Journal of Advances in Science and Technology
Vol. 17, Issue No. 1, March-2020, ISSN 2230-9659

A Study of Gamma-Irradiation's Impact on the Super capacitive Performance of Copper Oxide Thin Films

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Abstract - The most recent innovation in energy storage technology is the supercapacitor, which offers a number of advantages including power performance, stability, and the use of materials that are less expensive. Supercapacitors may be employed in space technology due to their small weight and suitability for power applications, in addition to these advantages. Any electronic device's properties may be changed by exposure to radiation when it is used in a space satellite or in radiation atmospheres. Supercapacitors have recently been tested using batteries in tiny spacecraft that orbit the earth. CuO thin films that have been chemically produced are affected by gamma-irradiation at dosages of 50, 100, and 150 kGy on their structural, morphological, and supercapacitive characteristics. Researchers will have a better grasp of the changes, evolution, and device manufacturing of metal oxide-based supercapacitors to be employed in gamma-radiation environments thanks to the outcomes of this research.

Keyword - gamma-irradiation, oxide

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INTRODUCTION

The diminishing non-renewable energy sources have captured more research attention towards developing renewable energy storage devices to solve the problems of the upcoming generation. Supercapacitors execute a dominant role in energy conversion and storage appliances. The functioning of efficient supercapacitors counts on the active materials, electrolytes, and CCs used. The nanoscale materials improve the specific surface area and increase the adsorption and diffusion of electrolyte ions which leads to the enhanced supercapacitive performance of electrodes. Therefore, potential investigation in the preparation of nanostructured materials directly on the CC has a great ability to increase the energy accumulating dimensions of the supercapacitors. Normally, pseudocapacitive transition metal oxides are widely used as supercapacitor electrode materials. To boost the supercapacitive properties of metal oxide-based electrodes, an effective way is to assemble the one-dimensional materials (i.e. nanowires and nanorods) directly on immensely conducting flexible CC.[1]

Among the various metal oxides, CuO is a popular candidate and has obtained growing attention due to its ease of preparation, low cost, non-toxic nature besides acts a good potential material to augment the supercapacitive performance The direct synthesis of CuO material on a conducting substrate produces various advantages such as quick and easy diffusion of electrolyte ions, a huge number of electrochemically active sites, and good contact with CC with better capacity retention. Besides, it provides good flexibility and porous nature with high electrical conductivity helps to enhance the E of supercapacitors.[2-4]

The metal oxide-based supercapacitors properties are presumed to be enhanced steadily by achieving different morphologies and structures with the help of various deposition methods. Hence, their applications in space technology like delivery of high pulse for ignition systems, in high power communication throughout interplanetary missions, and also in conventional electronics may be amplified. Thus, to assist the acceptance and application of supercapacitors in space technology, more research is required on metal oxide-based supercapacitors and their evaluation in a radiation environment. This calls for the study on the influence of radiation on the supercapacitive properties of materials and devices so as to ascertain their sustenance in the radiation atmosphere.

Irradiation (electrons, charged ions, gamma, and α-irradiation at different doses) has been regarded as one of the tools for improving the properties of materials. When ionizing radiations pass through materials, they deposit their energy in the materials, and cause irreversible modifications in the macromolecular structures of the materials. Therefore, the uses of radiation in materials science is of a great importance for achieving required alteration in the properties of materials. Many groups have investigated controlled alteration of shape and size of the particles implanted in various host materials employing SHI irradiation as ionizing radiation. This plays a very perceptible role in preparation and modification in structures that affect the conductivity. The modifications stated mainly count on the type of incident radiation, linear energy transfer rate, radiant energy fluence\dose, temperature at the interface of the material and radiant particles, and the nature of the target material itself. Gammairradiation performs a significant role in the alteration of electrical, morphological, and structural characteristics of materials as the radiation directly deposits the energy to the system.[5-6]

