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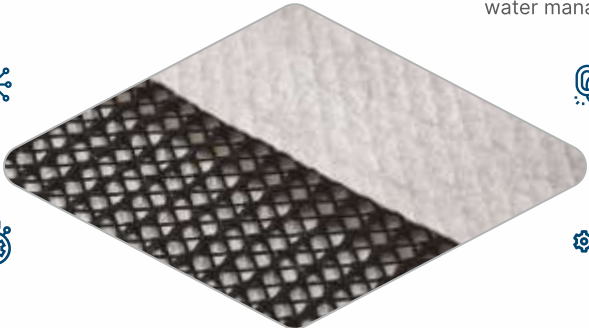



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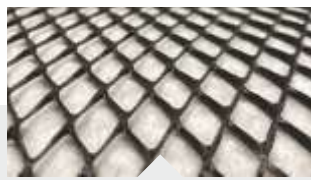
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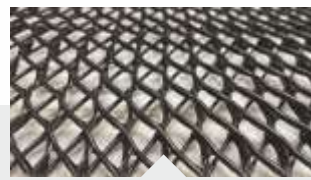
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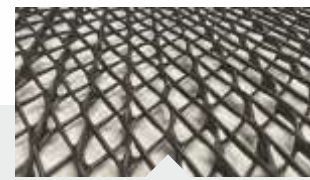
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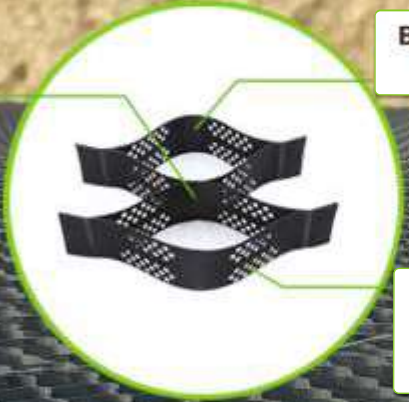




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Greetings!!

Research with persistent and focused efforts lead to a positive result. Fostering research and providing a platform to publish quality research papers and related articles has been a continuous effort of BTRA Scan. We are working hard to help the journal in climbing up the ranking ladder. In continuation to this effort, I am delighted to present to our readers the 4th issue of 52 Edition of BTRA SCAN.

This issue has papers from the different domains such as Engineering of fabric for EMI shielding, Effect of plasma treatment on khadi, Importance of alkaline resistant polyester in geosynthetic application and optical properties of Al doped ZnO film. Now we are open for authors from outside so researchers can send their original articles, case studies, research reviews or empirical contributions for publication in our journal.

I thank my entire publishing team for all their support. Together we would work towards making the journal a truly influential publication. Comments and suggestions are always welcome.

Our sincere thanks to all the reader and contributors for their support and interest.

T V Sreekumar, PhD
Director, BTRA

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Flexible EMI shielding fabrics by using conductive polymer

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Abstract

Nowadays, new development in electronics and electrical devices leads to a new type of electronic pollution, which is called electromagnetic interference. It affects the efficiency, life, and safety of the operation of electronic devices. Electromagnetic interference is the current major issue, and to overcome this issue, the EMI shield is used. For EMI shielding, metal oxide, magnetic materials, and metals are used, but they have some limitations like flexibility, heaviness and high costs. In this context, conductive polymers are widely studied and used to make conductive textile polymer composites due to their properties like electrical, high mechanical and optical properties, ease of synthesis, and environmental stability. The application of conductive polymers is done in many sectors, like industrial applications, and medical and scientific fields. Synthesis of these conductive polymers can be done by oxidative in situ chemical polymerization or by electrochemical polymerization. These conductive polymers can be applied over the fabric by using different application techniques like a jigger dyeing machine, electro-spinning techniques, and electrodeposition of conductive polymer on anode. This process involves the optimization of process parameters during the synthesis in terms of monomer concentration, reaction temperature, treatment duration and monomer: oxidant ratio. These ICP-coated fabrics can be then characterized in terms of surface resistivity (as ohms/square) and EMI Shielding effectiveness (dB).

Keywords

Conductive polymer, Conductive textile, Electromagnetic Interference, EMI shield, Polyaniline, Polypyrrole

Citation

Tanushree V. Tandel and Smita Deogaonkar-Baride- "Flexible EMI shielding fabrics by using conductive polymer", *BTRA Scan* - Vol. LII No. 4 Oct 2023, Page no. 1 to 7

1.0 Introduction:

Electrical and electronic devices are used worldwide for different purposes; electromagnetic interference is a major issue because it distracts electronic devices. For example, in the case of any electronic device like a computer, it generates broadband electromagnetic energy. But due to its energy, it is picked up by other electronic devices like antennas or wireless devices or any other devices, which cause abnormal performance of the electronic gadget. Many researchers and electronic companies have been working on this issue to overcome it with some solutions.

To produce EMI shield material, different metal sheet, metal tubes, and carbon nanotubes were used. But nowadays, textile products have caught more attention due to their properties like versatility and comfort, and ability to have different structures. Figure 1 shows the electromagnetic spectrum, the whole distribution of radiation according to radiation wavelength and its frequency. The rapid increase

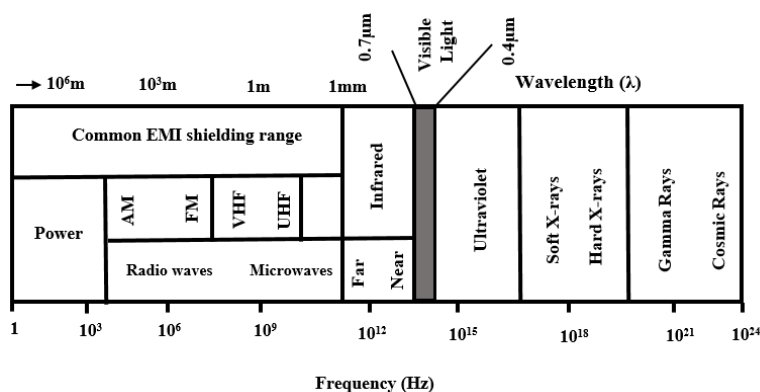


Figure 1: Electromagnetic Spectrum

in the use of electrical products and electronic devices in commercial, scientific, and military systems has raised the issue of electromagnetic interference. In other words, it is called electromagnetic pollution [1]. Due to this problem,

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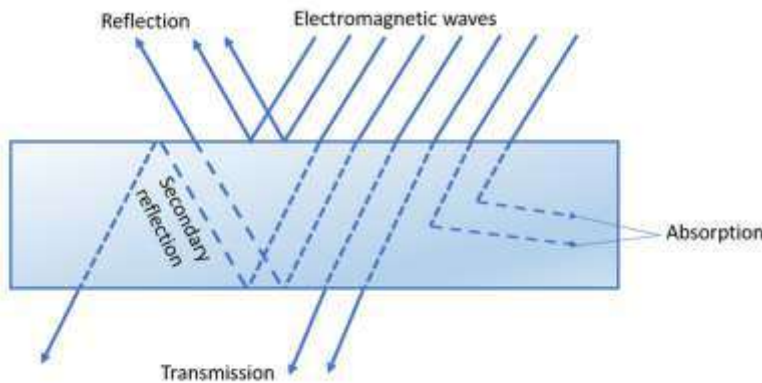


Figure 2: EMI Shield Working(modified and redrawn from reference [1].)

EMI shielding nowadays increases interest. Previously for shielding techniques, metals, and their composites were generally used as shielding materials, but they have drawbacks such as heavy weight, corrosion, poor flexibility and efficiency of shielding. To overcome these problems, conductive polymer composites are mainly of interest.

EMI shield or control is succeeded by reducing the electromagnetic interference emission from the source, by changing the path of electromagnetic energy, and by improving the susceptor. EMI can be controlled by reduction, or conduction depending on the coupling path involved in it [2]. Figure 2 shows how EMI shielding can work. Electrically conductive fabrics can be produced by using metal particles, carbon particles by using different metal salts, or it can be produced by using metal copper wires in fabrics during the weaving of fabric. But the physical and mechanical properties of textile materials are affected by the use of metal wires in textile substrates. To overcome these problems, and because of some advantages of conductive polymer (such as lighter in weight, ease of synthesis, corrosion resistance, can be easily blended with any other material and low cost of the polymer,) currently, conductive textile is produced by using conductive polymers over metal particles or instead of metal wires used in weaving[3,4].

Conductive polymers are from a specific family of polymers made up of monomer units with conjugated bonds, under doping conditions. Widely conductive polymers are used to make conductive coatings, sensor production, microelectronic devices, antistatic materials, etc. Intrinsically conducting polymers are capable of transferring electricity due to their structure of alternate single, and double bonds of polymeric chains[5].

Textile material because of its high surface area used to make composite with intrinsic conducting polymers like polypyrrole, polyaniline, and polythiophene. Intrinsically conducting polymers are organic polymer which is subdivided into no heteroatom, nitrogen-containing, and sulphur-containing. Examples of conducting polymers are such as polyaniline, polypyrrole, polyparaphenylene, poly(3, 4-ethylenedioxythiophene), etc.[6]. Conductive polymer is prepared by using monomers like aniline, pyrrole, thiophene, and its derivatives by electrochemical or

chemical synthesis method[7].

Conductive composite fabrics are prepared with a thin layer of intrinsic conductive polymer. In situ, chemical polymerization techniques for organic monomers are used to create a conductive coating on textile substrates like nylon, cotton, polyester, silk, etc. Monomer adsorption on textile substrate depends on concentration, the temperature used for polymerization, time given for reaction, properties of textile substrate, etc. Conductive polymer processing can be increased by using dopants[8]. Intrinsic conductive polymers are conductive because of the presence of conjugated π electrons in their system. The intrinsic conductive polymer can go easily under the oxidation process in the presence of dopants, which are charge transferring agents, and by using them; conductive polymer can achieve the highest conductivity, like metals. Conductive textile or conductive polymer coated textile composites can be made by using different techniques; in situ polymerization technique of the conducting polymer, or grafting conductive polymer on a textile substrate during polymerization, and used coating techniques where conductive polymer is coated on a textile substrate by coating or by printing. Also, electro-spinning techniques are used to make conductive textiles[9].

