Republic of Iraq,
Ministry of higher
Education and
Scientific research,
University of Diyala,
College of science,
Department of physics

Synthesis and Characterization of (Polypyrrole-Ferrites) Nanocomposites for Multi-Applications

A Thesis

Submitted to the Council of the College of Science, University of Diyala in a Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy of science in Physics

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

(قُلْ إِنَّ صَلَاتِي وَنُسُكِي وَمَحْيَايَ وَمَمَاتِي لِلَّهِ رَبِّ الْعَالَمِينَ(162)لَا
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صدق الله العظيم

سورة الأنعام (162-163)

Dedication

Words are not enough to describe people who stand by me in better or worse, so I dedicate my Ph. D. to …

My merciful parents

My supporters brothers and sister

My wonderful wife

My awesome children ..... Mohammed and Misk.

Omar

Acknowledgment

First of all, I would like to thank Almighty **Allah** for giving me the strength, knowledge, ability and opportunity to carry out this work.

It is high necessary to express my deep gratitude for people who support and encourage me during my study.

I would like to express my heartfelt thanks to my supervisors, **Prof. Dr. Tahseen H. Mubarak** and **Prof. Dr. Isam M. Ibrahim**, for their guidance, inspiration and encouragement.

I express my thanks to all members of Physics Department, especially postgraduate faculty members and staff of the college for their cooperation. I would also like to thank the staff of the thin-film laboratory in the Physics Dept. College of science, University of Baghdad for allowing me to finish my work.

I offer my special thanks to my research colleagues and friends, for their cooperation during the period of studies and thesis work.

My sincere thanks to my close friends (**Mr. Omar Yusuf, Dr. Rasheed Salih, Dr. Omar Al-Fahdawe, Dr. Hussein Sliman, Dr. Laith Ali & Dr. Mohammed Ihsan**) for their help and support.

Finally, I shall always be grateful to my father, mother, brothers (**Salih, Falih, Jassim, and Othman**), sister (**Wafaa**), and wife for their love (Noor), valuable advice, and support through the years of my study.

Supervisors Certification

We certify that this thesis entitled "***Synthesis and characterization of (Polypyrrole-ferrites) Nanocomposites for Multi-applications***" for the student (**Omar Ahmad Hussein**), was prepared under our supervisions at the Department of Physics, College of Science, University of Diyala in partial fulfillment of requirements needed to award the degree of ***Doctor of Philosophy (Ph.D.) of Science in Physics.***

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I certify that the thesis entitled **"*Synthesis and characterization of (Polypyrrole-ferrites) Nanocomposites for Multi-applications*"** presented by student (**Omar Ahmad Hussein**) has been evaluated scientifically, therefore, it is suitable for debate by examining committee.

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We certify that we have read this thesis entitled ***"Synthesis and characterization of (Polypyrrole-ferrites) Nanocomposites for Multi-applications"*** and, as an examining committee, we examined the student (**Omar Ahmad Hussein**) on its content, and in what is related to it, and that in our opinion it meets the standard of a thesis for the degree of ***Doctor of Philosophy of Science in Physics.***

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Abstract

This research concentrates on the preparation of polypyrrole nanofibers (PPy-NFs) polymer using chemical polymerization technique and the nanoparticles of ($Co_{0.8-x}Zn_xMn_{0.2}Fe_2O_4$) by co-precipitation technique followed by thermal treatment in a hydrothermal autoclave reactor where the values of (x) were within range (0-0.8) with (0.2) increment in each sample. Then the polypyrrole nanofibers were decorated with different ferrite nanoparticles to obtain (PPy-NFs/Ferrite nanoparticles) nanocomposite.