Metal oxides offer alternative electrode materials for high-performance supercapacitors as they have high Cs, high conductivity, and low resistance. To modify the properties of metal oxide thin films, many post-synthesis treatment strategies are reported such as annealing under controlled environment and exposure to highly energetic ionizing irradiation like gamma, protons, and charged particles. Irradiations at different doses or fluencies produce indicative modifications in the structural and morphological properties of metal oxides and develop a generous variety of defects. Metal oxides irradiation at high dosage level produces two prime irradiation effects: (i) provisional effects due to the generation of electron-hole pairs, and (ii) permanent effects due to the change in crystal lattice Gamma-irradiation is electromagnetic radiation that can be produced commercially employing Cobalt-60 (Co-60) as source material. Radiation environments like radiotherapy, nuclear power plants, military, and particle accelerator-based research, and satellite in space incorporate gamma-irradiation. When gamma radiation interacts with materials it result in atomic displacements and/or oxygen vacancies. This interaction can modify the material characteristics because of the development of lattice defects created by vacancies or dislocations. Keeping this in mind, it is anticipated that a CuO thin films exposed to gamma radiation would enhance the supercapacitive properties. Most of the work has been reported on the influences of irradiation on the characteristics of different materials but hardly any literature exists concerning the result of the effect of gamma-irradiation on the supercapacitive properties of CuO thin films so far. However, there is scanty of literature existing on the effect of irradiation on carbon-based materials and their supercapacitive properties. Therefore, systematic investigation is essential on the effect of gamma-irradiation on the supercapacitive properties of CuO thin films to reach conclusion.

LITERATURE REVIEW

M. Rajkumar et. al. (2017) For the future of energy storage, super capacitors have been identified as a viable technology. The development of basic and applied features of super capacitors is making tremendous progress in this approach. As a result, there are several methods for measuring capacitance. Increasing the specific capacitance of electrode materials has been the subject of several studies in the scientific literature. The construction of asymmetric super capacitors with extended cell voltage and different materials with complementary working potentials has recently attracted the attention of researchers. Asymmetric super capacitors are the subject of a number of studies attempting to improve their energy density (ASCs). For ASCs with battery-type electrodes, however, it is still difficult to identify optimal operating conditions for the devices. The performance of symmetric and asymmetric super capacitors, as well as fabrication of different nanostructure electrode materials and other studies, are all discussed in this paper. As a last experiment, we show that the capacitive performance of ASCs with a battery type electrode material and a capacitive material is affected by the charge balance. As part of this ASC demonstration, we also show how to analyze the charge capabilities of positive and negative electrode materials.[7]

B.Y. Guan et. al. (2017) Precursors for the synthesis of materials include metal–organic frameworks (MOFs) and coordination polymers (CPs). Since metal cation species are not unique to amorphous CP as they are in crystalline MOF, its composition may be readily adjusted. An amorphous carbon monoxide (CP) precursor for very complicated mixed metal oxide shells is shown here. The initial step is to create NiCo coordination polymer spheres, which are then converted into seven-layered NiCo oxide onions by fast heat oxidation. These ternary and quaternary metal oxide onions may be produced with this method in a variety of sizes and compositions. High specific capacitance (1900 F g1 at 2 A g1), excellent rate capability, and ultrahigh cycling stability are all features of the Ni-Co oxide onion (93.6 percent retention over 20 000 cycles). At 52.6 Wh kg-1 and 1604 W kg-1 (based on active materials weight), a graphene/multishelled mesoporous carbon sphere-based hybrid supercapacitor displays outstanding cycle stability.[8]

J. Liu et. al. (2016) Anode materials for rechargeable lithium-ion batteries (LIBs), such as Co3O4 and CoO, have been receiving growing interest because of their theoretical capacity. For LIB electrode materials, nanostructure engineering has been shown to be an effective method of improving their electrochemical performance. Cobalt oxide-based nonmaterial’s, including 1D nanowires, 2D nanosheets, 3D hollow/hierarchical structures, hybrid nanostructures with carbon (carbon nanotubes and graphene), and mixed metal oxides, are the focus of this study. Lithium storage capability of these nonmaterials is summarized. Effective methods for fabricating cobalt oxide/carbon hybrid nanostructures are emphasized by concentrating on the implications of their structural characteristics on their electrochemical performance. Such cobalt-oxide-based nanomaterials are very promising as anodes for the next generation of LIBs, according to this study.[9]

