Examine The Influence Of Various Rf Power On The Deposition Of Thin Films: To Analyze The Structural And Optical Properties Of Zns Thin Film

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***Abstract*- Nanotechnology has revolutionized the study of materials at the nanoscale, leading to applications in various fields like electronics, medicine, energy, and environmental science. Thin films, particularly wide-bandgap semiconductor Zinc Sulfide (ZnS), have remarkable optical and electrical properties, making them suitable for technological advancements. This study investigates the impact of varying ZnS concentration on the crystal structure, morphology, and optical properties of thin films, focusing on their potential application in solar cells. The research uses RF magnetron sputtering and advanced characterization techniques like X-ray diffraction, UV spectroscopy, and field-emission scanning electron microscopy. The study aims to assess the properties of thin films under varying powers and thicknesses, the findings are expected to provide valuable insights for device manufacturing and design methodologies.**

INTRODUCTION

The field of nanotechnology has made it possible to study materials at the nanoscale[1]. Numerous fields, including electronics, medicine, energy, and environmental science, could benefit from using nanomaterials[2]. Thin films have gained significant popularity in optical and optoelectronic devices due to their compact nature, amazing optical transmittance within the Visible to Near Infrared spectrum, and favourable conductivity characteristics. These attributes render thin films highly suitable for various technological advancements[3,4]. Wide-bandgap semiconductor thin films have easily controllable optical and electrical characteristics that have been studied extensively for optoelectronic fabrication. Zinc sulfide(ZnS) is unique among semiconductors because of its wide optical bandgap, which ranges from 3.60 to 3.90 eV[4]. Understanding their characteristics is essential for creating innovative technologies and products. Because of its strong antireflection qualities, low toxicity, and desired material features, zinc sulfide (ZnS) is a great choice for the n-type front layer in solar cells[5,6]. It should use less semiconductor material and have high conductivity. The material has a significant exciton binding energy of 39 meV[7]. The thickness of thin films and their optoelectrical properties, committed by their structure, interface morphology, and chemical composition, can vary the absorption edge[8]. Thus, to ensure they're suitable for different semiconductor device applications, Thin films must possess an optimal thickness and various other essential characteristics[9,10]. It is utilized in optoelectronics for various applications, including transparent dielectric materials, solar cells, LED lights, and LCDs[11,12]. The deposition of ZnS thin films on glass substrates was done using the RF magnetron sputtering technique, using various powers[13–16]. The thin films were subjected to analysis using X-ray diffraction (XRD), ultraviolet (UV) spectroscopy, and field emission scanning electron microscopy (FESEM) techniques. To elucidate the operational principles of optical devices, the present study employs a non-destructive technique that quantifies the thin film thickness (d), the refractive index (n), and the absorption coefficient (k) of thin film materials[17–20]. Consequently, the best thin film structure is chosen for a certain application. Our research team was commissioned to conduct a comprehensive investigation on ZnS samples, with the primary objective of examining the influence of ZnS concentration on the crystal structure, morphology, and optical properties of the thin films. In addition, we analyze the optical characteristics of Zinc Sulfide thin films through different powers and variable thicknesses[20–23]. The present study holds considerable significance as it elucidates the correlation between theoretically derived characteristics and empirically observed outcomes, thereby providing valuable insights before integrating this material into the manufacturing process of devices [24,25]. The optical properties of these materials are assessed in terms of their thickness, as indicated by the figure of merit [26,27]. It is expected that greater thicknesses will be advantageous for the design process. The figure of value assesses the optical characteristics of these thicknesses, which are anticipated to improve the design.