The prepared materials were characterized via several techniques, including X-ray Diffraction (XRD), infrared spectroscopy (FTIR) and Field emission Scanning electron microscopy (FESEM). (XRD) results demonstrated the amorphous character of polypyrrole and the single phase cubic spinel for the ferrite nanoparticles. The Crystallite size (D_{311}) of the ferrite particles was within the range (8.54-14.47) nm. Also, (FESEM) images revealed that polypyrrole has polymerized in form of a 1D nanofibers net. Also, ferrite nanoparticles are spherical with little change in particle size distribution. (FTIR) of ferrite nanoparticles revealed two distinct absorption bands belonging to the tetrahedral places and octahedral places, respectively. In addition to it exhibited fabulous coherence between polypyrrole (PPy-NFs) and Ferrite nanoparticles. This indicates for the infallible fabrication of nanocomposites. The optical characteristics of the samples had also examined, and it has been noted that the value of the energy gap and absorbance behavior change with the change in the addition ratios and ferrite content.

The magnetic measurements were made at room temperature showed that the prepared samples have definite magnetic properties. It was also observed that the values of the saturation magnetization altered through the cobalt

content change in the composition. It recorded highest value at (x=0) for ($Co_{0.8-x}Zn_xMn_{0.2}Fe_2O_4$), then it gradually decreases with the decrease in the cobalt content.

The prepared nanocomposite had been used to enhance the photodetector sensitivity. The highest photosensitivity for each of polypyrrole (PPy-NFs) was up to (43.42%) and ferrite nanoparticles was (81.47%) at (x=0.8). While Nanocomposite sample for (PPy-NFs/$Zn_{0.8}Mn_{0.2}Fe_2O_4$) was (103.74%) for light with power of (30 mW) and wavelength of (405 nm). The rise and fall time were about (0.5 sec).

The supercapacitors were prepared for polypyrrole, ferrite nanoparticles and nanocomposite samples in order to gain distinguish and periodically stable capacitances. The performance of samples had evaluated via CV, EIS as well GCD methods. The highest capacitance of the nanocomposite electrode for (PPy-NFs/$Zn_{0.8}Mn_{0.2}Fe_2O_4$) was equal (414.12 F/g) with scan rate (20mV/s).

Finally, the response of the prepared samples was studied for ammonia gas sensing. It was found that ammonia gas sensing increase gradually with the raise of the zinc content in the pure ferrite nanoparticles samples and the PPy-NFs nanocomposite samples. It was noted that the largest response of ammonia gas at a temperature of (50^0C) for ferrite nanoparticles at (x=0.8) equals (679.01%) and the nanocomposite samples for (PPy-NFs/$Zn_{0.8}Mn_{0.2}Fe_2O_4$) was equal to (423.11%).

Published and Accepted Research Articles

List of Publications

1- Omar A. Hussein, T. H. Mubarak, Isam M. Ibrahim, **Enhancement the photosensitivity of PPy-NFs/Nanoferrite for Photodetector**, International Journal of Mechanical Engineering, ISSN: 0974-5823, Volume 7, No.3, PP. 274-284, 2022.

2- Omar A. Hussein, T. H. Mubarak, Isam M. Ibrahim, **Magnetic properties of Hybrid inorganic-organic flexible nanofibers**, NeuroQuantology, Volume 20, issue 4, PP. 64-72, 2022.

3- Omar A. Hussein, T. H. Mubarak, Isam M. Ibrahim, **Designing inorganic-organic nanofibers nanocomposite for Supercapacitor Applications**, NeuroQuantology, Volume 20, issue 5, PP. 1972-1983, 2022.

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List of Symbols

Symbol	Meaning	Units
f	Frequency	Hz
θ	Diffraction Angle	Degree
T_c	Curie Temperature	K or ℃
T_N	Neel Temperature	K or ^{S}C
L	Hopping Length	Å
H	Magnetic Field Strength	A/m
M	Magnetization	emu/g
μ	Magnetic Permeability of Medium	Hm^{-1}
μ_0	Permeability of Free Space	$4\pi\times10^{-7}$ Hm^{-1}
μ_r	Relative Permeability	Dimensionless
M_s	Saturation Magnetization	emu/g
B_s	Saturation Flux Density	tesla (T)
B_r	Remnant Induction	tesla (T)
H_c	Magnetic Coercivity	A/m
τ_0	Characteristic Relaxation Time	s
τ_N	Néel Relaxation Time	s
τ_B	Brown Relaxation Time	s
τ	Effective Relaxation Time	s
T_B	Blocking Temperature	K
χ	Magnetic Susceptibility	--
k_B	Boltzmann's Constant	1.38×10^{-23} J·K^{-1}
T	Absolute Temperature	K
h, k, l	Miller Indices	Integer

