The Assessment of External Distortion of Electrodeposited Silver Chalcogenide Thin Films via Holographic Interferometry

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Abstract

To investigate the surface deformation of Silver Chalcogenide thin film electrodeposited on a chrome steel substrate, the process known as Double Exposure Holographic Interferometry or DEHI is repurposed. Using HNDT the sample that has been strained (loaded) and the test sample are compared interferometrically.

If the object is stressed to the point that the surface around the flaw exhibits an unusual deformation, the flaw can be identified. Through the use of holographic interferometry, objects with optically rough surfaces can have their static and dynamic displacement measured with optical interferometry precision. These measures can be used in non-destructive testing as well as stress, strain, and vibration analysis. Variations in optical path length in transparent medium can also be detected using it. Holographic interferometry with double exposure is employed in security applications towards help identify changes in the fringe pattern caused by the application of stress, strain, etc. We report a method for the in-situ creation and understanding of fringe patterns that arise when a comparison wave is interfered with in order to reconstruct a wave that was generated previously and stored in a hologram.

The techniques described in this research can be applied to quality control as well as the design stage. They measure the deformation of an object under study in all three dimensions when it is subjected to external loading or service conditions.

Keywords: DEHI, NDT, Hologram, Surface deformation, Silver Chalcogenide thin films, Fringe pattern

1. Introduction

An image of the optical interference pattern created at the junction of two coherent optical beams is called a hologram. The two fundamental ideas of holography are light wave diffraction and interference. Holographic interferometry-based Non Destructive Testing (NDT) emerged as a result of this. These days, a lot of research and testing is done on the stability of materials using this technology. Materials that fluctuate somewhat in size over time have been examined using the DEHI approach. Because interference fringes would cover the reconstructed picture at specific areas if the surface were slightly deformed during double-exposure hologram recording, the application of the DEHI technology is unique and ideal for a permanent record of relative surface. [1]

The techniques used to record and reconstruct a holographically encoded item demonstrated that the reconstruction includes all relevant information about the object. Therefore, it makes sense to attempt to cause a holographic object to interfere with the initially deformed item. Fringes typically emerge in two-wave interferences, and they are mostly the result of cosine modulation.

The difference in the optical phases of the interference-causing waves is directly related to this modulation. The interferences between the two wave fronts will enhance the differences in optical phase between the initial object and its reference if an object wave interferes with the object's holographic wave. It appears that structures that have been subjected to mechanical, thermal, or pneumatic stresses in a static, stationary, or transitory system can be studied using this method. Because of the straightforward display of the fringes that represent the deformation and the data reduction of these fringes, this kind of holography enables a comprehensive assessment that is both qualitative and quantitative. [2]

The only realistic source of monochromatic light that can be utilised to illuminate the specimen's surface while maintaining coherent light quality is a laser. Every kind of laser has a distinct wavelength; for example, Light from a helium-neon laser is produced at 632.8 nm. For holography, high-resolution films

are also required. Digital image processing and CCD technology have made digital holographic interferometry extremely flexible and real-time visualisation possible. Moreover, automated pattern analysis for flaw detection and analysis can be facilitated by image processing systems. For industrial uses including the thin film structures are becoming more and more important for the fabrication of solar panels, microelectronic devices, and micro systems. [3, 4]

With a focus on the mechanisms underlying interfacial failure and ongoing issues with thin-film structure machining, this paper reviewed the state-of-the-art to provide important insights into the interfacial failure under mechanical loading, it is necessary to comprehend the deformation properties of thin-film systems.

Within this research, we employed the DEHI approach to examine The substrate made of stainless steel has surface distortion following the dc electrodeposition method of Silver Sulphide, Silver selenide and Silver telluride films. We reported a quantitative assessment of the amount of film that has been deposited and the film's thickness after deposit.

To the best of our knowledge, this report is based on in-situ nondestructive testing (NDT) of silver chalcogenide thin film using DEHI. Surface deformation studies of silver chalcogenide thin films are extremely uncommon in the literature, so this study will undoubtedly serve as a thorough and fundamental foundation for future research on the use and application of silver chalcogenide thin film related applications.