EXPERIMENTAL TECHNIQUES

The glass substrates are initially immersed in an ultrasonic bath. The ultrasonic cleaning process involves using high-frequency sound waves to induce the formation of minute bubbles inside a solution designated for cleaning purposes. The bubbles facilitate the dislodgement and subsequent removal of impurities from the surface of the glass. Following the ultrasonic cleaning process, the glass substrates undergo degreasing using methanol. Methanol is a solvent known for its efficacy in removing organic pollutants from glass surfaces, including oils and greases. After the initial degreasing process, the substrates undergo an additional degreasing step utilizing acetone. Acetone is a frequently employed solvent to degrease and eliminate residual organic substances. The glass substrates undergo a rinsing process using deionized water. Deionized water is a type of water that has been purified to remove ions and contaminants, rendering it appropriate for use in the final rinsing stage. After cleaning, the glass substrates are subsequently dried using dry nitrogen gas ($N2$). This procedural step guarantees the absence of moisture or impurities on the glass surfaces before subsequent processing or coating procedures. Place the substrate onto the substrate holder or stage within the sputtering chamber. Mount the zinc sulfide (ZnS) target material, which has a purity level of 99.99%, onto the target holder installed within the sputtering chamber. Start the operation of the vacuum pumps to reduce the pressure within the chamber. Create a high-vacuum setting, typically ranging from 10^-3 to 10^-6 mbar, to reduce the presence of undesirable gas molecules. Maintaining a high-vacuum condition is of utmost importance in sputtering procedures, as it minimizes gas interference and guarantees a pristine deposition environment. This technique facilitates enhanced regulation of the sputtering process, leading to superior thin film depositions characterized by improved quality. Decreased gas pressure facilitates the enhanced transportation of sputtered atoms or molecules from the target material toward the substrate. Maintaining a controlled vacuum environment is crucial to achieving precise and dependable thin film deposition. The chamber is often filled with process gas, often consisting of argon. Maintaining a low pressure within the range of 1 to 2 mbars is recommended. The utilization of process gas is important for successfully executing the sputtering process. The system establishes a regulated setting for the process of thin film deposition. This gaseous substance facilitates the processes of ionization and sputtering of the material being targeted. Establishing optimal pressure conditions is of utmost importance in ensuring the efficacy of sputtering operations. Applying various radio frequency (RF) (50W, 70W, and 100W) power to the magnetron facilitates the generation of a plasma discharge. This discharge induces ionization of the argon gas, producing highly energetic ions that impinge upon the target material. The plasma-generated argon ions will impinge upon the target material, releasing (sputtering) atoms or molecules from the surface of the target. The atoms that undergo sputtering will subsequently migrate toward the glass substrate and adhere to its surface, forming a thin film. Control factors such as radio frequency (RF) power, gas pressure, and sputtering time must be adjusted to achieve the desired film thickness and characteristics. The primary objective of this investigation is to monitor the rate at which deposition occurs and assess the film's overall quality during the procedure. It is recommended to cease the application of RF power and terminate the process gas flow once the desired film thickness and corresponding properties have been achieved. Various analytical techniques, including X-ray diffraction (XRD), UV spectroscopy, and FESEM, are employed to examine thin films.

RESULTS AND DISCUSSION

When the RF power levels were changed, the results of the UV absorption analysis of Zinc sulfide thin films revealed impressive characteristics. At 50 W, the (Figure 1) UV absorption spectra showed a relatively low amount of absorption, indicating a limited interaction between the material and UV radiation. However, it is worth noting that a significant alteration in the absorption behaviour was observed as the radio frequency (RF) power was progressively enhanced to 70W and ultimately to 100W. The UV absorption spectra revealed significant improvements in absorption, showing that the ZnS thin films are more susceptible to UV light at higher levels of RF strength. This study's findings emphasize the importance of RF power in determining the UV absorption properties of ZnS thin films. These findings have implications for various applications that require precise UV absorption regulation.

Effect of RF Power on the Structural and Optical Properties of Zinc Sulfide Films