ρ_x	X-ray density	g/cm^3
D	Crystallite Size	nm
E_g	Energy Gap	eV
λ	Wavelength	nm
Q	Electron Charge	C
I	Electric Current	Ampere (A)
V	Electric potential	Volt (V)
E	Electric Field	V.cm^{-1}
a_{exp}	Experimental Lattice Constant	Å
M_r	Remnant Magnetization	emu/g
α	Optical Absorption Coefficient	-
R %	Response of the Sensor	-
R_{air}	Resistances of the Sensor in Air	Ω
R_{gas}	Resistances of the Sensor in Gas	Ω
σ	Conductivity	(Ω.cm)$^{-1}$
σ_e	Electrode Conductivity	S.cm^{-1}
Z_{real}	Real Parts of the Complex Impedance	Ω
Z_{imag}	Imaginary Parts of the Complex Impedance	Ω
C	Capacitance	F
Cs	Specific Capacitances	F.g^{-1}
m	Active Mass of the Electrode	mg.cm^2

List of Abbreviations

Abbreviation	Definition
CPs	Conducting Polymers
HCPs	Hybrid Conducting Polymers
Py	Pyrrole
PPy	Polypyrrole
PPy-NFs	Polypyrrole Nanofibers
MO	Methyl Orange
SQUID	Superconducting Quantum Interference Device
HUMO	Higher Unoccupied Molecular Orbitals
LOMO	Lower Occupied Molecular Orbitals
ppm	Parts Per Million
CV	Cyclic Voltammetry
GCD	Galvanostatic Charge-Discharge
MNPs	Magnetic Nanoparticles
VSM	Vibrating Sample Magnetometer
TEM	Transmission Electron Microscopy
XRD	X-Ray Diffraction
FTIR	Fourier Transform Infrared Spectroscopy
FESEM	Field Emission Scanning Electron Microscope
VSM	Vibrating Sample Magnetometer
JCPDS	Joint Committee on Powder Diffraction Standards
ESR	Equivalent Series Resistance
EMI	Electromagnetic Interference
SCE	Saturated calomel electrode

Chapter one

Introduction and Literature Review

1.1 Introduction

This work addresses the characteristics of composite material consisting of polypyrrole nanofibers supported by ferrite nanoparticles. To begin with, polymers are an essential sort of chemical that living would've been more significantly harder without it. Polymer comes from the Greece words poly, which means many, plus mers, which incomes components as well as units with an in height molar mass. Every molecule is comprised of a large number of distinct composition units that are arranged in a logical order. Polymers, also known as macromolecules, are large molecules with a high molecular weight that are made via combining a great number of small molecules called monomers. Polymerization is process of joining monomers together to produce a polymer [1].

Synthesis polymers have been known and used as effective insulators for a long time. Billingham as well as Calvert contend that, “For most of the history of polymer technology, one of the most important characteristics of these polymers is their ability to work as an excellent electrical insulators.” Massive efforts have been made in the last two decades to develop innovative materials known as “conducting polymers” (CPs) [2]. Conducting polymers have been extensively studied for optical, electrochemical, and electronic applications due to their unique optical, electrical, and chemical features. When the right elements are doped into products, they can have conductivity ranging from semiconductors to metallic materials [3].

Due to their electric as well as electrochemical properties which are equivalent with those of traditional semiconductors as well as metals, conducting polymers (CPs) have attracted a great attention across both basic plus applied investigation. CPs offer great features such as low manufacturing and treatment temperatures, adjustable conductivity, chemical and structural variety, and structural flexibility [4]. Impactful materials of CPs of good mechanical reliability, flexibility, as well as conductivities have been demonstrated to function as significant physical parts in light-emitting diodes[5], capacitors of electrochemical, actuators plus transistors [6], devices of electrochromic [7], cells of photovoltaic as well as sensors, battery, memories and electromagnetic induction (EMI) shielding [8].