Materials and Methods

For several decades, chalcogenide thin films have garnered significant interest due to their exceptional structural, electrical, and optical capabilities, as well as their abundance in the earth and environmental friendliness. It has been used in photoconductive devices and solar-specific coatings, photovoltaic cells as well as photochemical cells, electrochemical storage cells and supercapacitor.

Ag_2S barrier layer in the visible and near-IR cells have been utilized as detecting elements. Recently, the application of Ag2S in the electrochemical photovoltaic (ECPV) Since the current Ag/Ag2S couple's storage efficiency is approximately, there has been a lot of interest in storage cells as storage electrodes. 90% Holography a LASER application that is used to record interference fringe patterns, is the main goal of this study. By recording holograms, all the parameters can be measured, including The thin film's thickness, the mass deposited, along with the tension placed on the film's substrate.[5]

2.1. Experimental Set up

2.1.1 Making Ag_2S thin films using the electrodeposition method

By dissolving ethylene diamine tetra acetic acid (EDTA) in double-distilled water as a complexing agent, 0.02M $AgNO_3$ and 0.06M $Na_2S_2O_3$ were used to deposit the silver sulphide thin films cathodically. The electrodeposition approach was used to place the thin films uniformly and good adherently at room temperature. The substrates utilized were glasses coated in fluorine-doped tin oxide (FTO) and stainless-steel plates. The films were ready for varying intervals of time. Stainless steel substrates were washed with twice as much distilled water and polished with smooth polish paper (zero fine grade) prior to being used in the electrolytic bath. [6]. To get rid of the oily residue on the surface, the substrates were cleaned, etched in 10% H_2SO_4 for two minutes, and then dried using hot air and double distilled water. The substrates' area (3 cm^2) was electrodedeposited in an undisturbed bath while the substrates were in the potentiostatic state. Three electrodes were used for electrochemical research and film deposition. The standard hydrogen electrode, or Saturated Calomel Electrode (SCE, E = 0.244 V/SHE), served as the reference electrode. An anode consisting of area 5 cm by 2 cm graphite plate was utilized. The working electrodes were FTO-coated glass substrates and stainless steel. The DEHI technique was adopted to measure the film's mass, thickness, and pressure applied to the substrate during the film-deposition process [7]. As shown in Fig. 1, this is the experimental setup used to record the thin film hologram. The beam splitter (BS) receives the light from the laser supply. Mirror M1 is illuminated by 50% of the

incident light that is transferred, illuminating the stainless steel substrate. Object beams are created by collecting scattered light coming from the chrome steel substrate on holographic plates. Additionally, the reference beam a holographic plate is incident upon the 50% reflected beam First, without depositing any film, a metal substrate was recorded on a holographic plate. Second, by depositing film, say for a few seconds, the holographic plate was once more shown. It is recreated with the same mindset as when it was recorded [8].