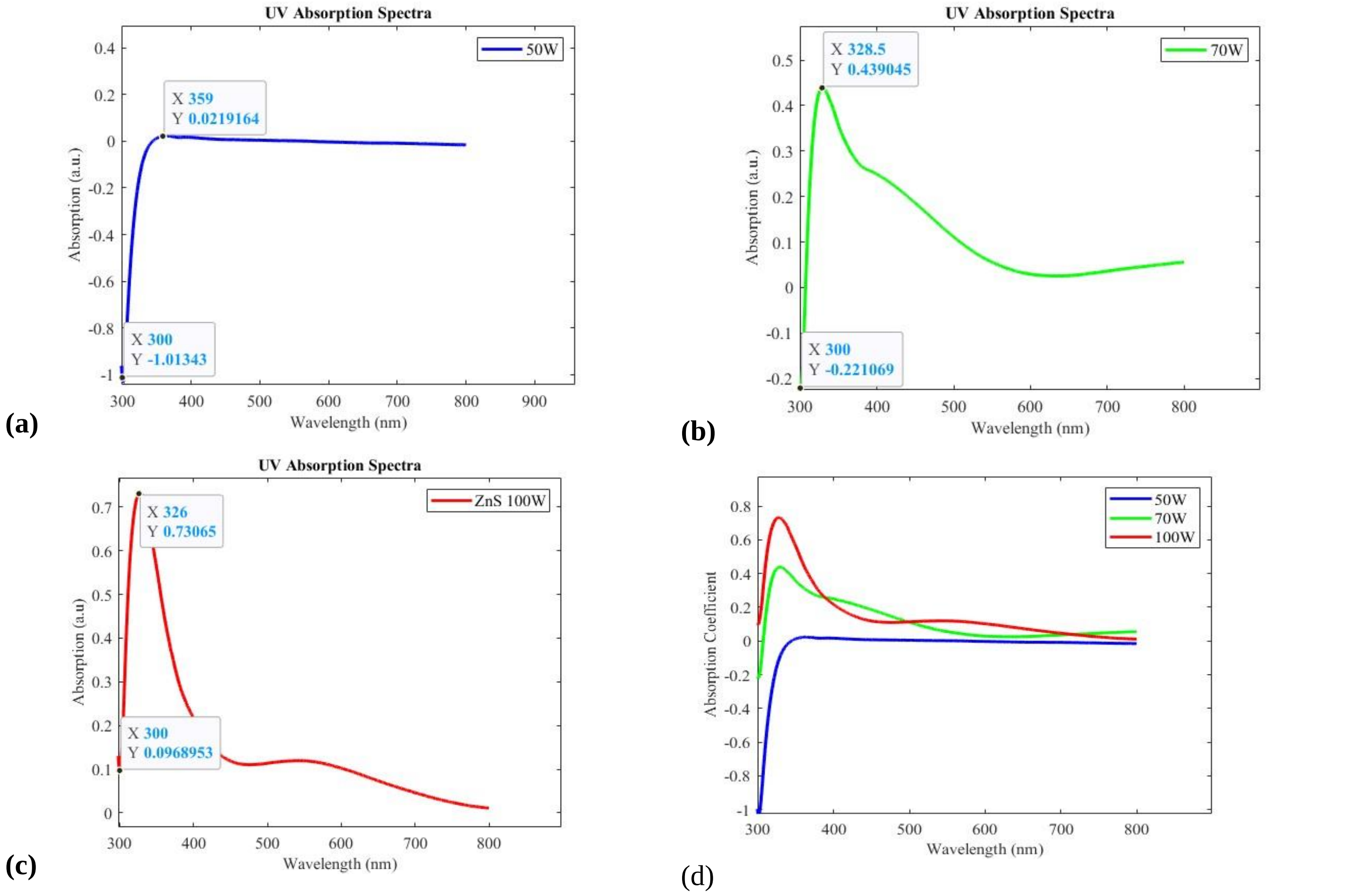
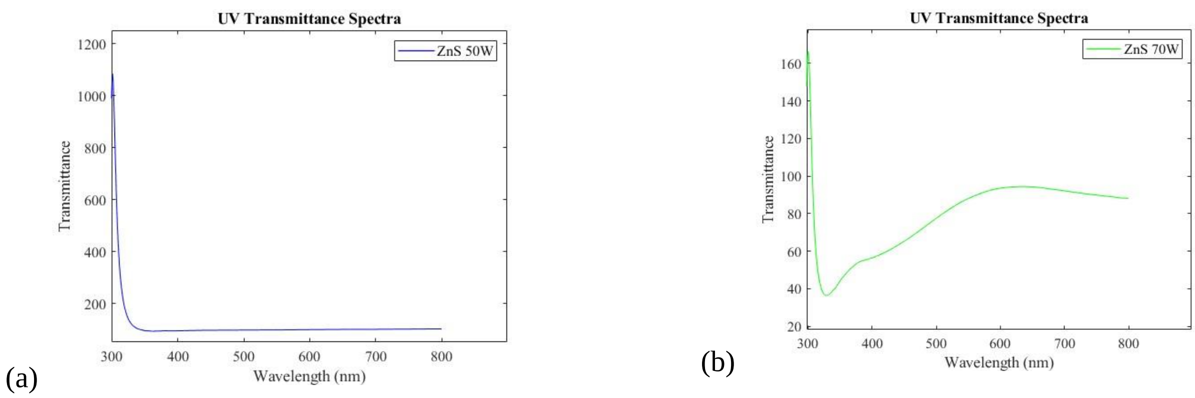