2. Conductive Polymers

Several inherently conductive polymers have been studied, viz. polyacetylene, polyaniline, polypyrrole, polypropylene, PEDOT: PSS poly(3-4 ethylene dioxythiophene): poly(styrene sulphonate), polyphenylene, polythiophene, etc. Among all conductive polymers polyaniline and polypyrrole have attracted the most attention nowadays due to their ease of synthesis, ease of processibility, monomer availability environmental stability, high conductivity and cost-effective nature. These conductive polymers can be coated over the fabrics to prepare a flexible conductive textile substrate which retains the comfort of the fabric as it is and does not deteriorate the mechanical and other textile properties of the textile substrate[10-12].

2.1 Polyaniline

Polyaniline is widely used to make conductive textiles due to its ease of synthesis & environmental stability. Polyaniline is made up of reduced and oxidised blocks. Polyaniline contains the chemical flexible $-NH-$ group present in the backbones of polymers which takes part in protonation, and deprotonation and also contributes to π bond formation[13]. Polyaniline is made up of aniline monomer in acidic conditions in the presence of oxidizing agents like ammonium peroxodisulphate, hydrogen peroxide, potassium dichromate, etc. The effective polymerization of aniline is effective under acidic conditions pH 1 to 2 where anilinium cation occurs. The stability and conductivity of polyaniline depend on the form of polymer. A conducting polyaniline polymer is prepared by electrochemically oxidative polymerization or by chemically oxidative polymerization. Chemical synthesis of polyaniline polymer requires three basic reactants; aniline monomer, acidic medium, and

oxidizing agent[14]. Polyaniline has different forms, which have different colours, conductivity, and stability. Figure 3 shows the oxidation stages of aniline. The leucoemeraldine form, which is a coloured substance that contains only amino groups and benzene, results in a non-conductive nature. When the leucoemeraldine form of polymer gets oxidised in acidic media, it converts to emeraldine salt which is conductive, showing a dark green colour to the polymer. Another form of polymer is pernigraniline, which is made up of quinonediimine, and amino benzene. Due to quinonediimine presence, it is unstable in nucleophiles' presence, specifically water, pernigraniline, and its salts readily decompose in the air[15].

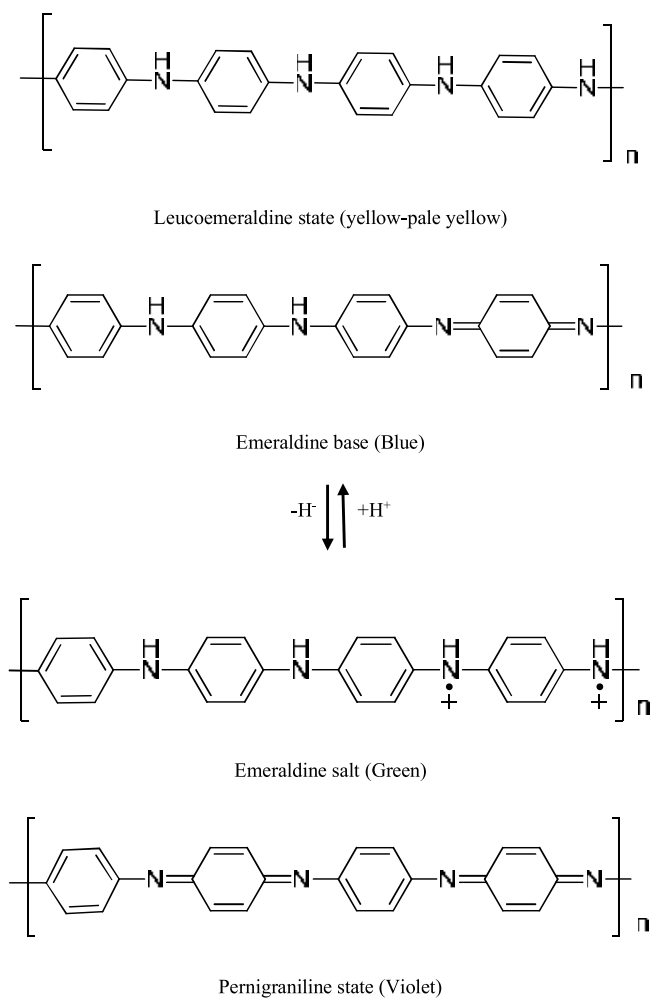


Figure 3: Oxidation stages of aniline

When polyaniline forms an emeraldine base, it is treated with acids where protons primarily react with imine atoms of nitrogen which results in polycations appearing. Because of the positive charge localised on the neighbouring nitrogen atom, it increases the total energy of the polymer. Polyaniline emeraldine salt is formed during the protonation of the emeraldine base with organic and inorganic acids. Polyaniline consists of both quinoid and benzenoid rings, different proportions and ratio differences cause the existence of three oxidised states; the fully reduced form of polyaniline is leucoemeraldine, which is in the quinoid state.

The other form of polyaniline that is fully oxidised is pernigraniline, which is in a benzenoid state, and emeraldine, the salt form of polyaniline, has an equal ratio between both quinoid and benzenoid. The dopant, which is generally used during the synthesis of polyaniline does not change chemical properties or does not create bonds with the main chain. It is present in the close vicinity of the polyaniline polymer chain. Different dopants were mainly used for polyaniline, like strong organic acid hydrochloric acid, organic base acids such as p-toluene sulphonic acid, Dodecylbenzene sulphonic acid, and some aliphatic acids like lauric acid.

The chemical oxidation process is a well-known method for synthesizing polyaniline. In this chemical oxidation method, the monomer of the precursor is mixed with an oxidizing agent in the presence of acids under suitable conditions for a polymer as a product. The color change of the reaction medium to green indicates the formation of polyaniline, which is conductive in nature.

2.2 Polypyrrole

The increasing demand for polypyrrole is due to its properties such as high conductivity and high stability. Initially, pyrrole was synthesized by using hydrogen peroxide to get black amorphous powder. In inorganic solvents, black pyrrole is insoluble and also shows conductivity in the range of 10^{-10} to 10^{-11} s cm⁻¹. Bulk polymer contains 15% crystallinity, and it is monoclinic, it acts as amorphous and not as crystalline. Polypyrrole is generally prepared by using oxidative in situ chemical polymerization of pyrrole using hydrogen peroxide, ammonium peroxide sulphate, potassium permanganate or ferric chloride as oxidizing agent. During this synthesis process, the addition of sulphonic acid-based dopants substantially increases the conductivity[16]. Doped polypyrrole has been the most thoroughly investigated conductive polymer for different applications, because of its high electrical conductivity, ease of preparation, and ease of surface modification. Polypyrrole can be synthesised in bulk quantity at room temperature by using different common organic solvents and also water can be used[17]. In the case of Polypyrrole factors affecting the synthesis process are monomer concentration, oxidant used, the ratio of precursor and oxidant, temperature and time of reaction. Conductive Polypyrrole, which is highly conductive, is synthesized by adding an oxidant and by controlling the oxidant potential of the solution when it is added. Polypyrrole is synthesized mostly by electrochemical synthesis method to obtain highly conductive polymer where the techniques and procedure use the same as other polymers. However due to small anode size; the yield of the product is limited[18].

2.3 Short review on adapting the various processes for coating conducting polymers on variable fabrics

Different techniques were developed to apply the conductive polymer to the substrate or prepare a composite of textile material and conductive polymer. A.J.Patil & S. C. Deogaonkar [2012] prepared a composite of cotton and polyaniline by using a jigger dyeing machine by two step in

situ chemical polymerisation. The concentration of monomer, oxidant to monomer ratio, concentration of protonic acid and duration of the polymerisation were studied. The minimum surface resistivity obtained resulted in 420 ohms/square. In this study, cotton fabric was first treated with monomer for a 1-hour duration by using a jigger dyeing machine and after the monomer application on cotton fabric ammonium peroxodisulphate was introduced in the same bath with suitable sulphonic acid dopants in a controlled temperature of $4 \pm 1^\circ \text{C}$ temperature [19]. YaphingZhao et al. produced a composite of polyaniline and polyester fabric by two-stage in situ polymerisation techniques where for the preparation of the conductive composite they used beaker dipping techniques. Different variables like temperature time of the reaction and initial concentration of the monomer which enhanced the equilibrium of the adsorption of monomer on polyester fibers were observed and studied. To prepare polyester-polyaniline composite fabric, the polyester fabric was soaked into the aniline and protonic acid solution for some duration and the polyester fabric dip the into oxidant solution to complete the polymerisation of the aniline monomer. To continue the polymerisation, fabric passed through the padder and was kept at a cooled condition of 273K for 2 hours [20]. The same techniques were used to produce a novel polyaniline bagasse fiber composite. Yang Zhang, et al discovered the bagasse fibre polyaniline composite. To prepare this polyaniline based fiber aniline monomer was added to protonic acid under ultrasonication conditions. After that oxidant was added to it to follow the polymerisation at a very low temperature. The conductivity achieved for this bagasse fiber polyaniline composite is $2.01 \pm 0.29 \text{ S cm}^{-1}$ [21]. Zhou, Hone J. et al. Prepared ultra-thin electro spun nanofibers using polyaniline in the presence of a doping agent and reported a bulk fiber conductivity of 10^{-2} S/cm [22]. In addition to this conductive textiles can be prepared by knife-over coating techniques where conductive polymers can be blended with acrylate binder, thickener and pH regulator. Surface resistivity obtained from it was found to be in the range of 10^8 to $10^{10} \Omega/\text{square}$ [23]. Based on the surface resistivity obtained by the conductive fabrics, it can be used in a wide range of applications. However, in this paper, our focus is on the EMI Shielding application. The desired resistivity range for EMI shielding application is between 0.001 to 100 ohms/square. [1][24-25].