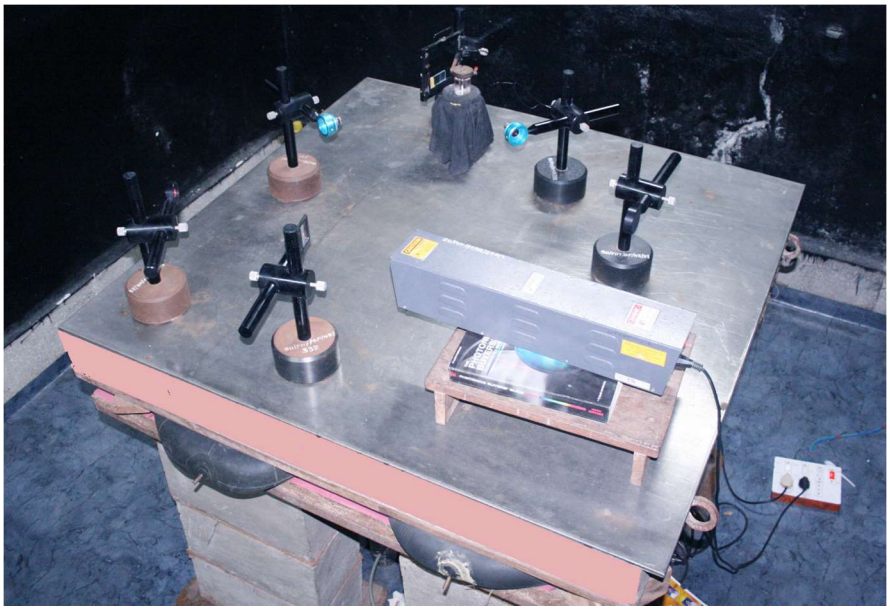


Figure 1: Surface deformation study of silver chalcogenide thin film

The holograms were captured for specific time periods on holographic plates (Kodak 8E 75 HD). The holographic film was analyzed and altered most efficiently in the direction of the reference wave. The reference beam reveals the reconstructed picture of the substrate, displaying the fringes that are located on the surface. The substrate is illuminated with a laser beam during the hologram recording process at an angle θ1 with the surface; subsequently, during reconstruction, it is taken into consideration at an angle θ2. A superimposed fringe pattern that resembles a surface displacement is present in the reconstructed image[9]. Ag_2Se and Ag_2Te were treated with the same method.

Results

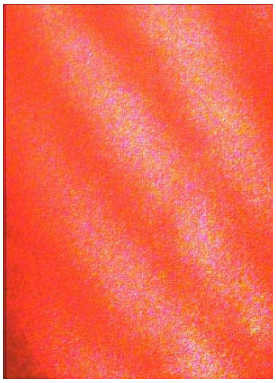
3.1 *To capture Ag_2S thin-film holograms*

3.1.1 *Getting ready for the bath:*

Electrolyte in the tub is preserved using a combination of 0.02 M $AgNO_3$ + 0.06 M $Na_2S_2O_3$ + 0.01 M EDTA in a volume of 10 ml + 10 ml + 10 ml. In a bathtub without stirring, electrodeposition is carried out at the substrate's element (3 cm^2) in the potentiostatic mode. Area 5 cm by 2 cm graphite plate serves as the anode substrate, with stainless steel acting as the working electrodes. This electrodeposition configuration helped with the recording of the Ag_2S thin film hologram that was discussed.

(i)

(ii)



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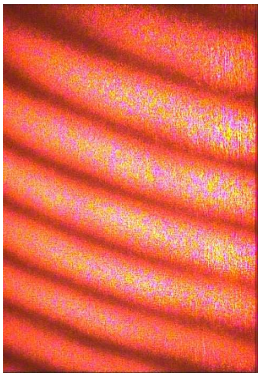


(iv)

(v)

Figure 2: Ag2S thin-film holograms for varying deposition times for 0.02MAgNO3 + 0.06 M Na2S2O3 + 0.01 M EDTA(i)20 seconds (ii) 30 seconds (iii) 40 seconds (iv) 50 seconds (v) 60 seconds

Time of deposition [s]	No. of fringes	Fringe width [cm]	Thickness of Ag_2S thin film [μm]	Mass of Ag_2S thin film deposited [mg]	Stress×10^{11} [dyne\cm^2]
20	2	0.320	0.63	1.92	0.0016133
30	3	0.245	0.94	2.88	0.001075
40	4	0.222	1.27	3.84	0.0008066
50	6	0.169	1.89	5.76	0.0005377
60	7	0.098	2.21	6.72	0.0004609

Table: 1The values of stress of Ag_2S thin film for 0.02 M $AgNO_3$ +0.06 M $Na_2S_2O_3$ +0.01 M EDTA

3.1.2. X- ray diffraction

Using a Philips PW-1710 diffractometer, the Ag_2S thin film's X-ray diffraction analysis was obtained inside the scanning viewpoint 10-100^0 with CuKα (λ=1.5406 Å). The Ag_2S thin film as it was deposited for 20–60 seconds (S1–S5) on the stainless steel substrate is depicted in Figure 3's X-ray diffraction patterns. One finding is that the as-deposited thin have a monoclinic crystal structure and are polycrystalline in character. The standard "d" values and the experimental "d" values are compared [10] and found to be in good agreement. This is demonstrated in the figure, suggesting that the insertion of a polycrystalline silver sulfide compound with an argentite[NR] structure.

