Masters Thesis Information Showcase
Spring-2026
Year 2026

	Department: Physics Programme: Masters of Science Specialization: Physics
1	**Title of the Thesis** Structural, Dielectric, and Impedance Spectroscopic Studies of MnAl0.2Fe1.8O4/rGO Nanocomposite for Energy Storage Applications
2	**Abstract** The nanocomposites of $MnAl_{0.2}Fe_{1.8}O_4$ with different weight percentage of rGO (x = 0, 1, 2, 3, 4, and 5 wt.%) were prepared by sol-gel assisted ultrasonication method and their structural, dielectric, impedance spectroscopic and electrochemical properties were systematically investigated for energy storage applications. The formation of a single phase structure was confirmed by X-ray diffraction for all compositions, and the crystallite size systematically decreased with increasing rGO content, indicating effective grain growth inhibition by rGO. The characteristic metal–O stretching vibrations at tetrahedral and octahedral sites were confirmed by Fourier transform infrared spectroscopy. Both the dielectric constant and the dielectric loss showed frequency dispersion at low frequencies, which matched the Maxwell–Wagner–Sillars interfacial polarization, and the value of both these parameters increased systematically with the rGO content, due to the increased interfacial polarization and the formation of the micro-capacitor network at ferrite/rGO interfaces. The tangent loss spectra showed clearly the existence of Debye-type relaxation peaks at mid frequencies for rGO loaded compositions, whose position moved to higher frequencies with increasing loading with rGO, thus confirming progressive reduction of relaxation time. AC conductivity showed a frequency-independent plateau at lower frequencies and a strong spike at higher frequencies, which increased with the rGO loading. The non-ideal relaxation behavior shown by the progressively incomplete semicircular arcs at higher rGO loadings was confirmed by the electric modulus and Cole-Cole modulus analyses. An