Polyacetylene is the first conductive polymer that was discovered by Alan Heeger, Hideki Shirakawa, and Alan MacDiarmid in1977. After this discovery, a variety of conductive polymers were investigated, including PANI, polypyrrole, polythiophene, PEDOT, besides PPV polymer [9].

Polyaniline (PANI), polypyrrole (PPy), and polythiophene (PTh) are the most appealing polymer groups [10]. Over the past decades, these conductive polymers have indeed been studied widely and described. Due to their low cost, great sensitivity, quick reaction, their ability to work at room temperature, those polymers but also its derivatives have frequently used in nanosensors [11]. Because of their exceptional electrical and magnetic properties, spinel ferrites are intriguing ceramic magnetic materials that have been the focus of extensive theoretical and experimental research. Spinel ferrite nanoparticles have remarkable physical and chemical features, including substantial anisotropy, high saturation magnetization, high magnetic permeability, good chemical stability [12], Superparamagnetism, and temperature-dependent hysteresis, among others. It is employed in a variety of applications, including soft magnetic powders, hyperthermia, magnetic fluids, heat transfer systems, transformer cores, drug delivery orientation, data storage devices, and magnetic sensors [13]. Many ferrites could be classified as magnetism semiconductors due to its distinctive features plus good functional features. They have a wide range of uses in a variety of industries. The magnetic characteristics of ferrites are determined by phase purity and crystalline nature. Magnetorheology[14] and microwave absorption are two further applications of magnetic ferrites [15]. The different ferrites can be synthesized using a variety of processes. The magnetic behavior of ferrites is determined by the structure of ferrites, the cations Spread at the octahedral plus tetrahedral positions, models defects, the nanocrystallites size, and other factors [16].

1.2 Literature Review

1. Hernandez et al. published a paper in 2007 about superior quality PPy-NWs made through template-directed chemical preparation. Temperature dependent electrical transport investigations revealed that the specimen was semiconducting with a minimal extent of disorder. For gaseous ammonia, sensors according to single nanowire demonstrated high sensitivity, detection limit, in addition to selectivity. At a concentration of approximately 40 ppm, the sensors provided reliable detection [17].
2. Yang et al. demonstrated in 2010 that using a $FeCl_3$-MO reactive template, they could make polypyrrole (PPy) nanofibers quickly and easily. Chemical sensors were built into the sensor device using the prepared PPy nanofibers to discover NH_3 vapors. In comparison to bulk Polypyrrole, sensor in accordance with PPy-NFs outperformed bulk PPy when it comes to time response plus sensitivity [18].

3. Dubal et al. in 2011 Here, electrodeposition process for the production of PPy nanobricks have been tested. X-ray Diffraction, FTIR, TEM, plus SEM are used to characterize these PPy nanobricks. CV in addition GCD methods were used to assess the electrochemical performance of PPy material (electrode). Within the voltage range of 4×10^{-1} to -6×10^{-1} Volt in 5×10^{-1} M sulfuric acid, a great Cs of 47.6×10 $F.g^{-1}$ had attained. Furthermore, PPy electrode had an 89% discharge/charge efficiency [19].
4. Hosseini et al. in 2012 synthesized polypyrrole-$MnFe_2O_4$ composites by core-shell construction using in situ-polymerization in the existence of surfactant plus doping. $FeCl_3$ also served as an oxidation factor. XRD, VSM, SEM, FTIR, and the four-wire technique were used to determine the structure and magnetic properties of manganese ferrite nanoparticles. Utilizing vector network analysers in the frequency region from eight to twelve GHz, the microwave-absorbing properties of nanocomposite powders were investigated. At 11.3GHz, A reflection loss of -1.2×10 dB measured as the minimal. The results of spectroanalysis show that Polypyrrole chains in addition to particles of ferrite have a mutual interaction [20].
5. Shinde et al. reported in 2013 a low-cost, innovative, in addition to easy chemical production of thin films PPy to supercapacitors applications. XRD, FTIR, and SEM are used to evaluate these PPy films. The electrochemical supercapacitors characteristics for PPy thin films were assessed via CV in a 5×10^{-1} M Sulfuric acid, with an extreme Cs of 32.9×10 F/g with a scan rate about 5mV/s. Furthermore, electrochemical impedance measurements revealed that the (ESR) for thin films PPy are 108×10^{-2} ohm The charge transfer is attributable to both redox and non-redox reactions, as indicated by the Nyquist and Bode plots, which is supported by the findings of charge discharge experiments [21].

