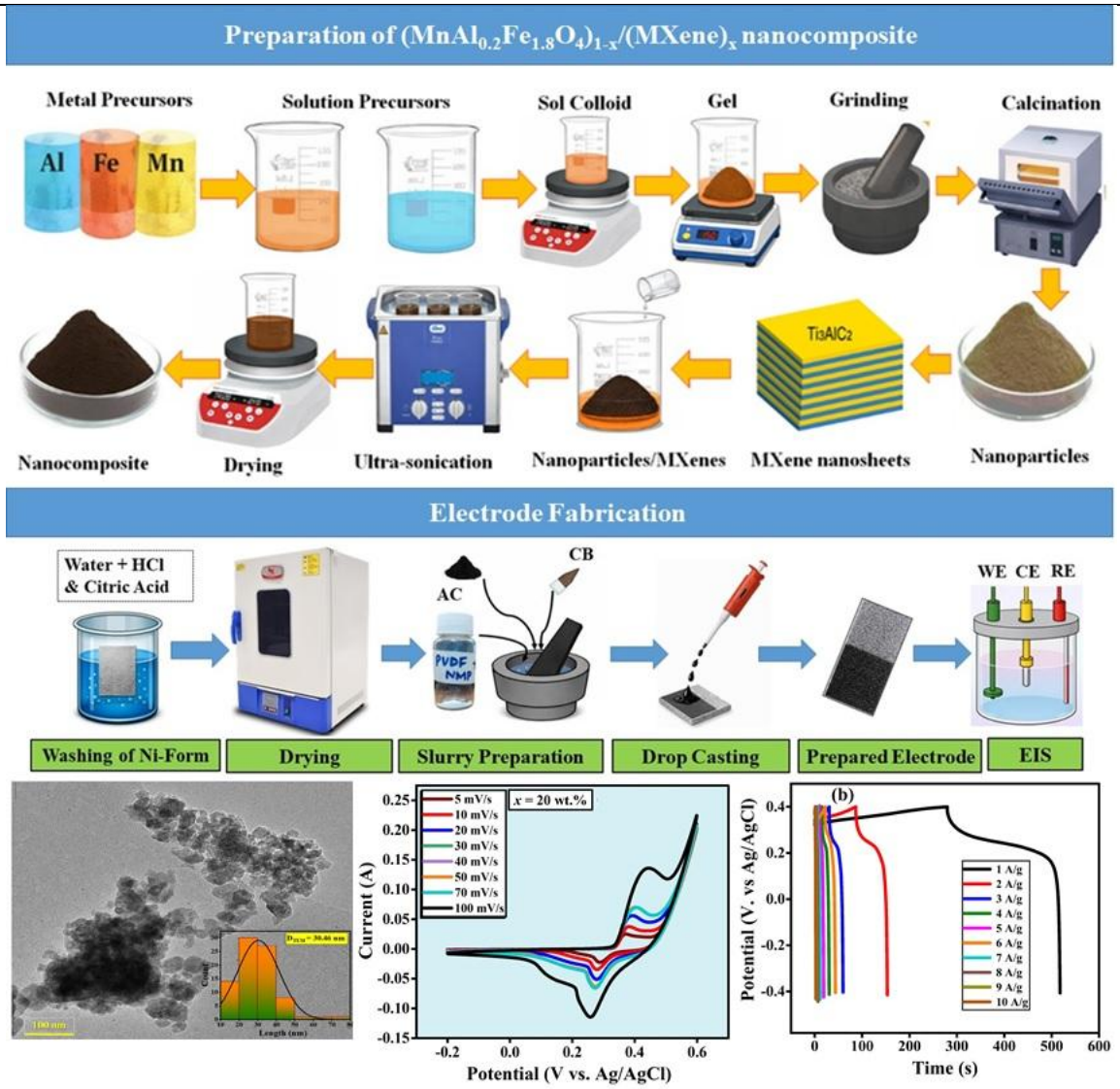
Master's Thesis Information Showcase
Fall Semester-2026
Year 2026