N. Agnihotri et. al. (2017) As an electrode material for high performance supercapacitors, a ternary nanocomposite of PEDOT: Grp-MnO2 was manufactured using a hierarchically organised design. An easy one-pot solvothermal approach was used to produce the graphene-coated MnO2 (Grp-MnO2) binary compound. Wrapping the binary compound in PEDOT conductive polymer layers completed the encapsulation process. XRD, TEM, Raman spectroscopy, and XPS were used to examine the structural morphology and oxidation states of the nanocomposite's Mangnese. For electrochemical tests including cyclic voltammetry and charge-discharge, the nanocomposites were used as electrodes. The PEDOT:Grp-MnO2 (with a ratio of 1:3) had the highest specific capacitance value of 213 Fg1 and increased energy and power densities. The pseudocapacitance resulting from the redox processes over the electrical double layer capacitance (EDLC) in composite materials was determined by conducting an AC impedance experiment.[10]

A. González et. al. (2016) various materials used in supercapacitors are discussed in this article. Research and application views on the most prominent supercapacitor active materials are reviewed, together with short descriptions of their characteristics, such as specific surface area and capacitance values, in these paper Different types of supercapacitor electrolytes are described, along with the pros and cons of each. As a last consideration, cell layouts are discussed, highlighting the merits and disadvantages of each.[11]

Q. Li et. al. (2018) in the development of supercapacitors, researchers have shown a great deal of interest in ruthenium-based materials with fast reversible redox processes, a diversity of valence possibilities, and environmental adaptability. An in-depth look at the use of ruthenium-based materials and composites in supercapacitors, with an emphasis on their synthesis, raw material selection, temperature control, electrolyte management, and electrochemical performance, is presented in this paper.[12]

N.A. Zubair et. al. (2017) The extraordinary capabilities of electrically conductive nanofiber have made it a well-known superb nanostructured material. By combining electrospinning and electropolymerization processes, researchers were able to create nanofibers coated with polyethylenedioxythiophene (PEDOT) and graphene oxide (GO). The optimal electrospinning settings were determined by systematically altering the PVA-GO solution concentration and the applied voltage during electrospinning. GO concentrations of 0.1 mg/mL and electrospinning voltages of 15 kV were found to be optimal, resulting in smooth nanofibrous morphology and a narrower diameter range. PVA-GO nanofiber mats were coated with PEDOT, a conjugated polymer, using electropolymerization, a simple method for coating nanofibers, in this study. These nanofibers were found to have cauliflower-like structures of PEDOT developed on their surfaces during the potentiostatic electropolymerization process, as seen by SEM pictures of the nanofiber samples produced. Nanofibers covered with PEDOT exhibit excellent conductivity because of the varied electro polymerization conditions. PEDOT electropolymerization occurred at a voltage of 1.2 V for 5 minutes. There was a clear improvement in the current responsiveness and reduction in charge transfer resistance with the use of the PVA–GO/PEDOT composite nanofiber.[13]