3. Electromagnetic Interference Shielding

Electromagnetic interference shielding (EMI Shield) is designed to isolate a device's energy so that it does not damage the environment and prevents external energy from attacking. All modern electronics release some electromagnetic radiation and have no EMI resistance. Along with grounding, filtering, and bonding procedures, EMI shielding is a way to attain EMC (electromagnetic compatibility). To change the route of the majority of unwanted electromagnetic waves entering or leaving the equipment, enclosures must be built using the proper material, structure, and form. Through conductive or

magnetic substances, the electromagnetic wave is either absorbed or reflected, changing the course.

Electromagnetic interference shielding can be categorised into four types, depending on continuous or pulse and frequency range. The first type of EMI shielding is known as EMI power spectrum shielding, which is in the range of 1–100 KHz. The second type of electromagnetic interference is in the range of 100 KHz-1GHz and it is the radio frequency range. The third type of EMI is microwave and beyond frequency range and forth type is an electromagnetic pulse which has a broadband, with high-intensity duration bursts of electromagnetic energy, such as nuclear explosion and electric discharge [27].

Electromagnetic interference shielding can be expressed in terms of electromagnetic shielding effectiveness. The EMI shielding effectiveness is measured in terms of the ratio of the power of incoming, and outgoing waves, and it is expressed as follows [28].

$$\text{SET (dB)} = 10 \log (\text{PT} / \text{PI}) = 10 \log (\text{HT} / \text{HI})$$

Based on the physical properties of the substrate, these theoretical formulas are given. Because of this, electromagnetic shielding effectiveness is divided into three terms reflection phenomena, absorption phenomena, and multiple reflections. [29-30]

Where P_i (E_i and H_i) are the power of incident electromagnetic waves and P_T (E_T and H_T) is the power of transmitted electromagnetic waves [31]. The total shielding effectiveness can be further expressed and divided into three components,

$$\text{SE}_T = \text{SE}_A + \text{SE}_R + \text{SE}_M$$

Where Shielding effectiveness due to SE_A absorption, SE_R reflection, and SE_M is multiple reflection. The S_{11} and S_{21} scattering parameters of the two port analyser networks can be related to the reflectance and transmittance, $T = \text{IE}_T / \text{E}_i I^2 = \text{IS}_{21} I^2 = \text{IS}_{12} I^2$ and $R = \text{IE}_R / \text{E}_i I^2 = \text{IS}_{11} I^2 = \text{IS}_{22} I^2$

The absorbance can be mentioned as $A = (1-R-T)$, where the absorbance coefficient is given with respect to the power of the incident EM wave. When SE_A absorbance is more than or equal to 10 dB, SE_M multiple reflection is negligible. Therefore, vanishes multiple reflections SE_M and SE_T can be expressed as $\text{SE}_T = \text{SE}_R + \text{SE}_A$ [28].

The intensity of the incident electromagnetic waves inside the substance after reflections depends on the quantity of (1-R). Effective absorbance can be expressed as

$$A(\text{eff}) \text{ Effective absorbance} = (1-R-T)/(1-R)$$

With respect to the power of the effectively incident electromagnetic wave inside the shielding material. Reflection and effective absorption losses are expressed in the form of $-10 \log (1-R)$ and $-10 \log (1-A_{\text{eff}})$, respectively.

It gives SE_R and SE_A as $\text{SE}_R = -10 \log (1-R)$ and $\text{SE}_A = -10 \log (1-A_{\text{eff}})$

Dielectric conductivity σ_e is related to the dielectric loss ϵ'' by the following expression,

$$\sigma_e = \omega \epsilon'' = 2\pi f \epsilon_0 \epsilon''$$

Absorption coefficient $A = \epsilon''/nc$ suggests that microwave absorption increases as an increase in dielectric loss [31].

Different methods were introduced to measure the shielding effectiveness of the material. The basic principle to calculate shielding effectiveness is the same for all types of methods, only testing setups will differ from each other. By using all these methods we calculate the energy of electromagnetic waves which goes into the substrate and the energy of electromagnetic waves which is transmitted through the substrate to calculate the shielding effectiveness [32]. The effectiveness of the shielding is measured through transmission between two antennas with the enclosure's door open and closed. The shielding efficiency is a difference between these two values, in decibel (dB) units [33]. In some methods, we can calculate the amount of electromagnetic waves reflected from the material. Four techniques are commonly used to measure shielding effectiveness, which are the open field method, shielded room method, shielded box method and coaxial transmission method. Vector Network Analyser is generally and subsequently used to check the electromagnetic waves [34].

The open field method is known to be the most realistic method of measuring the EMI shielding effectiveness of a material or an enclosure as it simulates the conditions the shielding material would be subjected to during its usage [35]. The transmitting and receiving antennas are kept on either side of the shielding material in the shielded box approach, while the receiving antenna and necessary instruments are housed inside a sealed box. The shielded room approach, which in terms of function is comparable to the shielded box method, fixes some of the problems with the shielded box method. In the shielded room method, the specimen is exposed to EMW radiation from the transmitting antenna outside the room while the receiving antenna and equipment are retained in a sealed room [35]. The most commonly used method to measure shielding effectiveness is the coaxial transmission line method because of its repeatability and ability to use a wide range of frequencies. The technique uses a sample holder to hold the reference and load samples needed to measure the shielding effectiveness [32].

Well-known two standards have been developed on this technique, ASTM ES783 and ASTM D493510. [37] As per the first method, a torus-shaped sample is placed at the centre of the coaxial cell which is tapered at both ends to match 50Ω impedance. Figure 4 shows the ASTM D4935 coaxial transmission line fixture setup to check the EMI shielding behaviour of the substrate. The inner and outer diameters of the sample are matched with the diameters of the inner and outer conductor of the coaxial fixture. The input and output powers are measured using a network analyser and substituted to compute the shielding effectiveness of the substrate. Analytically, the calculation of SE of the sample is

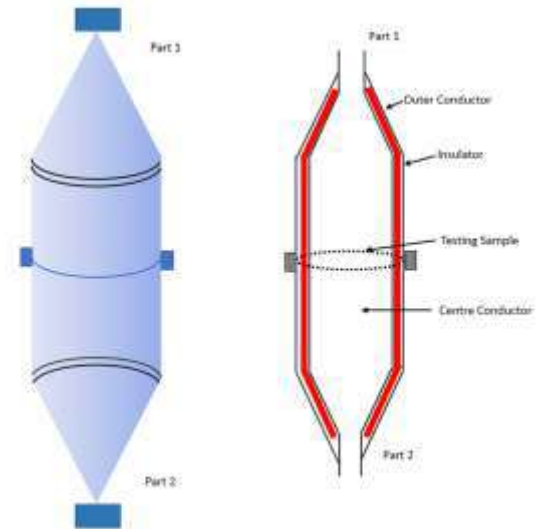


Figure 4: ASTM D4935-10 Coaxial transmission line fixture setup (modify and redrawn using data available in Ref [36])

based on the fact that the TEM (Transverse Electromagnetic) wave propagating in the coaxial transmission line mimics the far-field incident plane wave while the sample acts as a load. The EMI SE of the sample is then computed using the following formula. [36].

$$SE = 20 \log [1 + (Z_0 / 2Z_L)]$$

Where, Z_0 and Z_L are the characteristic impedance of the coaxial transmission line and the impedance presented by the load, respectively. This expression is applicable when perfect contact between the transmission line walls and the sample is established. However, practically achieving perfect contact is extremely difficult. Such imperfections lead to the generation of a contact resistance Z_{CR} in series with Z_L , which participates in SE determination as follows,

$$SE = 20 \log [1 + \{Z_0 / 2(Z_L + Z_{CR})\}]$$

The technique to measure the SE of a material is very simple but lacks accuracy and is not repeatable as the Z_{CR} may vary for different tests. Because of these reasons, the standards ASTM ES783 that was based on this technique were withdrawn in 1988. However, this technique is still very popular to make some crude lab estimations regarding the shielding material.

Each of these measurement techniques has specific measurement parameters such as the dimension of the sample and frequency of the electromagnetic waves.

D.C.Trivedi and S.K.Dhawan et al. produced electromagnetic interference shielding by using polyaniline textile composites using in-situ polymerization. In-situ polymerization of polyaniline is done over fabric in an aqueous condition at a low temperature of around 5-10°C in the presence of a dopant and an oxidizing agent. After grafting conductive polymer on a textile substrate, A.C. conductivity was measured at frequencies of 10 to 105 Hz at

amplitudes of 4 mV, and the coaxial transmission line method was used for measurement of EMI shielding effectiveness at frequencies of 1000 KHz to 1 GHz [38].

S. Geetha K.K. Satheesh Kumar, and D.C. Trivedi et al described a method for preparing and increasing the shielding effectiveness of polyaniline grafted e-glass fabric to control electromagnetic radiation. For the preparation of a composite of polyaniline and e-glass fabric para-toluene sulphonic acid, and camphor 10 sulphonic acid dopants were used. EMI shield effectiveness was checked by using the coaxial method with using frequency range of 0.1 to 1000 MHz. Different thickness samples give different EMI shield values, a 3mm thick sample of conductivity 0.8 S/cm of composite conductive e-glass SE of 39 dB at 0.1MHz and 54 dB at 1000 MHz.[39].