Department: Physics
Program: **MS Physics**
Specialization: **Physics**

1	**Title of the Thesis** Impedance Spectroscopic Analysis and Electrochemical Properties of Synthesized $MnAl_{0.2}Fe_{1.8}O_4$ with MXene Based Nanocomposite for Energy Storage Applications
2	**Abstract** MXene-based nanocomposites with various metal oxide nanoparticles improve energy storage applications such as Supercapacitors and batteries. This report focused on the synthesis and characterization of nanocomposites spinel ferrite and 2D MXene (Ti_3AlC_2) for supercapacitors. The novel $MnAl_{0.2}Fe_{1.8}O_4$ nanoparticles synthesized by using the sol-gel assisted auto-combustion route and their $(MnAl_{0.2}Fe_{1.8}O_4)_{1-x}/(MXene)_x$ nanocomposite (x = 0, 5, 10, 15 and 20 wt.%) prepared by dispersive ultra-sonication assisted method. To observe the significant changes in the properties of the prepared nanocomposites different characterization techniques were employed. X-ray diffraction (XRD) analysis were employed to examine the spinel phase and successful incorporation of the MXene nanosheets. The average crystallite size has decreased from 10.65 to 7.34 nm. FTIR (Fourier transform infrared) spectroscopy study to explore the two characteristic absorption bands of the spinel nature. Transmission electron microscopy (TEM) confirmed the successful decoration of MXene nanosheets with spinel nanomaterials, indicating the formation of a well-integrated nanocomposite structure. TEM images have shown an average particle size of 30.46 nm. The dielectric measurements were performed in a specific applied frequency range from 25 Hz to 1 MHz. Dielectric characteristics, including the dielectric constant (ε′), dielectric loss (ε″), tangent loss (tanδ), AC conductivity (σac), real (Z′) and imaginary (Z″) parts of impedance, along with both components of the electric modulus (M′ and M″), thoroughly discussed as a function of frequency at various wt.% of MXene nanosheets. Samples of the $(MnAl_{0.2}Fe_{1.8}O_4)_{1-x}/(MXene)_x$ nanocomposite x = 0, 10 and 20 wt.% were coated on the nickel foam using drop-casting method to prepare electrodes. Electrochemical analysis such as CV, GCD and EIS were investigated to examine the electrochemical performance of the prepared electrodes of the nanocomposite. Dunn's model is employed to distinguish the battery-type (diffusion-controlled) and capacitive (surface-controlled) contributions. The $MnAl_{0.2}Fe_{1.8}O_4$ and MXene combination is expected to significantly improve dielectric and electrochemical properties, making it a promising choice for advanced energy storage systems such as supercapacitors.
3	**Impact on SDG** Spinel ferrite-based MXene nanocomposites play an important role in advancing affordable and clean energy, particularly in alignment with **SDG 7**, due to their exceptional dielectric and electrochemical properties that make them highly promising materials for modern energy technologies. The functionalization of spinel ferrite nanomaterials with MXene nanosheets offers enhanced high dielectric polarization, large surface area and improved

	charge transport characteristics. Their superior electrochemical performance supports applications in advanced supercapacitors, rechargeable batteries, fuel cells and energy harvesting systems, while their dielectric properties contribute to improved energy management, reduced energy losses and enhanced device efficiency. The excellent stability and multifunctional behavior of these nanocomposites enable the development of durable and high-performance energy materials. Spinel ferrite-based MXene nanocomposites make a significant contribution to sustainable energy technologies by facilitating efficient energy storage, conversion and utilization supporting wider access to reliable, clean and affordable energy solutions.
4	**Scholar Name** Name: Wahab Ullah Seat No: PH-255012 Email address: wahabhassni96@gamil.com Phone No: 03108245702
5	**Supervisor & Co-supervisor Name** **Supervisor:** Name: Dr. Junaid Kareem Khan Email address: junaidkk@neduet.edu.pk Phone no: +923212142352 Department: Department of Physics, NED UET **Co-Supervisor:** Name: Dr. Muhammad Khalid Email address: mkhalid@uok.edu.pk Phone No: +923224169325 Department: Department of Physics, university of Karachi
6	**Graphical Abstract**


Preparation of $(MnAl_{0.2}Fe_{1.8}O_4)_{1-x}/(MXene)_x$ nanocomposite
Metal Precursors
Al
Fe
Mn
Solution Precursors
Sol Colloid
Gel
Grinding
Calcination
Nanocomposite
Drying
Ultra-sonication
Nanoparticles/MXenes
MXene nanosheets
Nanoparticles
Ti3AlC2
Electrode Fabrication
Water + HCl
& Citric Acid
AC
CB
PVDF
NMP
WE CE RE
Washing of Ni-Form
Drying
Slurry Preparation
Drop Casting
Prepared Electrode
EIS
x = 20 wt.%
5 mV/s
10 mV/s
20 mV/s
30 mV/s
40 mV/s
50 mV/s
70 mV/s
100 mV/s
Current (A)
Potential (V vs. Ag/AgCl)
(b)
1 A/g
2 A/g
3 A/g
4 A/g
5 A/g
6 A/g
7 A/g
8 A/g
9 A/g
10 A/g
Potential (V. vs Ag/AgCl)
Time (s)