X. Li et. al. (2016) Rechargeable batteries and supercapacitors may benefit from the high conductivity, superior mechanical integrity, and wide surface area of one-dimensional (1D) carbon composite nanostructures as electrodes. One-dimensional carbon-based nanocomposites may be created via electrospinning, a simple, low-cost, and scalable technique. In addition to becoming electrodes, these carbonaceous nanomaterials may also be employed as substrates for active materials including metal, metal oxide, and sulphur to improve the electrodes' structural stability and conductivity. Here, we begin by describing the structure and functioning of these energy storage devices in a straightforward manner. A summary of electrospinning parameters, distribution of different solution components before and after electrospinning (for example, polymer A in matrix polymer B and nanoparticle in matrix polymer) and post-electrospinning treatments (such as calcination, activation and hydrothermal process) on the influence of structural, compositional and morphological features of the resulting electrospun nanocomposites is then presented. As a result of these discussions, the design and synthesis of the necessary nanostructured structures as well as nanostructured architectures with unique physical/chemical features (e.g., pore volume and conductivity) are provided Carbon-based hybrids for developing applications in lithium ion, lithium ion-sulfur, and supercapacitor batteries are discussed. The link between electro spinning process parameters, post-electro spinning treatments, nanostructures, and electrochemical characteristics is being sought for. Finally, some final thoughts and perspectives on the existing issues and potential future research areas for these 1D carbon-based hybrid electrodes are provided.[14]

L. Xu (2019) A preferred contender with a bright future for next-generation energy storage applications is the supercapacitor. It is essential to combine carbon materials with metallic oxides in order to get better electrochemical performance. One-dimensional hierarchical nanofibers with a highly conductive core (NiCo2O4 embedded carbon fibre) and a sheath of Ni(OH)2 have been developed herein, which are very effective. It is created using electrospinning and chemical bath deposition. Optimum electrode material outperforms its Ni(OH)2 nanosheet-free equivalent in terms of energy storage (1925 F g1 at 1 A g1) and cycling performance (87 percent after 5000 cycles) (79 percent after 5000 cycles). In addition, the asymmetric supercapacitor built with this material and activated carbon has a high specific capacitance performance (135 F g1 inside 1.6 V). Its high power density and energy density, 323 W kg-1 and 48 Wh kg-1 for the asymmetric supercapacitor and remarkable rate capability surpasses most known metal oxide carbon-based composite materials.[15]

Q.-Z. Zhang et. al. (2018) Since fossil fuels have such a negative influence on our environment and the global economy is growing at such a fast pace, it is critical that we find ways to store energy that is both clean and useable. High-density, long-cycle, wide-temperature-range, and cost-effective, supercapacitors are a new form of green energy storage technology. In a wide range of sectors, they have a wide range of applications. The performance of supercapacitors is greatly influenced by the materials used to make the electrodes. Because of their high theoretical capacitance, superior chemical stability, cheap cost, and environmental friendliness, MnO2-based materials are often explored for supercapacitors. High specific capacitance is currently best achieved by using MnO2 and carbon composite materials. These materials, as well as their synthesis process and current research status, are discussed in detail as supercapacitor electrode materials composed of MnO2–carbon composite. An MnO2–carbon based supercapacitor's problems and potential future research paths are discussed in the last section.[16]

Obodo, Raphael & Ramzan, Muhammad & Nsude, Hope & Onoh, Edwin & Ahmad, Ishaq & Maaza, M. & Ezema, Fabian. (2017). "Radiations Induced Defects in electrode materials for energy storage devices". Many researchers are now working to develop methods for preserving and prolonging the optimal performance of energy storage devices exposed to radiation. Radiation such as gamma, ions, neutrons, and lasers may cause electrodes in energy storage devices to lose capacity, increase resistance, and break down due to radiation received from the surrounding environment. This article examines these impacts. Energy storage device electrodes are affected by radiation in a variety of ways, including ionization, atomic displacement, deformation, shift and impurity addition. Batteries and supercapacitors are examples of modern energy storage devices with respectable energy and power densities. Researchers' interest in these devices has been heightened by the global energy crisis, which has spurred them to look for methods to improve their performance. This research examined the radiation that affects energy storage devices, as well as the best techniques to manage radiation impacts on energy storage devices in order to achieve optimal performance.[17]