Overall ICP ICP-coated fabrics can lead to excellent EMI shielding property (i.e.>99.9%) by tuning the process parameters of synthesis of ICP-coated fabrics. However, the

washing and atmospheric durability of these developed fabrics limits its application commercially.

4. Conclusion

This review article aims to explore the application of conducting polymer and textile composite in electromagnetic interference shielding. The in situ polymerisation technique can be used to produce flexible conductive textile composite which can be used as EMI shielding. By using suitable dopants and conditions like concentration of monomer, temperature, and time of reaction, metallic conductivity can be achieved for textile conductive polymer substrate. EMI-shielded textiles can be characterised by surface resistivity, the conductivity of the fabric, and coaxial line transmission electromagnetic shielding effectiveness. Based on ease of synthesis and good flexibility, ICP-coated fabrics can be one of the best alternatives towards EMI shielding materials however its durability concerns to be considered for further commercial applications.

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Importance of Alkaline Resistance Polyester in Geosynthetic Application

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Abstract

Geosynthetic materials are innovative and versatile synthetic products that play a vital role in various civil engineering and construction projects to reinforce soil and control erosion. These materials are engineered from polymers and designed to exhibit specific properties that enhance their performance in geotechnical, hydraulic, and environmental projects. Unlike traditional construction materials, geosynthetics offer a range of benefits that can significantly improve project efficiency, sustainability, and long-term durability. When these materials are used in environments with high alkalinity, such as soil with elevated pH levels or exposure to alkaline solutions, they can undergo degradation and lose their effectiveness over time. Therefore, the development of alkaline-resistant polyester for geosynthetics applications is crucial to ensure the long-term performance and durability of these materials. Polyester materials have gained widespread use due to their excellent mechanical properties, chemical resistance and ease of processing. However, their susceptibility to degradation in alkaline environments has driven the need for the development of alkaline-resistant polyester materials. This review aims to provide an in-depth overview of recent advancements in the field of alkaline-resistant polyester materials, focusing on various strategies employed to enhance their resistance to alkaline conditions

Keywords:

Alkaline resistance, Geo-natural, Geosynthetic, Geotextile, Polyester.

Citation

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1.0 Introduction:

Geonatural products encompass materials derived from natural fibers such as jute, cotton, wool, and wood. These materials find their primary application in temporary civil engineering endeavours. However, their usage is somewhat limited due to their rapid biodegradation when interfacing with earth materials, resulting in fewer practical applications compared to geosynthetics. In contrast, geosynthetics refers to man-made materials meticulously engineered for terrain stabilization and tackling the multifaceted challenges encountered in civil engineering projects. These materials take the form of planar, fabricated components, manufactured from polymers like polypropylene, polyester, polyethylene, polyamide, and PVC. Geosynthetics are seamlessly integrated into various civil engineering undertakings, structures, or systems in conjunction with soil, rock, earth, or other geological materials, where they assume a pivotal role.[10]

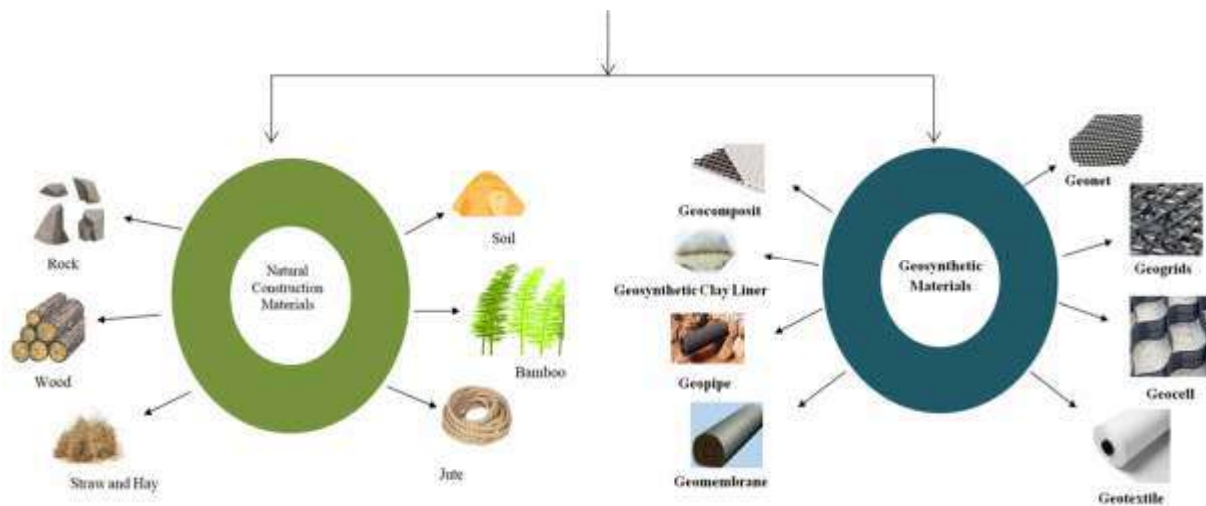
Geosynthetics, as synthetic materials, serve as indispensable assets in diverse civil engineering and environmental

domains. Their versatility is exemplified by their capacity to reinforce soil and provide stabilization in a multitude of applications. Geogrids, geotextiles, and geocells are frequently harnessed for soil reinforcement objectives. Geogrids, characterized by their mesh-like configuration and composed of high-strength polymers, excel in distributing loads efficiently, thereby enhancing the load-bearing capacity of soil. On the other hand, geotextiles, permeable fabrics designed to segregate distinct soil strata while permitting water permeation, serve as effective safeguards against soil erosion and facilitate efficient drainage. Geocells, adopting a three-dimensional honeycomb structure, effectively confine soil, rendering them ideal for tasks such as slope stabilization and erosion control. [2]

Another pivotal role played by geosynthetics pertains to containment systems, including landfills, mining operations, and reservoirs. Here, geomembranes, impervious synthetic liners, take center stage by preventing the migration of liquids and gases. By establishing an impermeable barrier, geomembranes not only safeguard the surrounding environment from potential contamination but also ensure the structural integrity of containment systems.

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Common materials used in civil engineering and environment application



Furthermore, geosynthetics significantly contribute to sustainable construction practices. They often obviate the need for conventional construction materials like aggregates, resulting in a reduced environmental footprint and lower construction expenditures. Additionally, the flexibility in their design allows engineers to tailor solutions to meet the precise requirements of each project. This adaptability fosters innovation in engineering design and construction methodologies. [3]

Certainly, here is a list of both Geo-natural and geosynthetic materials commonly used in civil engineering and environmental applications.

Geonatural Materials:

Soil: The natural foundation for construction, used in embankments, foundations, and other earthworks.

Rock: Used for riprap, gabions, retaining walls, and erosion control.

Wood: Used for various structural applications, such as timber retaining walls and bridge construction.

Straw and Hay: Utilized in erosion control applications and as additives to stabilize soil.

Bamboo: Used in the construction of temporary structures, scaffolding, and erosion control measures.

Jute: Used for erosion control blankets and geotextiles. [4]

Geosynthetic Materials:

Geotextiles: Permeable fabrics used for separation, filtration, drainage, and erosion control.

Geogrids: Mesh-like structures used for soil reinforcement and stabilization.

Geomembranes: Impermeable liners used for containment and environmental protection.

Geocells: Three-dimensional honeycomb-like structures used for slope stabilization, erosion control, and load distribution.

Geocomposites: Combinations of different geosynthetic materials for multiple functions in one product.

Geonets: Open-mesh geosynthetics used for drainage and soil reinforcement.

Geopipes: Perforated pipes encased in geotextiles, used for drainage and fluid transportation.

Geosynthetic Clay Liners (GCLs): Composite materials combining geosynthetics with bentonite clay for containment and barrier systems. [5]

Both Geo-natural and geosynthetic materials have their advantages and are often used in combination to address specific engineering and environmental challenges, providing effective and sustainable solutions in construction and land management. [6]

Alkaline resistance is a critical property for materials used in various applications, such as geotextiles, coatings, and construction materials. Alkaline-resistant polyester refers to a type of polyester material that exhibits resistance to degradation or deterioration when exposed to alkaline environments. This property is particularly important in applications where the material may come into contact with alkaline substances, such as in certain industrial processes, construction materials, chemical storage as well and Geosynthetic applications. Through a combination of theoretical understanding, experimental exploration, and advanced characterization techniques, the development of alkaline-resistant polyester materials is advancing, opening doors to applications in textiles, coatings, construction

materials, and beyond. Further research and collaboration in this area hold the promise of uncovering new avenues for the design and utilization of alkaline-resistant polymers. [7]

Polyester is a man-made material that is produced from ethylene glycol and terephthalic acid. It has some characteristics that are suitable for geosynthetics, such as:

- It has high resistance to deformation and tension, which means it, can maintain its shape and size.
- It has a low tendency to stretch or shrink over time under constant load, which means it does not change its dimensions.
- It has a good ability to withstand chemical reactions, which means it does not deteriorate or corrode in most soil conditions.
- It is denser than water, which means it does not rise or displace when submerged.
- Some of the benefits of using polyester for geosynthetic applications are:
- It can enhance the stability and performance of soil structures, such as roads, embankments, retaining walls, and landfills.
- It can provide different functions for different soil layers and fluids, such as separation, filtration, drainage, reinforcement, and barrier.
- It can reduce the cost and environmental impact of construction by using less natural resources and producing less waste. [8,9]

Polyester finds extensive application as a polymer owing to its favorable mechanical characteristics, resistance to chemicals, and convenient processing. This alkaline-resistant polyester material has gained significant attention as industries seek materials that can withstand exposure to alkaline environments. The development of alkaline-resistant polyester is a multidisciplinary effort that combines polymer chemistry, materials science, and engineering principles. Researchers continue to explore innovative strategies and techniques to create polyester materials that can withstand the challenges posed by alkaline conditions, thereby expanding their range of applications and improving overall performance. Researchers and scientists have explored some strategies to achieve this goal. This review focuses on the latest progress made in the advancement in the development of alkaline-resistant polyester materials.