electric double-layer capacitance and pseudocapacitive charge storage mechanism was revealed by electrochemical evaluation, The electrochemical test results showed that the specific capacitance, energy density and ion diffusion kinetics were all enhanced gradually with increasing rGO content, and the charge transfer resistance was systematically reduced. The results validate rGO content as a reliable and adjustable parameter in the engineering of the dielectric and electrochemical response of the $MnAl_{0.2}Fe_{1.8}O_4$-based nanocomposite, which shows promising potential for advanced energy storage applications.
3	**Impact on SDG#7 and SDG#9** (min 500 words) The current research on energy storage applications using MnAl0.2Fe1.8O4/rGO nanocomposites is directly related to two important United Nations Sustainable Development Goals namely SDG 7 (Affordable and Clean Energy) and SDG 9 (Industry, Innovation and Infrastructure). Access to affordable, reliable, sustainable and clean energy for all by 2030 is a goal of the United Nations SDG 7. A major hurdle to achieving this objective is the ability to store

	energy efficiently and at a low cost to capture and provide energy from intermittent renewable sources like solar and wind energy. The present study projects the MnAl0.2Fe1.8O4/rGO nanocomposites as attractive electrode materials for supercapattery devices, directly addressing this challenge to achieve better electrochemical performance, specific capacitance up to 272 F/g at 5 mV/s and energy density as high as 33.1 Wh/kg for the optimized x = 4 wt.% rGO composite makes them good candidates for applications in renewable energy storage, portable electronics and hybrid electric vehicle energy storage systems. One of the special features of SDG 7 is its affordability. Synthesis of the present composites involves a simple sol-gel ultrasonication route with earth abundant, cheap transition metal precursors namely manganese, iron, aluminium and reduced