6. Geng et al. in 2013 synthesized polypyrrole/γ-Fe_2O_3 hybrid materials in situ via sol-gel polymerization and studied them using FTIR, XRD, and HRTEM. At thirty, sixty, plus ninety Celsius, the sensitivities of gas in ammonia, CO, H_2, acetone and ethanol atmospheres had measured. The gas sensitivities findings revealed which the polypyrrole/γ-Fe_2O_3 had a great sensitivity for ammonia at a low working temp (<hundred Celsius), overcoming disadvantages of PPy's slow response time and γ-Fe_2O_3 high operating temperature. As a result, the hybrids had crucial and practical properties for the production of gas sensors [22].
7. Eeu et al. in 2013 reinforced polypyrrole by reduced graphene oxide plus (Fe_2O_3) to obtain electrochemical stabilization and improvement, A simple one-pot chronoamperometry technique was used to create the ternary nanocomposite film. When comparing the nanocomposite to their individual (polypyrrole) as well as binary (polypyrrole/RGO) counterparts, cyclic voltammetry measurements revealed a two-fold and four-fold increase in current for the nanocomposite. Even after 200 charge/discharge cycles, the film of ternary composite retained its Cs quite well. The PPy/RGO/Fe_2O_3 electrode has a specific capacitance of 1257×10^{-1} $F.g^{-1}$, while the Polypyrrole/reduced graphene oxide plus polypyrrole materials (electrodes) have 933×10^{-1} and 766×10^{-1} $F.g^{-1}$, respectively [23].
8. Ullah et al. In 2013 investigated the response mechanism of polypyrrole as a sensor to ammonia. The interaction of ammonia with the oligopyrrole lowers the impedance to electron transport across the oligomer backbone. Changes in electronic characteristics like as ionization potential, electron affinity, HOMO, LUMO, band gap, and λ_{max} are also used to assess resistance decrease. The capacity of nPy oligomers to detect ammonia is additionally aided by their electron affinity and band gap (HOMO to LUMO). When

oligopyroles interact with NH_3, band gaps narrow and LUMO energies rise [24].

9. Navale et al. In 2014 used a spin coating method on a glass substrate to produce Polypyrrole-iron oxide hybrid nanocomposite sensor films, which were then analyzed for structural and morphological features using XRD, FTIR, and SEM. The hybrid nanocomposites' gas-sensing properties were investigated and compared to Polypyrrole plus α-ferric oxide (Fe_2O_3). This was discovered which polypyrrole/α-ferric oxide (Fe_2O_3) hybrid composites could somewhat compensate for limitations for pristine polypyrrole and ferric oxide. this was discovered that a polypyrrole/α-ferric oxide (Fe_2O_3) (fifty %) hybrid sensing working at room temp can discover Nitrogen dioxide (NO_2) at small concentrations (ten ppm) and high selectivity compared to C_2H_5OH as well as sensitivity (5.6×10%) and superior stabilization (85%) [25].
10. Moloudi et al. In 2015 prepared a nanocomposite of hard ($BaFe_{12}O_{19}$)/soft ferrite, and then produced an in situ polymerisation method to create a PPy-$BaFe_{12}O_{19}/Fe_3O_4$ multicore-shell. VSM and the four-wire approach were used to characterize the nanocomposite's magnetic characteristics and electrical conductivity, respectively. Electrical conductivity of conducting ferromagnetic polymer nanocomposites is order of $0.5\times10\,\frac{S}{cm}$, as well as M_s is $0.3\times10\ \frac{emu}{g}$ as prepared [26].
11. Elahi et al. In a 2015 used sol-gel and in situ chemical polymerization to synthesize $Zn_{0.5}Ni_{0.45}Mn_{0.05}Fe_2O_4$ and polypyrrole-ferrite nanocomposite structures. The formation of a two-phase system is revealed by XRD, FTIR, and FESEM experiments. When ferrite was added to PPy, the phase separation increased. Because of the bonding influence among the metals

cations with the polypyrrole, the electric density for the polypyrrole chain decreased, lowering conductivity. When ferrites are included into a conducting polypyrrol matrix, the dielectric constant and dielectric loss increase. When comparing pure samples to composite materials, the loss tangent was found to have large values. The magnetic characteristics of composites were also affected by the amount of ferrite [27].