Literature

Key points for Alkaline Resistance developments in this area include

Monomer Selection: The choice of monomers used in the polymerization process can significantly impact the material's resistance to alkaline substances. Certain monomers or combinations of monomers can lead to polymers with improved alkaline resistance.

Functional Group Modifications: Introducing specific functional groups into the polyester backbone can enhance its resistance to alkaline degradation. For example, incorporating aromatic or heterocyclic groups can provide increased stability in alkaline environments.

Crosslinking: Crosslinking the polymer chains can improve the overall durability and resistance of the polyester material. Crosslinked polymers are less susceptible to chemical degradation, including that caused by alkaline substances.

Additives and Fillers: Incorporating additives or fillers into the polyester matrix can provide additional alkaline resistance. These additives may include nanoparticles, reinforcing agents, stabilizers, and other compounds that enhance the material's overall performance.

Coating and Surface Treatments: Applying coatings or surface treatments to the polyester material can create a barrier that prevents alkaline substances from reaching the polymer matrix. This approach can be particularly useful in applications where the polyester is exposed to intermittent or localized alkaline exposure.

Key considerations

Mechanical Properties: The mechanical properties of the polyester geotextile, such as tensile strength, elongation, and tear resistance, are crucial for its performance in geotechnical applications. Researchers work to ensure that the modifications made to improve alkaline resistance do not compromise these important properties.

Long-Term Durability: Alkaline resistance is particularly important for geotextiles used in applications where they will be exposed to alkaline conditions over extended periods. Research focuses on evaluating the long-term durability and performance of the modified polyester geotextiles under realistic alkaline exposure scenarios.

Compatibility with Soils and Aggregates: Alkaline-resistant polyester geotextiles need to be compatible with the surrounding soils and aggregates in geotechnical applications. Compatibility ensures the effective functioning of the geotextile and prevents any adverse interactions that could compromise its alkaline resistance.

Accelerated Aging Tests: Researchers use accelerated aging tests to simulate long-term exposure to alkaline conditions and assess how the polyester geotextile material will perform over time. This involves subjecting samples to controlled alkaline environments and monitoring changes in physical, mechanical, and chemical properties.

Field Trials and Performance Monitoring: Real-world field trials are conducted to evaluate the performance of alkaline-resistant polyester geotextiles under actual environmental conditions. This helps validate laboratory findings and provides insights into the long-term behavior of the materials.

Regulatory Standards: The development of alkaline-resistant polyester for geotextile applications aligns with regulatory standards and guidelines for construction and civil engineering materials. Meeting these standards ensures that the materials are suitable for use in various infrastructure projects. [10]

Specific factors to consider in the context of geotextiles include

Polymer Chemistry

Researchers focus on modifying the chemical structure of the polyester polymer to enhance its resistance to alkaline degradation. This may involve selecting suitable monomers, incorporating functional groups, or exploring copolymerization techniques that lead to improved alkaline resistance.

Incorporation of Aromatic Moieties: - One of the key strategies to improve alkaline resistance is the incorporation of aromatic moieties into the polyester backbone. Aromatic structures, such as phenylene rings, provide increased stability and hinder the susceptibility of the polymer to alkaline hydrolysis. This modification enhances the material's resistance to chemical attack. Various aromatic monomers, such as terephthalic acid and isophthalic acid, have been used to introduce aromaticity into the polyester structure. Additionally, the use of diols like bisphenol-A can improve alkaline resistance through the enhancement of crosslinking within the polymer matrix. [11]

Functional Monomers and Copolymerization: - Incorporating functional monomers or copolymerization with other monomers that offer alkaline resistance can lead to enhanced properties. For instance, the incorporation of acrylic or methacrylic acid-based monomers into the polyester structure can introduce functional groups that react with alkaline species, reducing the material's susceptibility to degradation. Copolymerization with vinyl monomers can also impart improved alkaline resistance due to the altered chemical composition of the resulting polymer. [12]

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Surface Modification Techniques

Surface modification plays a crucial role in enhancing the alkaline resistance of polyester materials. Plasma treatment and grafting are common techniques used to modify the surface properties, leading to improved interfacial adhesion and a protective layer against alkaline degradation. Plasma treatment introduces functional groups onto the surface, allowing for enhanced interactions with alkaline-resistant additives. Grafting of alkaline-resistant monomers onto the polyester surface can create a protective layer that shields the material from direct exposure to alkaline environments. [13,14,15]

Nanocomposites for Alkaline Resistance

The incorporation of nanoparticles into polyester matrices has gained significant attention for enhancing alkaline resistance. Nanoparticles, such as clay minerals (e.g., montmorillonite) and nano-sized metal oxides (e.g., zinc oxide), can act as barriers against alkaline attack and improve the mechanical properties of the material. The intercalation of clay minerals between polymer chains creates a tortuous pathway for the diffusion of alkaline ions, thereby improving the material's resistance to alkaline environments. [16,17]

Testing and Characterization:

The evaluation of alkaline resistance involves various testing methods and characterization techniques, such as exposure to alkaline solutions of varying pH, measurement of mechanical properties such as tensile strength and elongation at break and modulus before and after exposure to alkaline conditions to determine the extent of degradation and analysis of surface morphology. Analytical characterization techniques like Fourier-transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) provide insights into structural changes and surface morphology, these characterization methods aid in elucidating the mechanisms of alkaline degradation and guide the design of more resistant materials. [18]

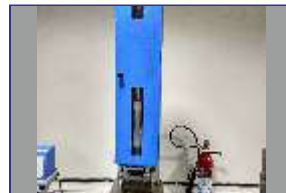
Conclusion:

The development of alkaline-resistant polyester materials is a dynamic area of research with potential applications in diverse industries. Through polymer modification, Nanocomposites, surface modification, blending, and copolymerization, researchers are continually advancing the understanding and capabilities of polyester materials in alkaline environments. Further research is needed to optimize these strategies and tailor alkaline-resistant polyester materials for specific industries and applications.

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Installation Damage of Geosynthetics

The geosynthetics are prone to some amount of damage during their installation. To assess the quantity of the installation damage, a standard method was initially developed by Watts and Brady of the Transport Research Laboratory in the United Kingdom. The procedure has also discussed in the ASTM D 5818 with similar requirements. We are at BTRA doing the test following same ASTM D 5818 method followed by respective tensile strength. For the time being we are using the construction site for the sample preparation. If customer will agree, BTRA will collect the sample from site after standard procedure and provide the report.



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Study of structural and optical properties of aluminium-doped ZnO films on polyethylene terephthalate substrate via radio-frequency sputtering

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Abstract

Al/ZnO films, which are ZnO doped with aluminium, were created by radio-frequency magnetron sputtering in this instance. Polyethylene terephthalate was used as a substrate to prepare Al/ZnO films. The radio frequency (RF) magnetron sputtering power varied from 120 to 140W. Through the use of ultraviolet (UV), field emission scanning electron microscopy (FE-SEM), and X-ray diffraction (XRD), this article investigates the effects of varying the radio frequency power during magnetron sputtering while film production is underway. The XRD confirmed the (002) and (102) planes specific to the hexagonal wurtzite structure. We also found that the average crystallite size decreased from 25.56 to 24.11 nm with the change of RF power in the deposition. In addition, the energy band gap shrank from 3.58 to 3.56 eV. As spherical grains become visible, SEM images show that the surface morphology of the produced films has changed preferentially. The refractive index, film surface roughness, and energy band gap decreased as the RF magnetron sputtering power increased.

Keywords:

Composites, Thin Films, Magnetron Sputtering, Flexible electronics, Wearable electronics

Citation

Abhishek Panwar, Nishant Chandel, Sanjay Kumar - "Study of structural and optical properties of aluminium-doped ZnO films on polyethylene terephthalate substrate via radio-frequency sputtering", *BTRA Scan* - Vol. LII No. 4, Oct. 2023, Page no. 13 to 15

1.0 Introduction

Zinc oxide is known as a potential candidate for transparent conductive oxide (TCO) due to its direct energy band-gap in the range of 3-3.37 eV and significant excitonic binding energy of 60 meV. It also has quite impressive and distinctive structural and optical properties.[1,2] It is a n-type semiconductor having a wurtzite crystal structure. It is thermally and chemically stable, less expensive, abundantly available, and non-toxic [3,4]. Therefore, the preparation of ZnO thin films for various applications such as chemical and bio-sensors [5], catalysts [6], UV photodetectors [7], Schottky diodes⁸, and light-emitting diodes⁹ is currently in use. It is transparent to visible light and can be made highly conductive by doping. The TCO that is now in use is indium tin oxide (ITO); however, it is not a good option because it is poisonous, brittle, expensive, and less stable for H₂ plasma [10]. TCO film's excellent transparency and conductive qualities have led to their widespread use as flexible electrical devices [11]. TCO is frequently employed in

piezoelectric transducers, solar cells, photodetectors, and light-emitting diodes because it produces excellent electrical conductivity when doped with aluminium. However, most of the aforementioned devices are made with Silicon wafers as substrates limiting their potential application of flexible electronics. In this work, we studied the structural, morphological, and optical properties of Al/ZO thin films on polyethylene terephthalate (PET) substrate. Here, we used 2.5% Al-doping by weight of ZnO. The film's thickness significantly impacts the deposited thin films, which are highly crystalline and aligned. We will investigate the structural, morphological, optical, and electrical aspects of the Al/ZnO films deposited using RF magnetron sputtering powers.