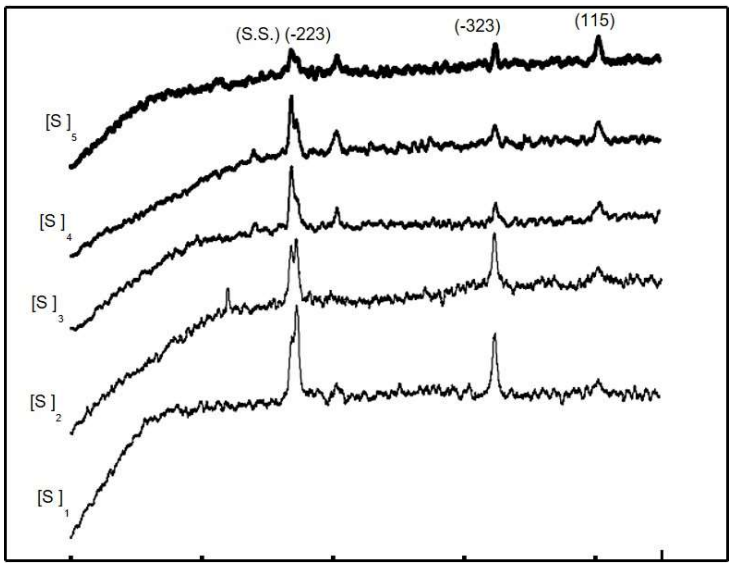
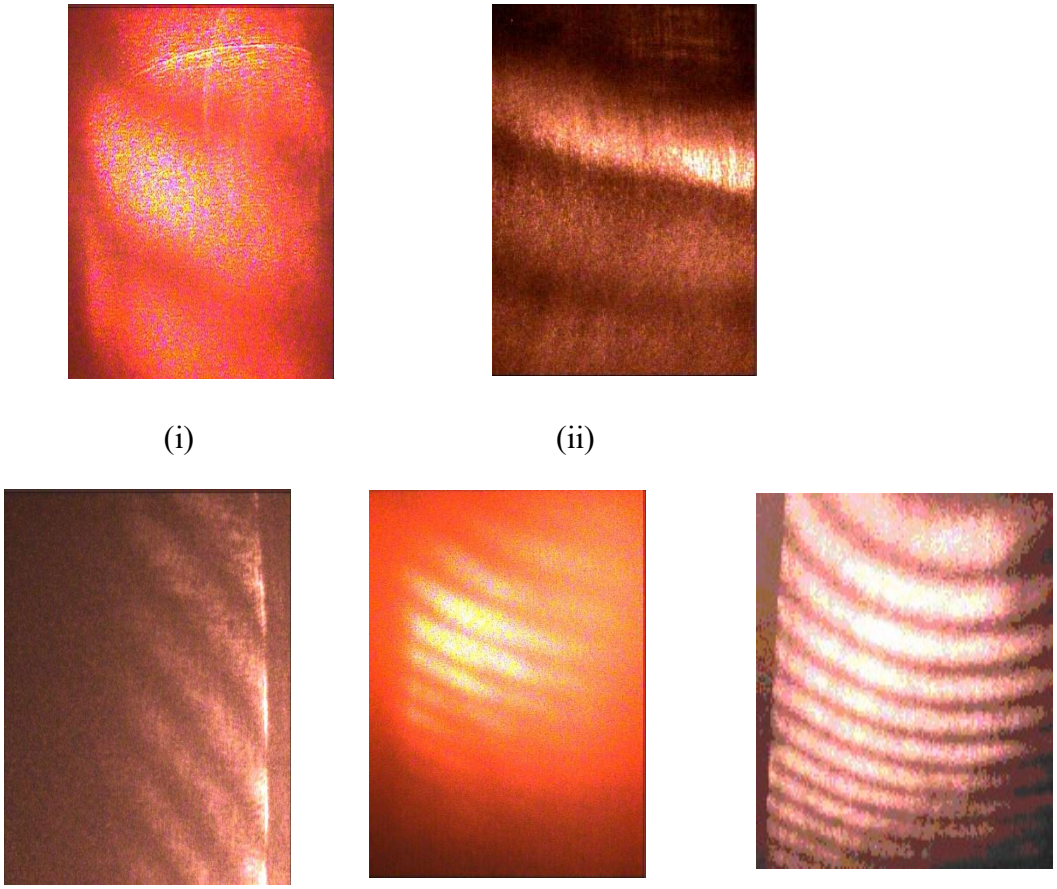