graphene oxide which can be derived from widely available graphite. The material abundance, low precursor cost, and ease of synthesis make these nanocomposites economically accessible, and economically viable in resource-constrained environments directly contributing to the affordability of SDG 7. Also, the high value of the dielectric permittivity (ε'= 2.7×10^3 at a low frequency) of these composites makes them promising as dielectric materials to build power conditioning components for solar inverters and wind turbine converters, which help to integrate clean energy technology into the technological ecosystem. The low dielectric loss at high frequencies also suggests low energy loss during device operation, which is significant for enhancing materials-level energy efficiency, aligning with SDG 7's focus on sustainable energy use. SDG 9 calls for building resilient infrastructure, promoting sustainable industrialization, and fostering innovation. The present study helps in this direction first of all by real scientific innovation as the first systematic investigation of the combined effect of $Al3^{+}$ substitution and incorporation of the rGO in the MnFe2O4 based system, yielding original findings about Debye-type relaxation behavior, non-ideal Cole-Cole modulus response, and systematic correlation between rGO content and charge transport dynamics. This is the kind of fundamental knowledge creation that forms the scientific foundation from which future industrial applications arise, embodying the innovation principle of SDG 9. The straightforward, scalable synthetic method used in this work provides the potential for easy scale-up from laboratory to pilot plant scale, and will enable local industrial capacity development for advanced material production in developing countries. Materials like the ones developed here are essential to the creation of energy storage devices, supercapacitors, dielectric capacitors, EMI shielding components, that are also key to