2.0 Experimental procedure

Al/ZnO thin films (unit model: 12 "MSPT) were deposited on an ITO-coated PET substrate using RF magnetron sputtering). ZnO: Al (2.5 wt. % Al₂O₃) was used as the target material for the deposition of film. The substrates were

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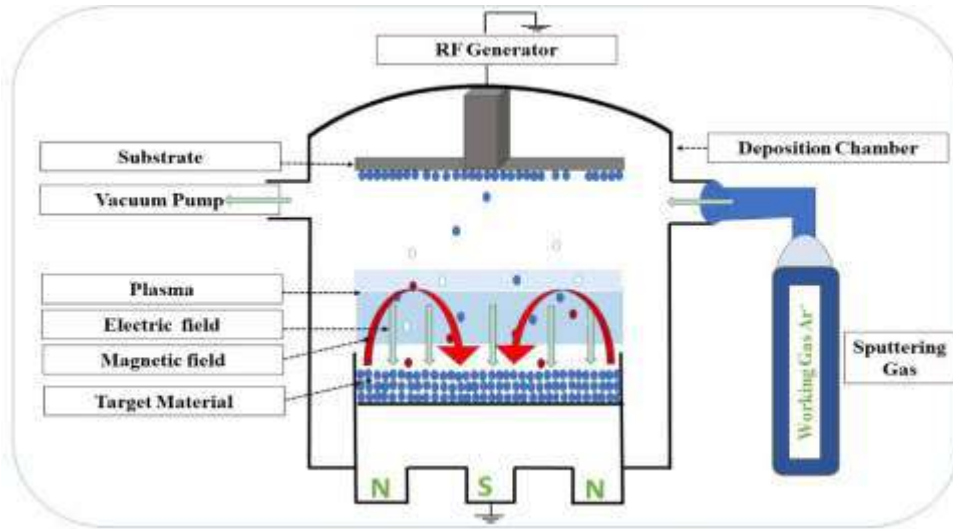


Figure 1. Schematic setup of RF Magnetron Sputtering

ultrasonically cleaned in acetone and deionized water for 10 minutes before thin film deposition. Sputtering gas, or argon, was added into the vacuum chamber after it had been evacuated and pushed down to 4.0×10^{-6} Torr. The thin film deposition technique involved maintaining a pressure of 3.0×10^{-2} Torr throughout and using two radio frequency magnetron sputtering powers, 120 W and 140 W for 20 minutes.

2.1 X-ray Diffraction Pattern (XRD)

Fig. 2 shows the XRD spectrum for Al/ZnO thin films deposited by the RF magnetron sputtering method on PET as substrates with different power, 120W and 140W. ZnO thin film patterns exhibited diffraction planes at (002) and (102) corresponding to the hexagonal wurtzite structure of Zinc oxide, and other diffraction patterns at (222) and (113) represented the mixed phase of aluminium oxide and aluminium oxide (indicated by * and by \$ respectively) [11, 12]. A broader PET substrate pattern, indicated by #, was also acquired. Equation 1, where d is the interplanar spacing for the plane (hkl), and hkl are miller indices, was used to compute the lattice parameters 'c' given in Table 1 from (002) peaks.

$$\frac{1}{d^2} = \frac{4}{3a^2} (h^2 + hk + k^2) + \frac{1}{c^2} \dots\dots\dots(1)$$

The Debye Scherrer formula was applied to find the crystallite size,

$$D = \frac{0.9 \lambda}{\beta \cos \theta} \dots\dots\dots(2)$$

Where λ is the X-ray wavelength (1.54 Å), θ is Bragg's diffraction angle, and β is the full-width half-maximum of (002) peak of the XRD pattern [13]. It was observed that there was no independent peak for aluminium doping in the ZnO thin films. It is since there is a difference in ionic radii of $Zn^{2+}(0.74 \text{ \AA})$ and $Al^{3+}(0.54 \text{ \AA})$. Because of the small ionic

radii of aluminium, it gets induced in the interstices of the ZnO structure without altering the wurtzite structure of ZnO [14].

Table 1. Showing the various parameters of Al/ZnO films

Sample	Position [2 θ]	FWHM	Lattice Parameter (c) Å	Crystallite size (nm)	Optical bandgap (E _g) (eV)
120 W	34.43	0.323	5.220	25.56	3.56
140 W	34.33	0.345	5.203	24.11	3.58

The tabular data observation indicates that as the RF magnetron sputtering power increases, the crystallite size and the band gap decrease, showing that aluminium is being absorbed into interstices suitably.

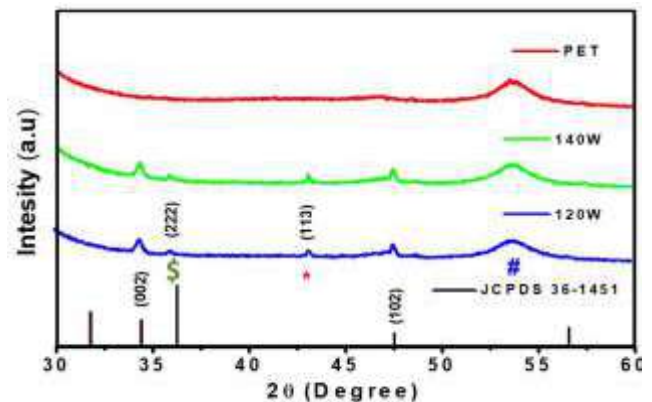


Fig. 2 XRD Spectrum of the Al/ZnO thin films at different Radio Frequency magnetron sputtering powers.

2.2 Field Emission Scanning electron microscopy (FE-SEM)

The surface morphology of Al/ZnO thin films on PET substrate was analyzed by FE-SEM as shown in fig 3(a) & (b). Both films showed signs of spherical grain growth. Surface roughness and Grain size were increased rapidly with the increasing sputtering power from 120W to 140W [15,16]. Spherical grains were uniformly distributed on the substrate, confirming the good adhesion to the substrate. It also considers that grain growth occurs because of the annealing of the thin film, which results in a significant driving force for internal atomic diffusion for grain growth.

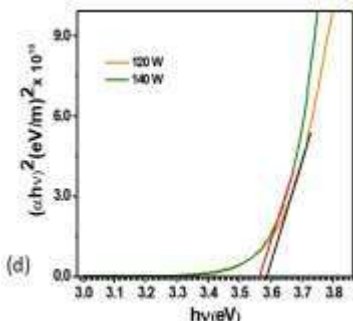
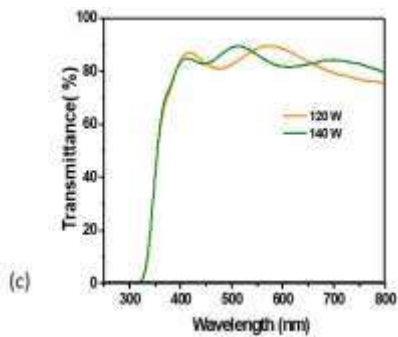
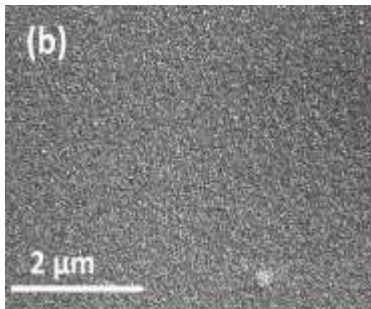
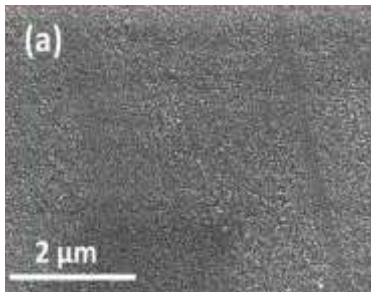


Fig. 3SEM imagesat (a) 120W; (b) 140W.(c) Optical transmittance as a function of wavelength (d) Tauc's plot for the optical energy band gap of the Al/ZnO thin films at various substrate RF magnetron sputtering powers.

2.3 Optical Study

Fig. 3(c) & (d) displays the optical transmittance of the Al/ZnO thin films deposited at various RF magnetron sputtering powers. The transmittance spectra of Al/ZnO thin films were measured between 250 and 800 nm in wavelength. It was observed that both the thin-film samples showed 80% average transmittance in the visible wavelength range. [17]

The optical energy band gap of Al/ZnO thin films was calculated using $(\alpha h\nu)^2$ versus $h\nu$ plots, which resulted in a straight-line fit to the absorption edge of the glass and extrapolation to the $(\alpha h\nu)^2 = 0$ axis. It gives a way to produce an optical energy band gap. As for allowed direct transition, the variation of $(\alpha h\nu)^2$ with photon energy obeys Tauc's plot method.

$$(\alpha h\nu)^2 = A(h\nu - E_g) \dots\dots\dots(3)$$

Where A is the equation constant, E_g is the optical band gap, h is Planck's constant, and α is the absorption coefficient. The value for optical band gaps for both films is given in Table 1. The E_g values were found to be 3.58 and 3.56eV for 120 W and 140 W, respectively. The energy band gap was found to be inversely proportional to the power of Radio Frequency magnetron sputtering. It decreases the carrier concentration, moderating the wide optical band gap [17].

3.0 Conclusion:

This study successfully deposited Al/ZnO thin films on ITO-coated PET substrates with Radio Frequency magnetron sputtering. Hexagonal wurtzite structure with (002) and (102) orientation for ZnO structure was confirmed from XRD patterns. The morphological studies showed that the growth of spherical grains in Al/ZnO thin films was more uniform with the increasing power of Radio Frequency magnetron sputtering in film deposition. The decrease in energy band gap and crystalline size of Al/ZnO films with the increasing of substrate Radio Frequency magnetron sputtering power indicate that control of deposition power is an excellent tool to change the properties of Al/ZnO films. Varying the Radio Frequency magnetron sputtering power of the substrate during film deposition makes the materials developed in this study suitable for use in solar cells, TCO, and flexible/wearable electronics.