Figure 3: Ag_2S thin-film X-ray diffraction patterns as deposited on a stainless steel substrate.

3.2 *To capture Ag_2Se thin-film holograms*

3.2.1 *Getting ready for the bath:*

Electrolyte in the bathtub is composed of 5 mM $AgNO_3$, 2 mM SeO_2, and 0.05 M EDTA in a volumetric ratio of 10 ml + 10 ml + 10 ml combined. On the area (3 cm^2) of the substrates in a potentiostatic mode in an undisturbed tub, electrodeposition became well-known. An anode was created using a 5 cm by 2 cm graphite plate. Stainless steel substrates were employed as functional electrodes. These electrodeposition configurations were utilized as a recording medium for Ag_2Se thin-film holograms. [11]



(i) (ii) (iii) (iv) (v)

Figure 4: Ag_2Se thin-film holograms for varying deposition times for 5mM $AgNO_3$ + 2 mM SeO_2 + 0.05 M EDTA (i)7 minute (ii) 10 minute (iii) 15 minute (iv) 20 minute (v) 25 minute

Time of deposition [min]	No.of fringes	Fringe width [cm]	Thickness of Ag_2Se thin film [μm]	Mass of Ag_2Se thin film deposited [mg]	Stress× 10^{11} [dyne/cm^2]
7	2	0.314	0.63	2.17	0.001991
10	3	0.255	0.94	3.26	0.001327
15	5	0.187	1.58	5.44	0.0007967
20	7	0.141	2.21	7.62	0.0005690
25	9	0.080	2.84	9.80	0.0004426

Table 2 The values of stress of Ag2Se thin film for 5 mM $AgNO_3$ + 2 mM SeO_2 + 0.05 M EDTA

3.2.2 *X-ray diffraction:*

The as-deposited X-ray diffraction patterns of silver selenide thin films on substrates made of stainless steel for deposition times ranging from 7 to 25 minutes are displayed in Figure 5. This indicates the lifestyles of (023), (212) and (016) planes of reflections of orthorhombic segment of Silver selenide, indicating crystal structure of silver selenide skinny movies are Naumannite [12].

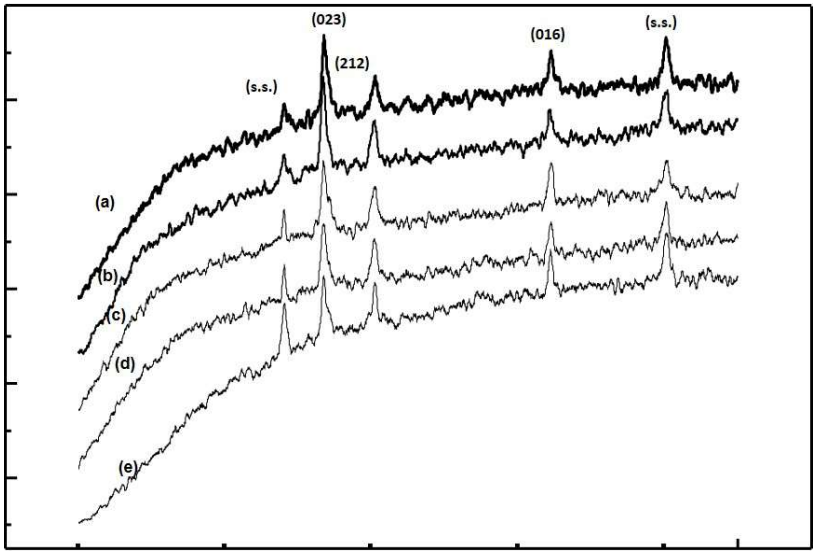


Figure 5: Ag_2Se thin-film X-ray diffraction patterns as deposited on a stainless steel substrate.