12. Sun et al. in 2016 synthesized PPy/coated $ZnFe_2O_4$ double-shelled hollow spheres in a study conducted. The $ZnFe_2O_4$/PPy composite that emerges combines the benefits of hollow structure and nanocompositing. The hollow interior reduces volume changes during charge and discharge, while the PPy coating improves structural stability and conductivity. The electrochemical performance of the $ZnFe_2O_4$/PPy composite is much better than that of pristine $ZnFe_2O_4$ with a double-shelled hollow structure. This study found that combining hollow structure and nanocompositing to develop the electrochemical act of anode materials (Transition metal oxides or TMO) [28].
13. Mažeika et al. in 2018 synthesized $CoFe_2O_4$/polypyrrole composite nanoparticles using a high energy ball mill. For sample characterisation, Mössbauer and FTIR spectroscopies, VSM, and TEM were used. Nanoparticles were exposed to an alternating magnetic field to assess the specific loss power. When comparing $CoFe_2O_4$ nanoparticles to $CoFe_2O_4$/polypyrrole composite nanoparticles, some differences in coercivity were detected and explained [29].
14. Zhang et al. in 2018 reported new NH_3 gas sensing according to self-assembled Polypyrrole/Zn_2SnO_4 composite. In-situ chemical oxidative polymerization was used to prepare the PPy nanospheres, and C element microspheres had used as a sacrificial model to synthesize the Zn_2SnO_4

hollow nanospheres. The reported materials were characterized using XRD, FTIR, EDS, XPS, TEM, in addition to SEM techniques. When exposed for ammonia gas, gas sensor characteristics for Polypyrrole/Zn_2SnO_4 nanofilm had studied. In terms of a reduction discovery limit, greater responsiveness, shorter response with recovery time, and exceptional repetition to ammonia gas, the PPy/Zn_2SnO_4 Nanofilm sensor outperformed its pristine Polypyrrole and Zn_2SnO_4. The substantial improvement in gas sensor characteristics for PPy/Zn_2SnO_4 Nanofilm is attributed to the deprotonation/protonation technique of NH_3 adsorption/desorption on the Polypyrrole surface, unique relations at the p-n Hetero junction, as well as large surface area of the PPy/Zn_2SnO_4 composite [30].

15. Assar et al. in 2019 prepared $Co_{0.5}Ni_{0.2}Li_{0.15}Fe_{2.15}O_4$/Polypyrrole using the mechano-synthetic technique. Their magnetic plus structural features were studied. The rise of the nonmagnetic Polypyrrole shell in comparison with nanoparticles magnetic in the core resulted in a linear drop in M_s, M_r, K_1, and an almost stable value of H_c, which was found and explained. This could also explain why the composite samples' σ_{dc} values were higher than the pure models'. The frequency dependency of the composite models ε', ε'', σ'_{ac}, and tanδ has been studied. (Z'-Z'') graphs of composite models revealed various overlapping semi-circles based on electrical variables. The semicircles relate to series parallel resistor-capacitor circuits. Depending on the electrical conditions, the composite models' (Z'-Z'') charts revealed distinct overlapped semi-circles parts. These semi circles relate parallel series resistor-capacitor pairings [31].
16. Scindia et al. in 2019 prepared the composite electrode of $NiFe_2O_4$/PPy using easy with low cost in-situ chemical oxidation route in an aqueous medium by the presence of surfactant and described of the structural,

spectral, electrical, morphological and thermal investigations. The super capacitive behavior of NFO/Polypyrrole material (electrode) had studied in an aqueous 10^{-1}N sulfuric acid (electrolyte sol). The NFO/polypyrrole electrode has the maximum Cs of 72.166×10 F.g^{-1}. The specific power, specific energy, as well as coulomb efficiency, respectively, were found to be 61.8×10^{-1} $\frac{\mathrm{kW}}{kg}$, 519.5×10^{-1} $\frac{\mathrm{Wh}}{kg}$, with 990.8×10^{-1} %. This material electrode demonstrated electrochemical stabilization after $(10^3)^{th}$ continuous CD cycles, and it was found to be an effective electrode substance for supercapacitors deices [32].