Manoj B. Gawande (2016) Cu and Cu-Based Nanoparticles: Synthesis and Applications in Catalysis Recent years have seen an increase in interest in the use of Cu nanoparticles, which are based on the plentiful and affordable copper metal, in the area of catalysis. These nanoparticles and their applications in catalysis have grown in popularity because to the possibility of altering their chemical and physical characteristics by various synthetic procedures and circumstances and/or post-synthetic chemical treatments. New support and/or multimetallic systems (e.g. alloys, etc.) have also contributed significantly to the sector, as have their design and development. Here, we report on a wide range of techniques to synthesising several types of Cu-based and Cu-based nanoparticle (metal copper, CuO, and CuHN), as well as the uses of these nanoparticles in catalysis (SiO2, magnetic support materials, etc.). The preparation techniques for Cu and Cu-based nanoparticles are discussed in the synthesis section, while their applications as catalysts, such as electrocatalysis, photocatalysis, and gas-phase catalysis, are described in the application sections. Cu-based nanostructured materials in catalysis need further background knowledge, and we hope that this critical assessment will give it. [18]

METHODOLOGY

Irradiation of chemically produced CuO thin films for supercapacitor applications is the subject of this research. There were three doses of gamma radiation applied to the CuO thin films: 50 kilovolts (kilovolts), 100 kilovolts and 150 kilovolts at room temperature, each with an average energy of 1.25 MeV from a Co-60 source. There are three types of CuO samples: ICuO0, ICuO50 and ICuO100 for the gamma-irradiated CuO samples, respectively. The chamber had a capacity of 1200 cubic centimetres. IUAC (Inter-University Accelerator Center) in New Delhi, India, conducted this irradiation experiment. The gamma chamber and different dosages of ICuO0, ICuO50, ICuO100, and ICuO150 thin films' experimental settings are shown. Later, XRD, FE-SEM, and EDAX were used to analyse the ICuO0, ICuO50, ICuO100, and ICuO150 thin films to investigate any structural or morphological changes after gamma radiation exposure, while supercapacitive assessment was carried out utilising CV, GCD, EIS, and stability tests. effect of gamma-irradiation on chemically synthesized CuO thin films for supercapacitor applications at different doses. For more details on the synthesis parameters of the CuO sample,. The synthesized CuO thin films were exposed to gamma-radiation using a gamma chamber (Model: GC-1200) with an average energy of 1.25 MeV having Co-60 source at a dose rate of 3.39 kGy/hr for different doses of 50, 100 and 150 kGy at room temperature. The schematic of gamma exposure to CuO thin films is illustrated and the actual setup of the gamma chamber.

DATA ANALYSIS

XRD Study:

The XRD plots of ICuO0, ICuO50, ICuO100, and ICuO150 thin films are shown in Fig. 1(a-d), where the peaks are properly in agreement with the ICDD data (CuO 00-002-1041) confirming the presence of no impurities [like Cu_2O and $Cu(OH)_2$]. The highest intensity peak is observed along (002) and lower intensity peaks occur with (110), (200), (-202), and (020) planes. The XRD spectra confirmed ICuO0, ICuO50, ICuO100, and ICuO150 samples were pure phase monoclinic crystal structures and no noticeable modification in the crystallographic phase is found after gamma-irradiation. Similar results are obtained by Mirzayev et al. for SiB_6 thin films, Lavanya et al. for SnO_2 thin films, and Todica et al. for PVA-TiO_2 membrane after exposure to gamma-radiation. There are no significant changes observed in the lattice constants and unit cell volume of CuO samples after gamma-irradiation, that coincides with the standard values of CuO.

The peak intensities decreased conspicuously with an increase in FWHM (β) of diffraction peaks after gamma-irradiation for ICuO100 sample because of crystal rearrangement during irradiation process resulting into modifications in the crystal structure of CuO thin films. For ICuO150 sample the intensity of peak increased as compared to ICuO0. The modifications in the peak intensities is based on different conditions like crystal structure, multiplicity, absorption, Lorentz, temperature, and polarization factors. This factor counts on the number of electrons near the atoms in the crystal lattice. Hence, the observed changes in peak intensities after exposure to gamma-radiation may depend on these factors. Similar results are reported by Souli et al. and Zaki et al. for MoO_3 and polyethylene materials, respectively. The decrement in the peak intensity and increment in the FWHM results decrease in the crystallite size.