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Effect of Plasma on the Mechanical Strength of Khadi Cotton

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Abstract

Exposure to plasma does lead to surface erosion of textile material, we were interested in evaluating the effect of plasma treatment on the mechanical strength condition for Khadi cotton fabrics. Although surface erosion roughens and creates a larger contact area, and it is ideally suited for better dye uptake of the cotton fabrics. The surface erosion also led to the change in the content of carboxyl and carbonyl groups of the cotton fibers which was established by XPS studies. Through the study, it was inferred that the mechanical strength of Khadi cotton was affected significantly less during 1 minute of the plasma exposure.

Key words:

Plasma treatment, Khadi cotton, XPS measurements, mechanical strength

Citation

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1.0 Introduction

Plasma technology has been proven to be having considerable potential in textile processing. It is advantageous as it is a clean, dry and energy-saving technology. Air plasma treatment has been used by several researchers et al.[1] reported a substantial increase in the wettability and wickability of grey cotton fabrics by the treatment of atmospheric air plasma. The introduction of polar groups due to the air plasma was observed by them. Karahan and Ozdogan[2] studied the effect of DBD plasma on raw cotton fabric using air and argon gases. There was an increase in the hydrophilicity and the wickability of plasma-treated samples. Modification on the surface properties of cotton fabric was reported by them, which did not alter the interior parts of the cotton fiber. Similarly, Lam et al.[3] reported improved hydrophilicity of cotton fabric, which led to enhanced effectiveness of post-finishing processes by the oxygen plasma treatment. Similar observations were found by Inbakumaret al.[5] on exposure of low-pressure DC glow discharge in argon to cotton fabric, which showed a significant increase in wicking properties. This was found to be directly related to treatment time, discharge power, and pressure during the plasma exposure.

The physical properties of natural fabrics are also affected by plasma treatment. It does have a detrimental influence on weight loss, whiteness, and yellowness indexes. Even air permeability and water-vapour permeability are affected.

The pilling resistance, thermal properties, and fabric hand properties are also affected by plasma treatment. Inbakumar and Anukaliani[5] used low-temperature glow discharge air plasma to treat silk and wool fabrics. They found that with increasing exposure time, there seemed to be increased loss of the weight of the fabric.

The surface erosion after the plasma treatment of the cotton fibers, has been found to change the carboxyl group and carbonyl group contents of the fiber. Air/oxygen plasma pre-treatment causes improvement in the wettability of the fabric. The enhanced wicking ability can be attributed to the chemical changes caused due to plasma treatment which is responsible for introducing polar oxygen-containing groups such as C–O, C=O, O–C–O, and O–C=O groups on the cotton fibers. As the FTIR–ATR penetrates only on the thin surface of the fabric, the spectra of untreated and plasma-treated samples showed very insignificant changes in chemical composition particularly in C–O and O–H bonds. No conclusion could be drawn from the spectrum.

Some researchers have worked on the effect of Plasma on wool fibers; however, not much have been researched on cotton fiber.

The tensile properties at breaking load, surface morphology, and several low-stress mechanical properties of LTP-treated and untreated wool fabrics have been studied by Goud [6]. Surface morphological changes were found to be dependent on plasma processing parameters. According to this study, the surface thickness, bending rigidity, and shear rigidity of

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the wool fabrics seem to have increased after the plasma treatment. These properties were found to be directly proportional to the applied voltage and inversely proportional to the inter-electrode spacing. The etching effect of low-temperature plasma resulted in fiber roughening. This roughening is higher at higher voltage and lower electrode spacing. There is a decrease in extensibility of the plasma-treated fabrics at lower loads. However, at breaking load, the extensibility as well as the breaking strength of the plasma-treated fabrics are found to increase. This study creates a basic understanding of how different plasma process parameters affect the properties of wool fabrics.

The effect of oxygen plasma treatment on the surface roughness, morphology, chemical surface structure, crystallinity and tensile properties of wool fiber yarn was evaluated. The wool fibers were treated with oxygen plasma at different treatment times. High-resolution scandisk confocal microscopy and scanning electron microscopy were used for the morphological surface characterization of wool fibers. Attenuated Total Reflectance Fourier Transform Infrared spectrometry was used for the analysis of the chemical structures of untreated and plasma-treated wool fiber surfaces. In addition, the percentage of crystallinity and the size of the crystals were investigated using an X-ray diffractometer. Barani et al. reported that oxygen plasma treatment led to the removal of surface lipids and, oxidized the cysteine in the exocuticle, and increased the surface roughness of the wool fiber [Barani and Calvimontes, [7].

Some important physical and mechanical properties of a wool fabric treated with a roll-to-roll atmospheric plasma jet equipment were carried out by [Ceria et al., 8]. Wool fabrics were processed at three different velocities (1, 3 and 6 m/min); the other process variables were kept constant. They reported that the tensile strength, elongation at break, surface thickness, wettability, and air permeability increased after the plasma treatment.

Kan et al. [10] showed that grey cotton fabrics when treated with different combinations of plasma parameters with helium and oxygen gases, showed better desizing, scouring, and bleaching processes when compared with the conventional methods. Wicking and water drop tests showed improvement in wettability of grey cotton fabrics after plasma treatment and yielded better results than conventional desizing and scouring.

The use of Air Plasma treatment brings several advantages to textile processing (i) It can be applied to the continuous processing of fabric rolls; (ii) It is not capital and maintenance intensive (iii) most importantly, it offers a milder surface treatment to substrates within short duration of exposure of the plasma active species.

Therefore, this study aims to investigate the efficiency of plasma and its effectivity on the mechanical strength of Khadi cotton and to analyze how the Air plasma treatment affects the surface of the Khadi cotton when exposed to 1 min of plasma treatment.

We have attempted to study the mechanical strength of the yarn and fabric of Khadi cotton in the present work and correlated it with XPS measurements.

2. Experimental details

2.1. Materials: Khadi cotton fabric was bought from the KVIC store, in Mumbai.

2.2. Atmospheric plasma treatments: Atmospheric air plasma was used. This was operated with, four cylindrical electrode pairs with three power sections. Each electrode pairs were placed 4 cm apart from each other. The samples were placed between the electrodes and passed at various plasma powers (100–300 W) for 8-10 exposures within 1 min. In all treatments, air was used.

2.3. Characterization techniques

2.3.1. Tensile testing : The tensile strength of Khadi fabric was measured in accordance with ASTM standards-For single yarn strength test - ASTM D- 2256, for fabric tensile strength -ASTM D - 5035.

2.3.2. X-ray photoelectron spectroscopy (XPS) analysis- Surface characterization of Khadi cotton and plasma-treated Khadi cotton was performed with a Specs ESCA instrument. Spectra were recorded by using a monochromatic Al Ka radiation source at a power of 200 W (10 kV, 10 mA) electrostatic energy analyzer. X-ray photoelectron spectroscopy (XPS) survey spectra were collected. The concentrations of different chemical states of carbon in the C1s peak were obtained by fitting the curves with Gauss–Lorentz functions.

3. Results and discussion

3.1. Tensile : According to Kawabata [1980], the surface property of the fabric is related to its physical-mechanical properties indirectly. In both the physical properties and chemical properties of the plasma treated substrate, there is evidence evidence that the surface of the fabric gets altered, which depends on the used plasma gas(or gases) and treatment parameters. To determine the extent to which plasma treatment of Khadi Cotton affects the strengths of treated fibers, the tensile strengths of Khadi fibers were determined using a tensile test of the yarn and Khadi cotton fabric which is presented in Table – 1-2. After air plasma treatment of Khadicotton yarn and fabric at 200 W, fabric strength loss occurred at about 8.54% and 5.91%,

respectively. From these tests, we can certainly see that the strength of the Khadi yarn and Khadi cotton fabric was retained by 91.46 % and 94.09 % respectively. The loss in fabric strength of the plasma-treated sample shows very minimal for both Khadi cotton yarn and cotton fabric. Thus, we can say that plasma treatment does not cause any detrimental loss during the exposure when the exposure time was kept for 1 min.

Table - 1 a and b Strength of Control and Plasma treated Khadi Cotton Yarn

Single Yarn Strength of Untreated khadi cotton		Single Yarn Strength of Plasma treated khadi cotton	
Sl.No	Breaking Force (gF)	Sl.No	Breaking Force (gF)
1	100.8	1	95.21
2	107.9	2	92.53
3	104.7	3	100.4
4	108.3	4	97.83
5	103.2	5	94.25
Mean	105	Mean	96.04

Strength Retained(%) =91.46

Table - 2 Strength of Control and Plasma treated Khadi Cotton Yarn

Strength of Untreated Fabric		Strength of Plasma Treated Fabric	
Sl.No	Max Force (N)	Sl.No	Max Force (N)
1	235.8	1	226.8
2	230.3	2	221.56
3	246.8	3	228.95
4	233.56	4	214.63
5	237.72	5	222.48
Mean	236.87	Mean	222.88

Strength Retained(%) = 94.09

3.2 XPS measurement

It was done for control and plasma-treated Khadi cotton samples. It is the most widely used surface analysis technique where surface characterization near the surface region up to 1-2 nm can be determined. In all samples, carbon and oxygen elements were detected. For plasma treated sample, a prominent increase in the height of the oxygen peak to that carbon peak was observed in the survey spectrum. Figure1 shows the C1 scan of the Control Khadi cotton fabric and Figure2 shows the C1 scan of the Plasma treated Khadi cotton fabric. Figure3a and b show the scan survey of control and plasma treated Khadi cotton samples.