17. Chunping Xu et al. in 2019 used a one-step hydrothermal technique to synthesize polypyrrole-modified iron oxide nanomaterials. By performing the synthesis at various temperatures, the impact of the reaction temperature was examined. Nanohybrids manufactured were incorporated into electrodes to create supercapacitors devices. Controlling the (C+N)/Fe ratio on the surface, which is highly sensitive on reaction temperature, allowed for effective tailoring of the electrochemical characteristics. Ppy@Fe_2O_3-180°C nanohybrid had the highest electrochemical performance, with a noticeable capacitance amount of 56×10 F.g^{-1} at a current density of 5 A.g^{-1} in addition to an extraordinary cycling stability of 9.73×10% after 2×10^4 cycles of CD at 4×10 A.g^{-1} [33].
18. Yağan in 2019: Use aqueous solution comprising monomer and oxalic acid, polypyrrole was electropolymerized potentiodynamically on a prepassivated Fe electrode. PPy was electropolymerized between 3×10^{-1} and 8×10^{-1} Volt against saturated calomel electrode (SCE) at a scan rate about 20 $\frac{mV}{s}$. CV, GCD cycling, plus EIS were utilized to investigate the electrochemical features of PPy coated Fe electrode. The greatest specific capacitance of a Fe

electrode covered with PPy is 2280 $F.g^{-1}$ [34].

19. Liu et al. in 2019 used a simple and quick microwave approach to manufacture polypyrrole nanofiber (PPyNF)/NiO_x composites. The samples were analyzed using differential scanning calorimetry and thermal gravimetric analysis, as well as X-ray photoelectron spectroscopy and SEM. PPyNF/NiOx nanocomposites were also electrochemically analyzed via GCD, CV, as well as EIS methods. They are the higher Cs (65.7×10 $F.g^{-1}$ at 0.05×10 A/g , which means that it can be used in supercapacitors [35].
20. Wang et al. in 2020 synthesized polypyrrole/Fe_2O_3 nanocomposites using a one-step hydrothermal method in order to improve polypyrrole's gas response to NO_2. XPS, HRTEM, and TG studies have all shown the presence of ferric oxide in composites. At 50°C, the polypyrrole/Fe_2O_3 sensor has a good selectivity for NO_2 and a fast response. The polypyrrole/ Fe_2O_3 materials are easier to manufacture in comparison to other polypyrrole/metal oxide materials, and the gas sensor has a greater response of 220.7%, a lower detection limit of 0.1 ppm, and a strong linear relationship when NO_2 concentrations vary from 0.1 ppm to 10 ppm. In comparison to pure polypyrrole and Fe_2O_3, the gas response is dramatically improved [36].

1.3 Aims of the study

1- By simple methods and effective cost, polypyrrole nanofibers (PPy-NFs) were synthesized by chemical oxidative polymerization technique. Nanoparticles of $Zn_{0.8}Mn_{0.2}Fe_2O_4$ were prepared by the co-precipitation method and followed by heat treatment in an autoclave reactor As well as, (PPy-NFs/$Co_{0.8-x}Zn_xMn_{0.2}Fe_2O_4$) nanocomposites from PPy-NFs and ferrite nanoparticles.

2- Studying the influence of zinc replacement in magnetite structure on the structural properties, magnetic properties, optical properties, and performance efficiency of manufactured devices.

3- Selection of optimal conditions for the preparation of samples and their uses in electrochemical applications such as Supercapacitors, Optoelectronic Applications, and Gas Sensing.