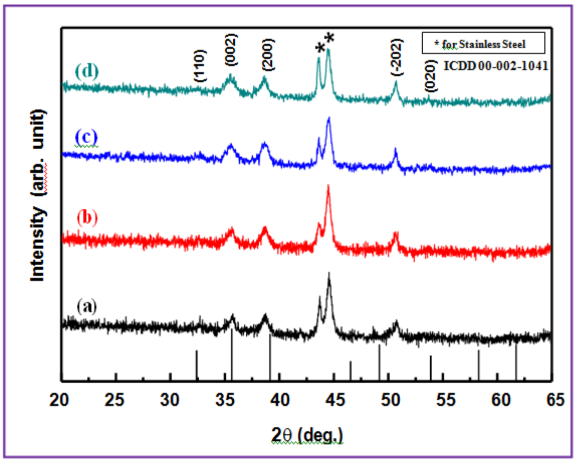
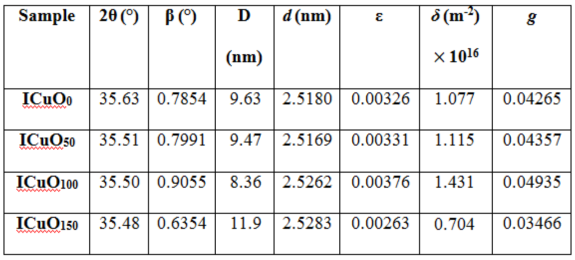


Fig.1 (a-d): The XRD patterns of (a) ICuO0, (b) ICuO50, (c) ICuO100, and (d) ICuO150 thin films.

The crystallite size calculated by using Scherrer's formula (equation 2.2) for the (002) peak in ICuO0, ICuO50, ICuO100, and ICuO150 thin films are found to be 9.6 nm, 9.4 nm, 8.3 nm and 11.9 nm, respectively. The crystallite size slightly increases with dose rate due to localized heating during gamma-irradiation resulting in changes in the lattice volume which causes movement of defects and atoms.

Table 1: XRD parameters of pre- and post-gamma irradiated CuO samples:



Sample	2θ (°)	β (°)	D (nm)	*d* (nm)	ε	*δ* (m^{-2}) × 10^{16}	*g*
ICuO0	35.63	0.7854	9.63	2.5180	0.00326	1.077	0.04265
ICuO50	35.51	0.7991	9.47	2.5169	0.00331	1.115	0.04357
ICuO100	35.50	0.9055	8.36	2.5262	0.00376	1.431	0.04935
ICuO150	35.48	0.6354	11.9	2.5283	0.00263	0.704	0.03466

However, the given gamma dose (i.e. 150 kGy) is sufficient for the perversion of the lattice from their initial states but it is not enough for phase transformation of CuO thin films. It is shown that 'd' values calculated from XRD spectra are slightly amended because of variation in the bond lengths and angles between atoms develops the strain. As per Braggs law, 'd' value changes because of tensile and compression stress, where tensile stress increases 'd' value and compression stress decreases it resulting into shifting of the peak towards lower and higher angle respectively in the XRD pattern

ATR-FTIR Study:

The chemical structure modifications in ICuO50, ICuO100, and ICuO150 thin films as compared to ICuO0 thin film were investigated by ATR-FTIR spectroscopy at room temperature. The FTIR spectra of ICuO0, ICuO50, ICuO100, and ICuO150 thin films are shown in Fig.2(a-d) recorded in the range of 400 to 4000 cm^{-1}. Fig. 2 (a) shows FTIR spectra of ICuO0 thin-film confirmed bands at 523 cm^{-1} and 593 cm^{-1} which are due to the bending vibrations of Cu–O bonds. For the ICuO0 sample, all the observed peaks are discussed. However, the effect of gamma-irradiation on FTIR spectra of ICuO50, ICuO100, and ICuO150 thin films is discussed here.