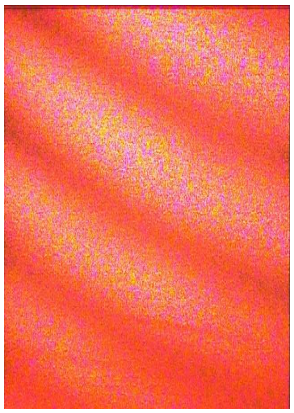
3.3 *To capture Ag_2Te thin-film holograms*

3.3.1 *Getting ready for the bath:*

The electrolyte in the bath is composed of a mixture of 0.02M $AgNO_3$+ 0.02M Na_2Te+0.02 M EDTA in a volumetric ratio of 10ml+10ml+10ml. In an undisturbed bathtub, electrodeposition is achieved at the

substrate site (3 cm^2) in potentiostatic mode. Area 5 cm by 2 cm graphite plate served as the anode. Stainless steel substrate was utilized as a working electrode. The electrodeposition of these setups are utilized as a tool for Ag_2Te thin film hologram recording.

(i)



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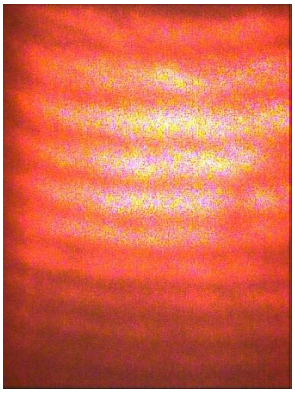

(v)

Figure 6: Ag_2Te thin-film holograms for varying deposition times for 0.02 M $AgNO_3$ + 0.02 M Na_2Te+ 0.02 M EDTA(i) 10 min. (ii) 15 min. (iii) 20 min. (iv) 25 min. (v)30 min

Time of deposition [min]	No. of fringes	Fringe width [cm]	Thickness of Ag_2Te thin film [μm]	Mass of Ag_2Te thin film deposited [mg]	Stress×10^{11} [dyne\cm^2]
10	3	0.326	0.94	3.34	0.0015488
15	5	0.301	1.58	5.58	0.0009292
20	6	0.266	1.89	6.69	0.0007744
25	8	0.232	2.53	8.93	0.0005808
30	9	0.159	2.84	10.04	0.0005162

Table 3 The values of stress of Ag_2Te thin film for 0.02 M $AgNO_3$ +0.02 M Na_2Te + 0.02 M EDTA

3.3.2 *X-ray diffraction*

The X-ray diffraction technique was used to study the structural identification of Ag2Te thin films. The XRD patterns were confirmed to be within the 10°–100° diffraction perspective range. XRD patterns of silver telluride thin film deposition on a chrome steel substrate are displayed in Figure 7. It suggests the existence of (113), (-333) and (313) planes of the monoclinic segment of Silver telluride [13]. These peak positions are in suitable agreement with fashionable diffraction records of monoclinic Ag_2Te.