Figure 1 *ZnS Thinfilm UV Absorption Spectral optical characteristics (a), (b), (c) are 50W, 70W, 100W, and (d) is the UV Absorption Coefficient.*

Concurrently, research into the transmittance of ZnS thin films at various radio frequency (RF) power levels revealed unexpected optical phenomena showed in (*Figure 2)*. The transmittance profiles exhibited effective ultraviolet (UV) light transmission at a power output of 50W, confirming the material's transparency within discrete UV wavelength intervals. Nonetheless, the transmittance spectra changed noticeably when the radio frequency (RF) power was increased to 70W and 100W. The observed change in the UV light transmission qualities of the material reveals alterations that could affect applications that require precise control over UV transparency. The results show the importance of RF power in altering the transmittance characteristics of ZnS thin films, providing insights into their optical behaviour under changing power situations. The next sections concisely review the UV absorption and transmittance results found in ZnS thin films at various RF power levels. The authors show how changes in power dynamics affect the optical properties of the subject matter.



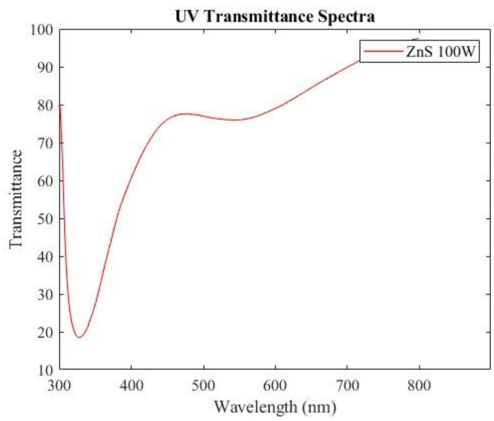


Figure 3 *ZnS Thinfilm UV Transmittance Spectral optical characteristics (a), (b), (c) are 50W, 70W, 100W*

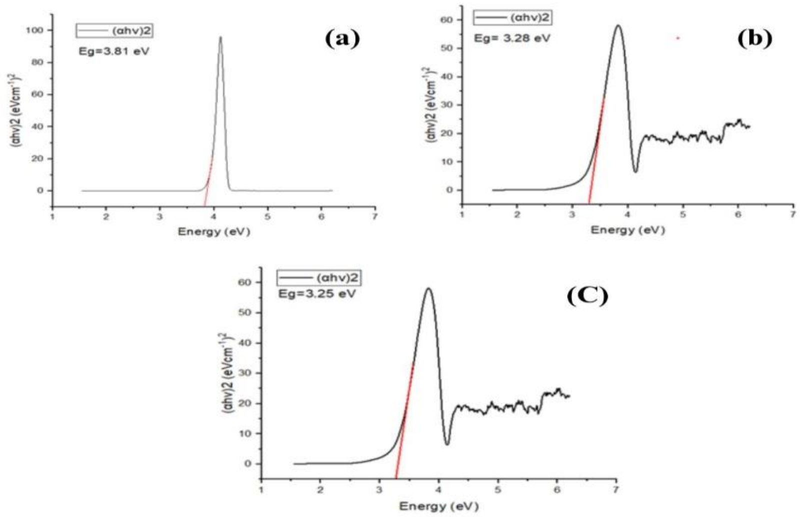


Figure 4 Tauc plots for the ZnS films(a.50W, b.70W, c.100W) deposited on glass substrates by the RF magnetron sputtering technique with various RF powers

Table 1 Analyze the Bandgap(eV) of ZnS thin flms(a, b, c)

Sample Name RF Power(Watt)	Deposition Time(min)	Substract Temp	Base Pressure (m.bar)	Ar	Bandgap(eV)
a) ZnS 50W	20min	RT	2×10^{-5}	1.96 bar	3.81
b) ZnS 70W	20min	RT	2×10^{-5}	1.96 bar	3.28
c) ZnS 100W	20min	RT	2×10^{-5}	1.96 bar	3.25

The XRD Method to examine the structural characteristics and alignment of ZnS nanoparticles at the crystalline layer level. The results acquired from the experiment are visually depicted in Figure 2. The XRD patterns obtained from the analysis of zinc sulfide exhibit a distinct and notable peak. The diffraction peaks observed in the data correspond to certain lattice planes inside the crystalline structure, namely (111). The XRD analysis elucidates the crystalline arrangement of the ZnS nanoparticles, exhibiting a harmonious correspondence with the hexagonal wurtzite phase. Therefore, the absence of an impurity peak in the graph suggests that the ZnS nanoparticles exhibited a high purity level. The average particle size, wavelength, and FWHM are determined using Debye-Scherrer's equation, deduced from the X-ray diffraction (XRD) graph.