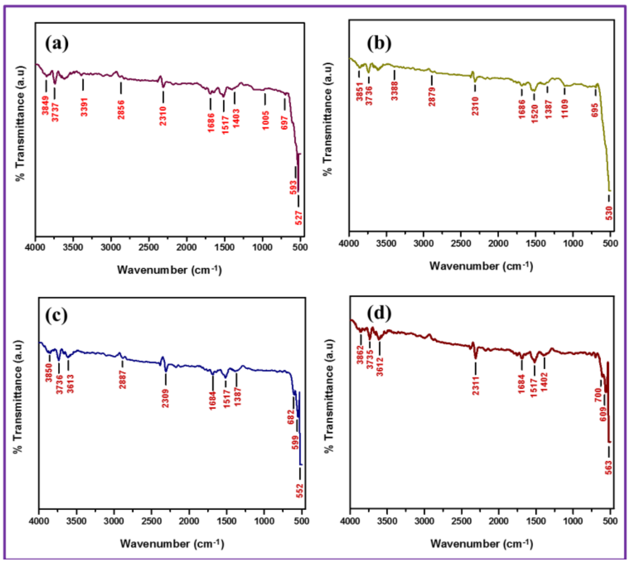


Fig. 2(a-d): The FTIR spectra of (a) ICuO0, (b) ICuO50, (c) ICuO100, and (d) ICuO150 thin films

Morphological Study:

It is known that the performance of active material is strongly associated with its surface morphology. The materials with nanostructured morphology enhance the specific surface area, permits easy adsorption/desorption of electrolyte ions which subsequently ameliorate the electrochemical properties of the electrode. To investigate the surface changes induced in the CuO samples with increasing gamma-radiation dose, FE-SEM images of ICuO0, ICuO50, ICuO100, and ICuO150 thin films were obtained at two different magnifications (25000 X and 50000 X). The FE-SEM woollen-like morphology of the ICuO0 sample, Cracks are observed on different bunches of the woollen-like structure electrodes which are due to the thermal treatment after the growth of films.

EDAX study:

The EDAX spectra of ICuO0, ICuO50, ICuO100, and ICuO150 thin films. The EDAX spectra confirmed that the Cu and O elements are present in the ICuO0, ICuO50, ICuO100, and ICuO150 thin films. The EDAX spectra of ICuO0, ICuO50, ICuO100, and ICuO150 thin films show extra peaks for Fe, Cr, Mo and Ni element which are due to the f-SS substrate. A negligible amount of Sulphur (S) is also detected on account of the $CuSO_4$ precursor used for deposition of CuO thin films. The presence of the C element peak in the EDAX spectrum is of carbon conducting tape on which the sample was mounted during recording.

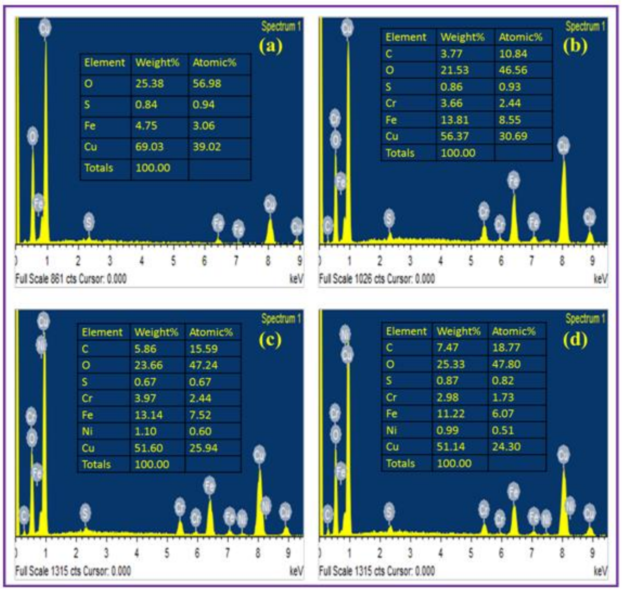


Fig. 3 (a-d): The EDAX spectra of (a) ICuO0, (b) ICuO50, (c) ICuO100, and (d) ICuO150 thin films.