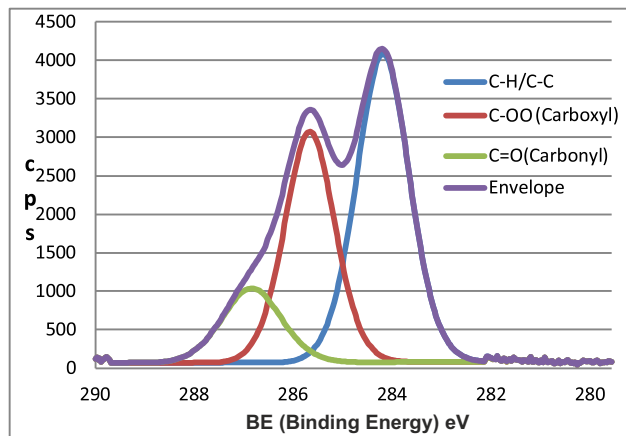


Figure -1 : C 1 scan of control Khadi cotton fabric

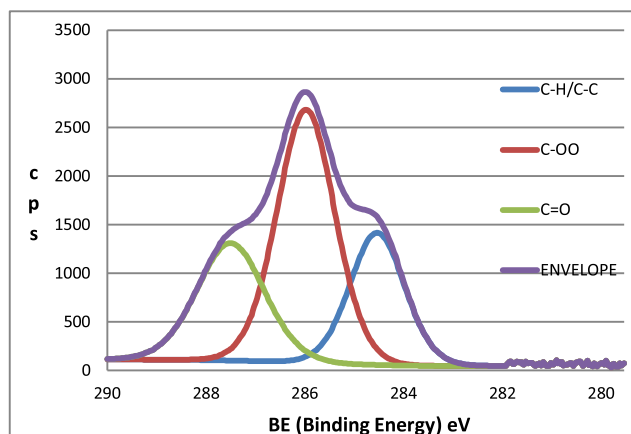


Figure-2 C 1 scan of plasma treated Khadi cotton fabric

The X-ray photoelectron spectroscopy analysis showed discrete differences in the surface groups of Khadi cotton fabric. After the plasma treatment, there was an increase in the oxygen content on the sample surface. This was due to the generation of C=O and C-OO species during the plasma process, which was confirmed by the data obtained from the high-resolution XPS spectra as shown in Table 3, in which an increasing number of carbonyl and carboxyl groups can be seen as well as a relative decrease in the C-H/C-C species. The intensity of the oxygen peaks from the air plasma-treated surface is much stronger than untreated surfaces. It is in concurrence with the findings of Sarma et al.[9].

In the case of the Khadi cotton sample treated by the plasma for 1mins through 8-10 exposure cycles), the C=O increased almost one and a half times (13.62 to 22.84), which confirms the strong surface oxidation mainly to produce the C=O and O-C=O species. C-H/C-C species showed a reduction from 50.55 to 39.54, however the C-O-O species showed a marginal increase from 35.82 to 37.61 in control and plasma-treated cotton fabrics, respectively..

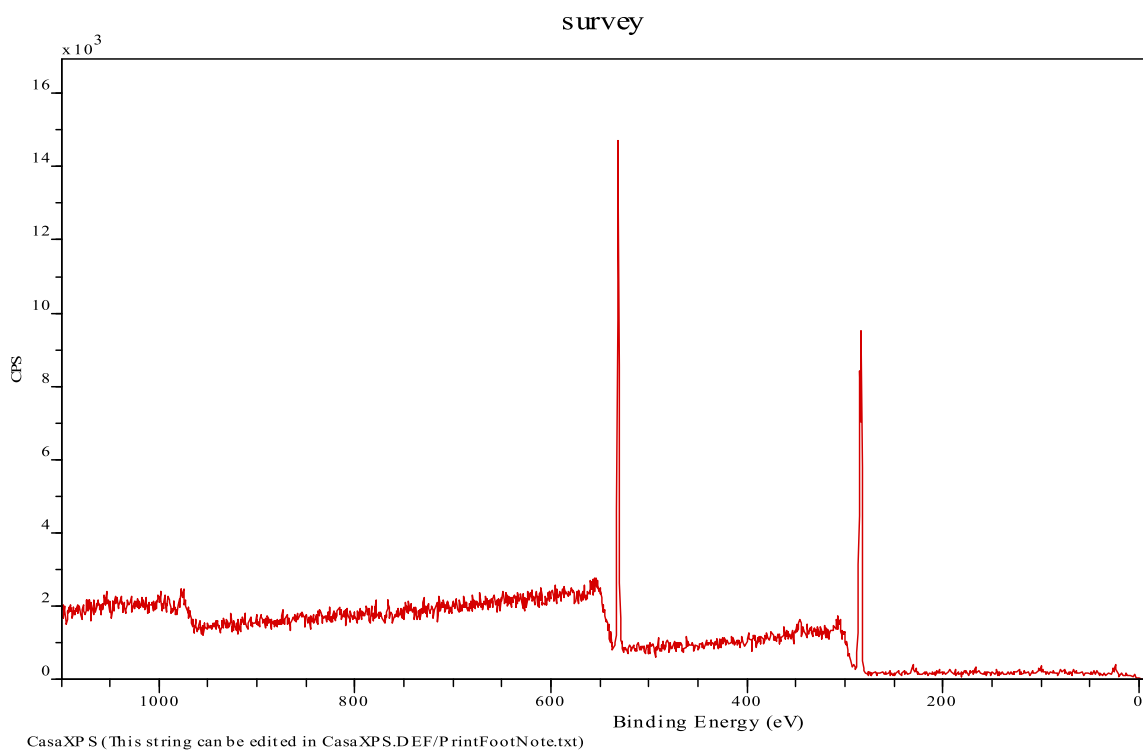


Figure 3 a XPS scan survey of Control Khadi Cotton

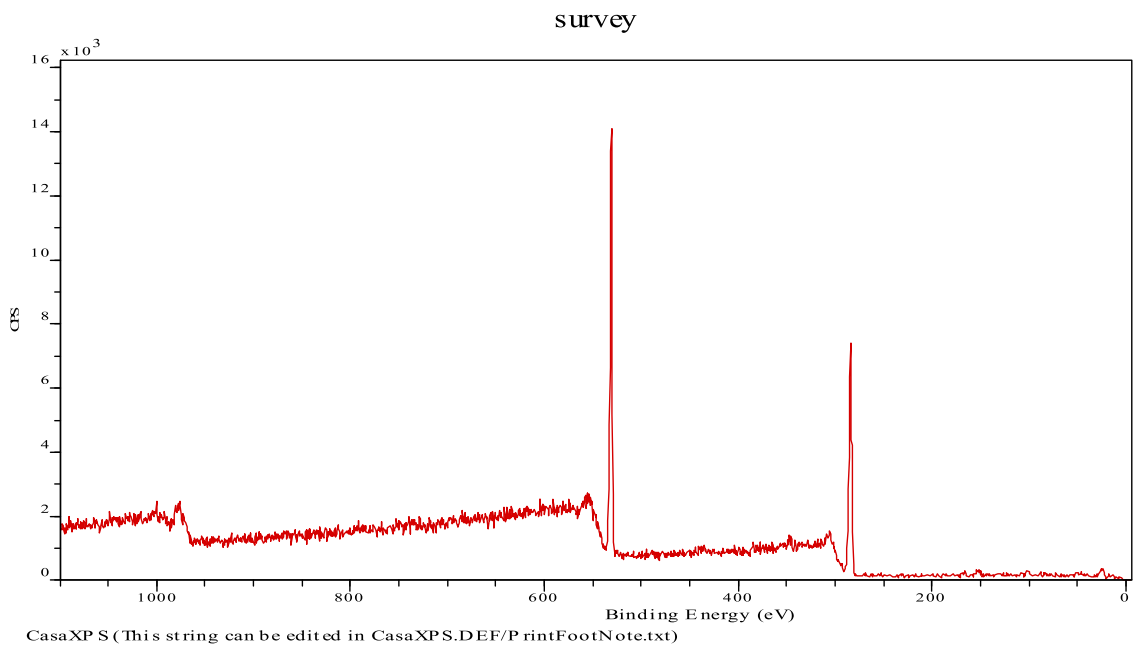


Figure 3b XPS scan survey of Plasma Treated khadi cotton

The X-ray photoelectron spectroscopy analysis showed discrete differences in the surface groups of Khadi cotton fabric. After the plasma treatment, there was an increase in the oxygen content on the sample surface. This was due to the generation of C=O and C–OO species during the plasma process, which was confirmed by the data obtained from the high-resolution XPS spectra as shown in Table 3, in which an increasing number of carbonyl and carboxyl groups can be seen as well as a relative decrease in the C-H/C-C species.

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Table 3 : Atomic Composition of Control and Plasma Treated Samples

FUNCTIONAL GROUP ATOMIC WT %	PEAK POSITION	UNTREATED KHADI COTTON	PLASMA TREATED KHADI COTTON
C—H/C	284.4	50.552	39.547
C-OO	286	35.828	37.613
C=O	287.2	13.62	22.84

Although the plasma treatment increased the oxygen content on the surface of the Khadi cotton fabric as shown by XPS analysis it did not affect the mechanical strength of the fabric during 1 min exposure to the plasma treatment.

4. Conclusion: In this paper, a simple correlation has been drawn between the loss of tensile strength of plasma-treated Khadi cotton through tensile strength evaluation of Khadi cotton and yarn. The XPS evaluation of the Khadi cotton showed that after plasma-treatment, surface oxidation takes place, which enhances the formation of C=O and C—OO species. It was found that the 1 min plasma treatment showed very little change in the tensile strength.

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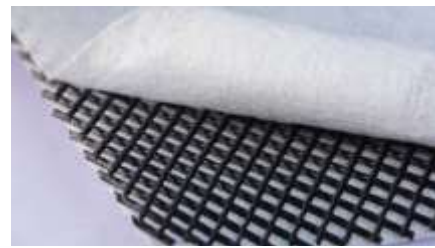
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