$D=K\lambda/\beta \cos\theta$

The equation provided calculates the crystalline size (D) in nanometers (nm) based on the variables K, λ, β, and θ. The dimensionless form component, denoted as K-constant, is contingent upon the crystalline shape. The FWHM is a measure utilized to quantify a peak width in a distribution and is denoted by the symbol **β (°)**. The diffracted Bragg average refers to the average of the diffraction angles (θ) in a Bragg diffraction experiment. The symbol denotes the wavelength of the incident X-ray- ***λ***.

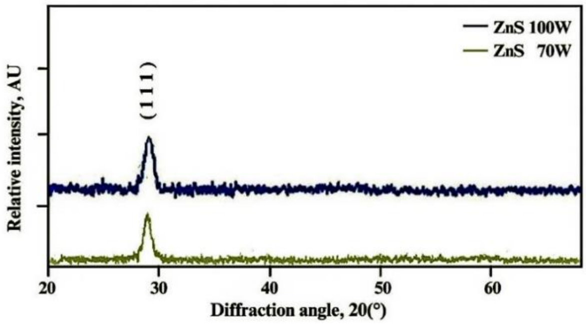


Figure 5XRD patterns of as-deposited on 70W and 100W at (RT)

Table 2 Calculated values of structural properties of ZnS thin flms

Deposition Power (W)	**Thickness, t (nm)**	**Peak position, 2θ (°)**	**d-spacing, d (nm)**	**FWHM, β (°)**	**The lattice parameter, a (nm)**	**Crystallite size, D (nm)**
70 W	127	28.23	3.1325	0.562	5.4548	9.563
100W	165	29.37	3.1378	0.326	5.4831	12.783

The elemental composition of a Thin Film of zinc sulfide (ZnS) was investigated using Energy-dispersive X-ray spectroscopy (EDX). The elements Zn, S, dramatic peaks. In comparison to the samples, the EDX measurement of ZnS revealed a smaller amount of carbon in ZnS in the quantum state. The Zinc content in the sample amounts to 17.01% in 70Wand 18.27% in 100W of the overall weight, whereas the zinc sulfide sample as a whole accounts for 99%. This finding shows that the carbon content of the ZnS samples has decreased. The analysis of zinc sulfide thin films (ZnS) using electron dispersive X-ray (EDX) is reported