CV study:

It is a well-known fact that the morphology of nanomaterials performs a dominant role in their electrochemical performance. Supercapacitors can be used in space applications as power system stabilization in pyrotechnic mechanism. To use supercapacitors in space craft's or satellites, supercapacitor devices must be ensured for their stability in the harsh environment of space. To investigate the supercapacitive properties, the CV technique is an important and unique to study the energy storage mechanism and within short time it can provoke species forward as well as reverse scan. The CuO electrodes accumulate charges through faradic reactions appearing at the surface or in the bulk of CuO nanostructures.

Table 2: Electrochemical parameters of pre- and post-gamma-irradiated thin films

Sample	C_s (F/g)	SE (Wh/kg)	SP (W/kg)	ESR (Ω/cm^2)
ICuO$_0$	173	4.76	187.5	0.79
ICuO$_{50}$	231	6.19	125	0.46
ICuO$_{100}$	**345**	**9.58**	**140.62**	**0.29**
ICuO$_{150}$	216	5.77	93.75	0.37

Stability study:

Stability is the dominant parameter for evaluating the electrical characteristics of a supercapacitor . A good supercapacitor device needs to keep its stability throughout a high scan rate. Therefore, the cyclic stability of the optimized ICuO100 electrode is measured in 1 M KOH electrolyte employing CV measurement for 3000th cycles at 100 mV/s scan rate., the stability of the ICuO0 electrode is quoted 75 % after 3000th cycles, ,whereas the capacity retention after 3000th CV cycles are found to be 83 % for ICuO100 thin film.

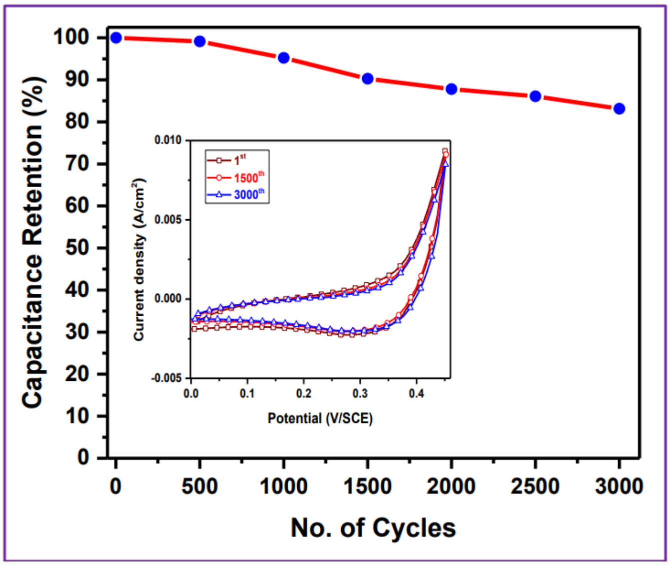


Fig 4: The plot of capacity retention versus cycle number.Inset figure shows CV curves of ICuO100 thin film for 1st,1500th, and 3000th cycles

CONCLUSION

This work tried to illustrate and present a better understanding of the modification of structural, morphological, and supercapacitive properties for CuO thin films as a function of gamma-irradiation. Finally, it may be concluded that gamma-irradiation is an effective technique for enhancing the supercapacitor performance of CuO thin films, and this has great potential for using gamma-irradiated CuO devices in space applications. From the electrochemical analysis of ICuO100 thin film, we can use this film as an electrode for device fabrication when the device has to work in gamma radiation environment for 100 kGy doses. Further studies will be undertaken on the effect of gamma-irradiation on the supercapacitive properties of pristine and 100 kGy irradiated devices.

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