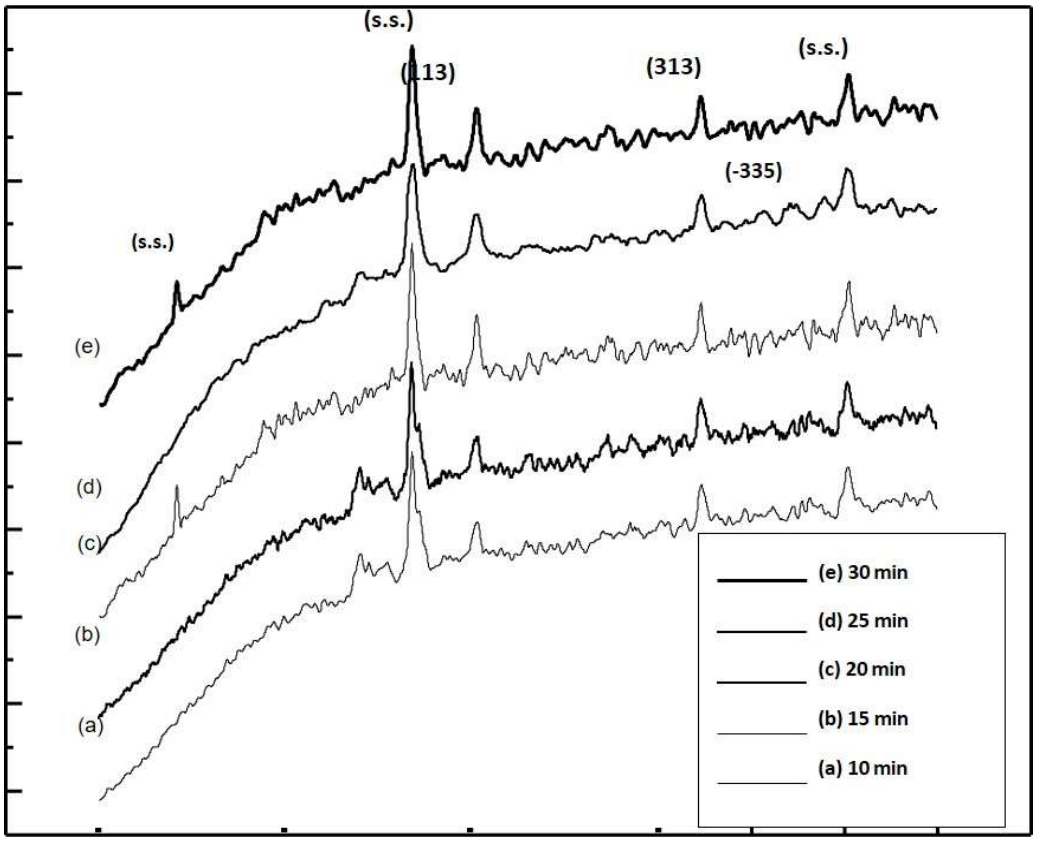

Figure 7. ***Ag_2Te thin-film X-ray diffraction patterns as deposited on a stainless steel substrate.***

Results and Discussion

Electrodeposition technique used to produce thin films of silver chalcogenide. The method of Holographic Interferometry has been successfully repurposed for the in-situ measurement of the thin film's thickness and stress. During the electrodeposition of films, the holographic fringes are recorded, and the fluctuation in the number of fringes, deposited mass, film thickness, and stress to surface with

respect to deposition time are examined. The holographic observation of thin films made of silver chalcogenide shows an increase in the number of fringes and thickness of the film during the deposition process, but a decrease in substrate pressure. When measuring thickness during the electrodeposition process, the DEDHI technique is proven to be more trustworthy.

Uniform stressing is a key factor in the generation of surface-localized interference fringes in the holography studies. We've used film loading on substrate as a stressing method. With the aid of the fringe pattern, deformation was seen during the continuous loading of the material on the plate by varying the time length. These measures can be used in non-destructive testing as well as stress, strain, and vibration analysis. Variations in optical path length in transparent medium can also be detected using it.

4. Conclusion

In conclusion, different surface flaws on the films can be studied using the DEHI technique. It has been noted that discontinuities in surface deformation are caused by faults that are subjected to appropriate stress. This kind of deformation is enough to produce an abnormality in the holographic fringe pattern. The mass of the material deposited affects how many fringes there are. According to our research, the DEHI approach can assess the features of various Double Exposure Holographic Interferometry systems and help identify how stress, strain, and other factors might alter the fringe pattern. This information can then be applied to security applications. This research introduces a new method that combines image processing with the holographic double exposure technique. We are able to discover internal faults in objects in a qualitative as well as quantitative manner.

To obtain the information on internal faults, this method only needs to record two holograms in different states. This method is faster and more accurate than previous methods at measuring thickness and obtaining defect information.

Conflict of interest

The authors confirm that there is No conflict of interest to declare for this publication.

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