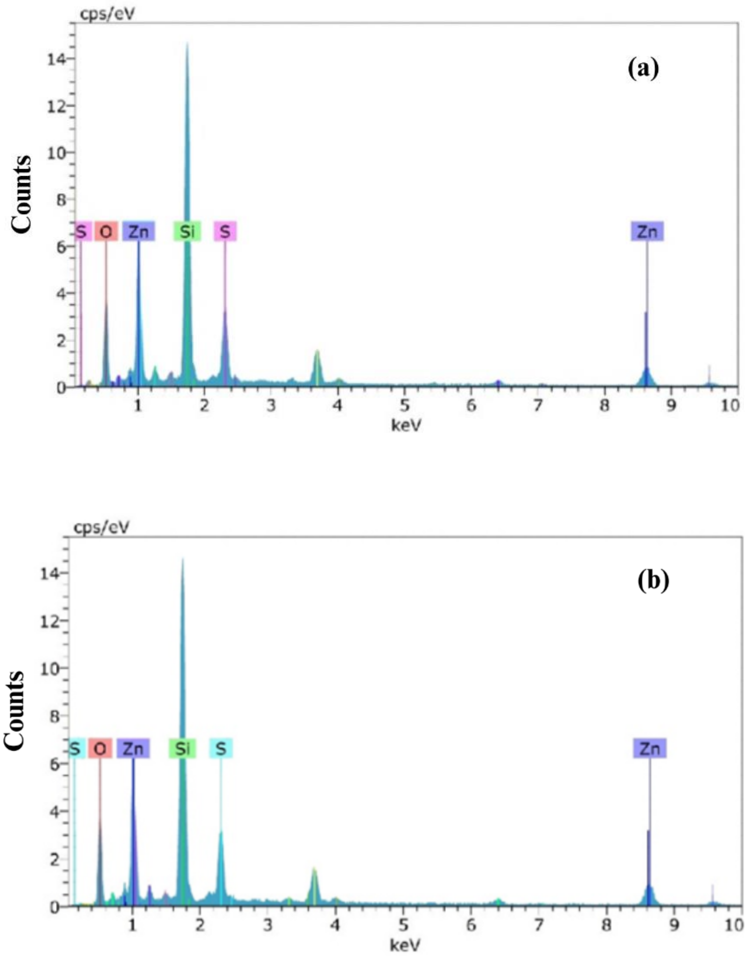


Figure 6 EDX spectra of a ZnS thin film deposited at 70W, 100W respectively (a), (b)

Table 3 EDX profile of ZnS film deposited at 70W, 100W

Element		Weight Percentage	Atomic Percentage	Atom Percentage in Series	Error (1 Sigma)
ZnS 70W	Zinc (Zn)	11.83%	17.01%	6.43%	0.44%
	Sulfur (S)	5.33%	7.66%	5.91%	0.24%
	Silicon (Si)	18.05%	25.96%	22.86%	0.81%
ZnS 100W	Zinc (Zn)	13.97%	18.27%	6.78%	0.48%
	Sulfur (S)	5.56%	7.27%	5.50%	0.24%
	Silicon (Si)	18.88%	24.69%	21.33%	0.84%

This investigation's primary Objective entailed utilizing FESEM to examine the morphological characteristics of zinc sulfide (ZnS). The spherical surface morphology of ZnS nanoparticles is evident. The FESEM images of zinc ZnS showcase the occurrence of particle aggregation, which is discernible in a non-uniform distribution across the sample.

The system under investigation comprises many particles that display a wide range of observed morphologies. The visual representation of the physical characteristics of zinc sulfide (ZnS) particles can be observed in Figures .

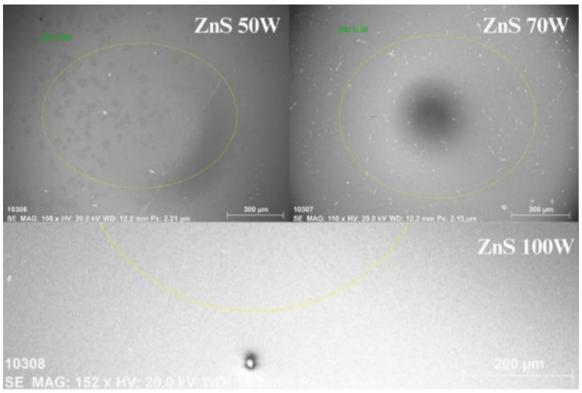


Figure 7 FESEM images of ZnS thin films for various RF Power 50W, 70W, 100W

Conclusion

The unique characteristics observed in the UV absorption behavior of Zinc sulfide (ZnS) thin films can be attributed to the variations in RF power levels. At a power level of 50 watts, the observed UV absorption spectra displayed a noticeable but relatively low level of absorption, indicating a restricted degree of interaction with ultraviolet radiation. Remarkably, a conspicuous alteration in the absorption characteristics was observed as the radio frequency (RF) power was incrementally raised to 70W and 100W, thereby unveiling an augmented vulnerability of ZnS thin films to ultraviolet (UV) light. The significance of RF power in influencing the characteristics of UV absorption is highlighted, indicating potential ramifications for applications that necessitate accurate management of UV absorption. Concurrently, a comprehensive investigation was conducted to analyze the transmittance characteristics of ZnS thin films under varying radio frequency (RF) power levels, leading to the discovery of unforeseen optical phenomena. The transparency of a material within specific UV wavelength intervals was confirmed through the assessment of effective UV light transmission at a power output of 50W. Significant alterations in the transmittance spectra were observed as the radio frequency (RF) power was progressively increased to 70W and 100W. This observation underscores the crucial role played by RF power in shaping the transmittance characteristics. The aforementioned findings offer valuable insights into the optical characteristics exhibited by ZnS thin films when subjected to different power conditions. These insights hold significant relevance for the field of optoelectronics, as they contribute to our understanding of the behavior and performance of ZnS thin films in various applications.

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