electric vehicle charging networks, smart grid management systems, and uninterruptible power supplies. The current research is making a contribution along the continuum of innovation from fundamental to commercialization to the modernization and resilience of energy infrastructure as part of SDG 9, infrastructure development. Taken together, this work shows that the systematic optimization of properties and simplicity of synthesis, coupled with the use of earth abundant precursors, can enable multi-faceted contributions towards multiple Sustainable Development Goals, highlighting the importance of fundamental scientific research for sustainable industrial and energy development,
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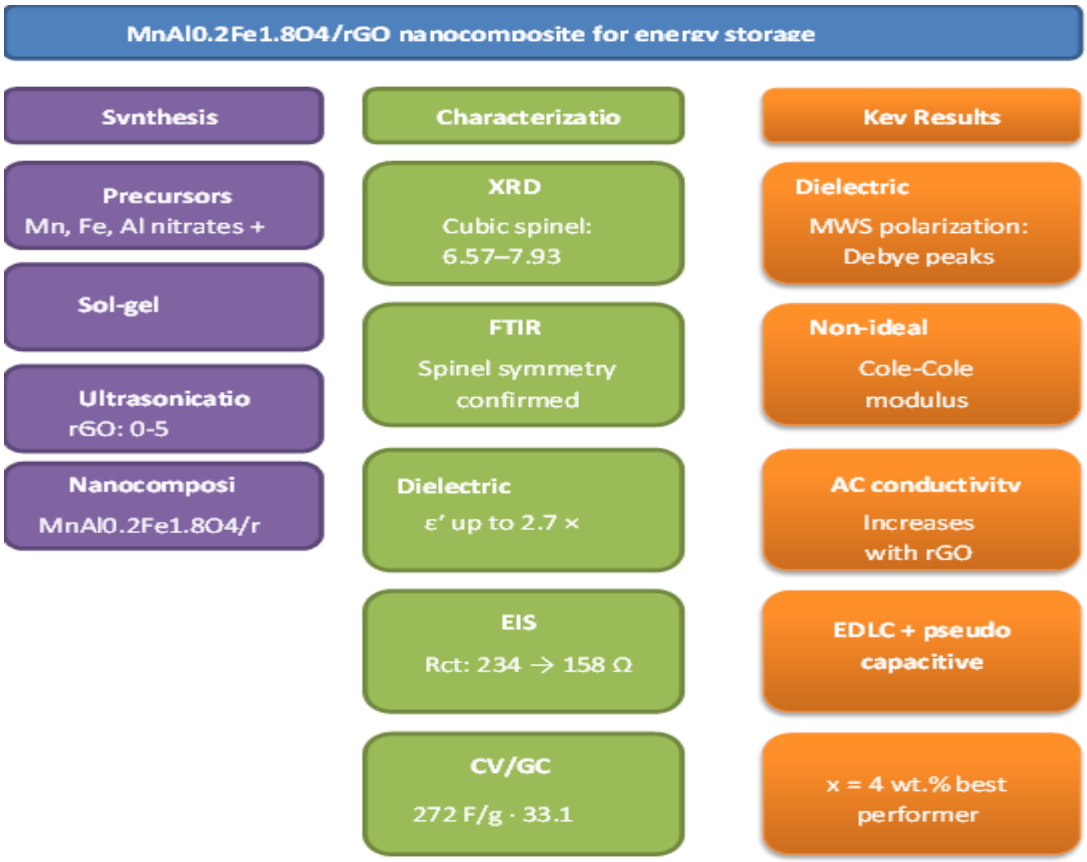
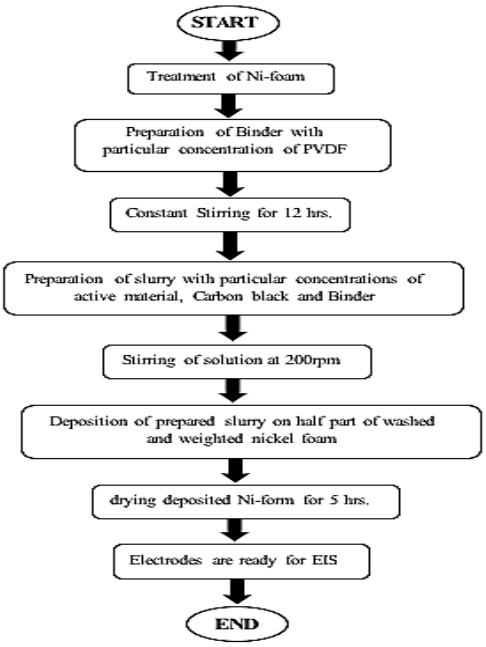
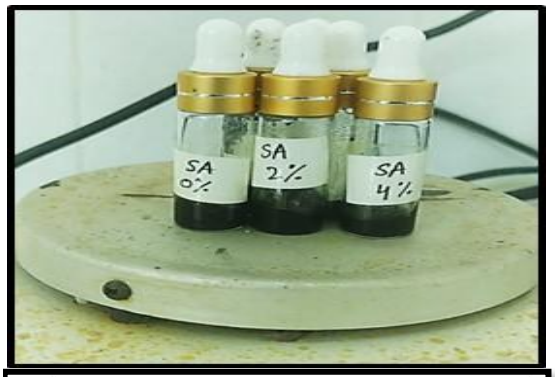
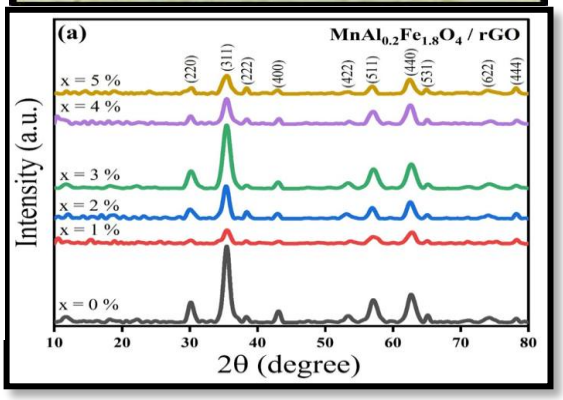
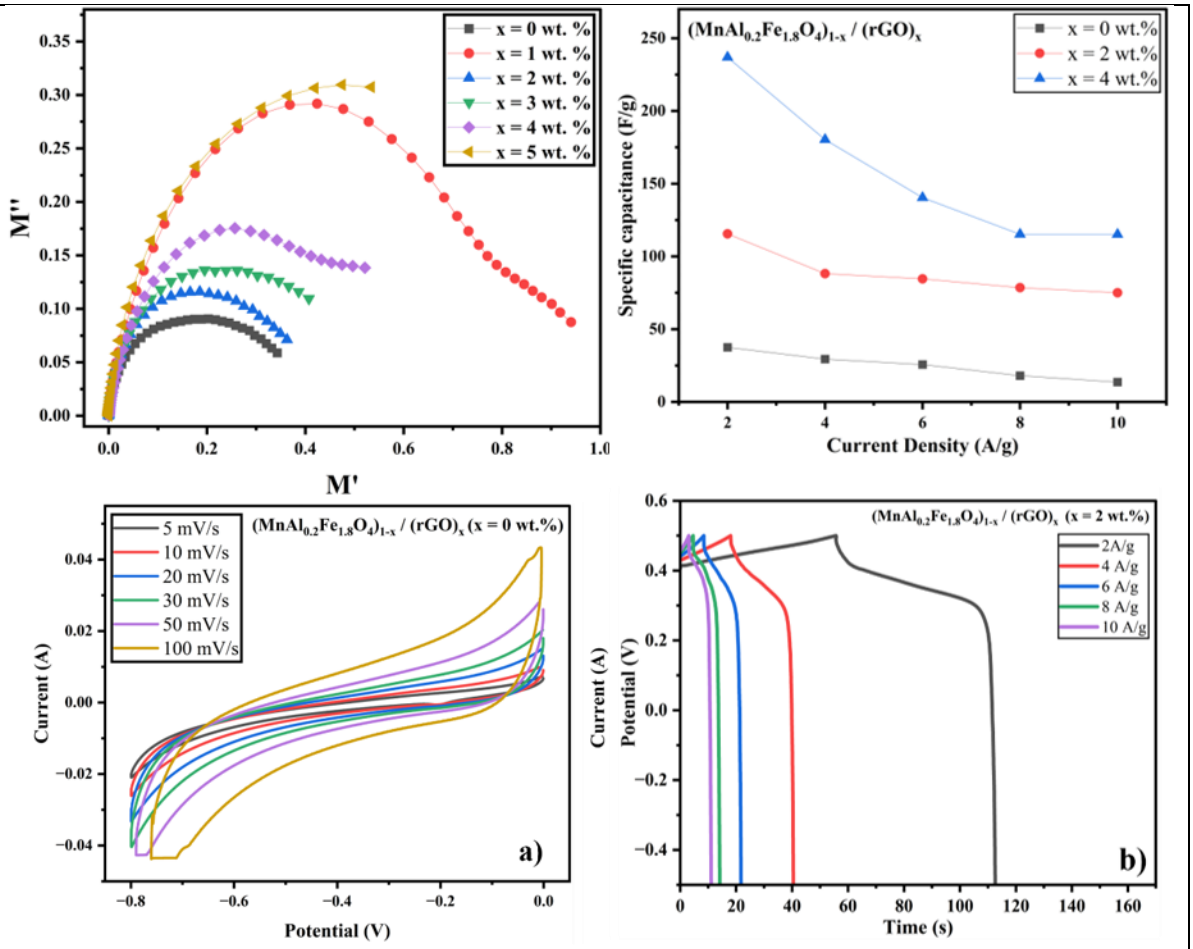
Graphical Abstract




START
Treatment of Ni-foam
Preparation of Binder with particular concentration of PVDF
Constant Stirring for 12 hrs.
Preparation of slurry with particular concentrations of active material, Carbon black and Binder
Stirring of solution at 200rpm
Deposition of prepared slurry on half part of washed and weighted nickel foam
drying deposited Ni-form for 5 hrs.
Electrodes are ready for EIS
END


SA 0%
SA 2%
SA 4%


(a)
MnAl0.2Fe1.8O4 / rGO
x = 5 %
x = 4 %
x = 3 %
x = 2 %
x = 1 %
x = 0 %
(220)
(311)
(222)
(400)
(422)
(511)
(440)
(531)
(622)
(444)
Intensity (a.u.)
10
20
30
40
50
60
70
80
2θ (degree)


x = 0 wt. %
x = 1 wt. %
x = 2 wt. %
x = 3 wt. %
x = 4 wt. %
x = 5 wt. %
M''
M'
(MnAl0.2Fe1.8O4)1-x / (rGO)x
x = 0 wt.%
x = 2 wt.%
x = 4 wt.%
Specific capacitance (F/g)
Current Density (A/g)
(MnAl0.2Fe1.8O4)1-x / (rGO)x (x = 0 wt.%)
5 mV/s
10 mV/s
20 mV/s
30 mV/s
50 mV/s
100 mV/s
Current (A)
Potential (V)
a)
(MnAl0.2Fe1.8O4)1-x / (rGO)x (x = 2 wt.%)
2A/g
4 A/g
6 A/g
8 A/g
10 A/g
Current (A)
Potential (V)
Time (s)
b)