A simplified optoelectronic technique for detection and size measurement of micro-holes in thin films

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Thin films have, now-a-days, become an important ingredient of scientific technology and can be regarded as one of the technology driver of the last century. It plays a pivotal role in the development of diverge and challenging frontier such as nanoelectronics, microelectronics, optoelectronics, molecular electronics, quantum electronics and engineering, high temperature super conductivity (HTSC), solar cell technology etc. Thus, the investigation of material surfaces like thin film surface, film uniformity and surface topography, film thickness measurement are considered as an advanced area of study in solid state science and material science. In addition, the number of various defects in thin films is very large as compared to the bulk solid material, and hence a careful control of the quality and nature of the defects in thin films can also control the properties of thin films[3]. Although various sophisticated characterization techniques such as AFM, STM, SEM, TEM etc. are available nowadays for surface studies, they are costly and not easily available in laboratories. They are also complex to operate and maintain. Thin films are eminently suitable for applications in areas where interactions with surfaces and also absorption only up to very small depths in the materials used are required. Further, dependence of the thin film properties on their thickness, grain size, surface to volume ratio and the defect structure enables one to tailor-make thin films to the desired requirements of their properties, if one has the knowledge of the various parameters influencing the properties and also the ability to control them adequately to the desired accuracy. In addition, just because of their thinness, they can be used in a number of devices and circuits simply, only to save space by miniaturization. As a matter of fact, because of these unique features, thin films find wide application in diverse and varied fields. But, quite often undesired microholes incorporated within these films as manufacturing defects or so affect their performance and may bring about remarkable change to the experimental result. Here, we put forward a very simple optoelectronic technique as a first hand tool for Determination and Measurement of such microholes in thin films with perfect accuracy.

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1. Introduction

The investigation of material surfaces like thin film surface, film uniformity and surface topography are considered as an advanced area of study in solid state science and material science. A variety of different imaging techniques exist from earlier days for characterization of surfaces up to atomic level. Out of those scanning optical microscopy (SOM) is an widely used optoelectronic technique. In SOM instrument, an intense laser beam is used to focus down to a diffraction-limited spot size which allows many imaginative exploration of microscopic world. The presence of a pinhole in front of the photodetector to block the stray light results in confocal imaging with increasing contrast; whereas its absence gives imaging which is directly comparable with conventional microscopy.

2. Experimental setup

The designed optoelectronic system consists of a two dimensional mechanical scanning mechanism along with a specimen holder, a laser source with it its own regulated power supply, optical-benches along with focusing arrangements and photo-detector arrangements, optical-fiber based laser transmission arrangement, electronic signal processing circuits along with data storage and output signal display system, a high resolution digital camera and an IBM Laptop PC. A mechanical light chopper along with speed control facility has been designed and incorporated to the set-up for thin film thickness measurement under chopped laser light. The analog signal processing unit includes precision instrumentation amplifiers for amplification of photo-detector out-put signals in both transmitted and reflected mode and a fly back-blanking circuit for suitable pixel by pixel scanning of the specimen under study. The designed optoelectronic system has also been provided with a suppressor system for noise generated due to external electro-magnetic disturbances and unwanted external mechanical vibrations. Fig. 1 shows the designed optoelectronic system and the complete experimental set-up and Fig. 2 shows the block-diagram of the designed optoelectronic system respectively.

Fig. 1. The complete experimental set-up.

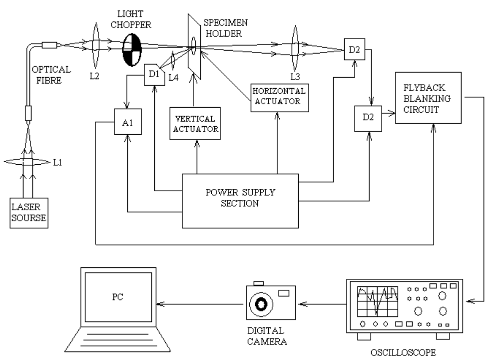

Fig. 2. Functional Block-diagram of the Designed Optoelectronic system.

3. Experimental techniques

For detection and measurement of size of micro-holes present in thin films by our designed optoelectronic system, we have used transmitted mode of the incident laser light passing through the thin films under study. In this case, we have kept the film in dynamic condition. The thin film under study is scanned horizontally keeping the incident laser beam fixed and moving the specimen along the horizontal x-direction. Spatially transmitted light from the film under study is focused onto another photo-detector (phototransistor) positioned behind the specimen holder. The transmitted laser beam passing through the thin film produces voltage signals from the output of the photo-detector. From the spatially transmitted light from point to point scanning of the film carries the information regarding the presence and position of any micro-hole from the photo-voltage signal generated by the detector corresponding to each and every point along the scanned line. Corresponding to any pin-hole at any point on the film, a sharp spike is observed in the voltage signal. This is due to the direct transmission of the incident light which produces a high photocurrent signal corresponding to the position of the pinhole at that point. From the observed signal the position of such a pin-hole could easily be determined with the help of CRO under the designed optoelectronic system.

Presence of such micro-holes on various thin films under study by our optoelectronic system has been shown in Fig. 3. The sizes of such micro-holes have also been found out by measuring the width of the spikes by fitting of calibration curves with the help of known pinholes of different sizes.

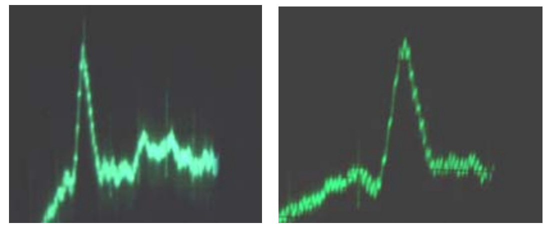

Fig. 3. Pin-holes present in various thin films.

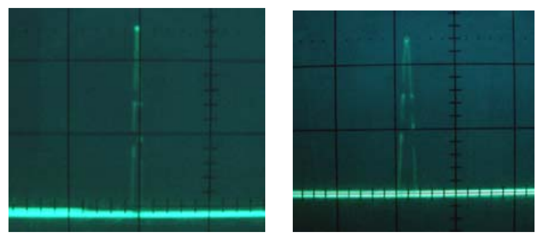

Fig. 4. Spikes observed with pinhole of known size.

To calibrate the designed optoelectronic system for measurement of pin-hole size, several standard pinholes of different known sizes have been made from dark, hard but light plastic material and cut to the size of the specimen holder to fit into it. The size (diameter) of each of the standard pin-holes has been measured by optical microscope (Table 1). Putting inside the specimen holder, each of the standard pin-holes is scanned horizontally keeping the incident laser beam fixed and moving the specimen along the horizontal direction. Spatial transmitted light from the pin-holes is focused onto the photo-detector positioned in front of the specimen holder. The transmitted laser beam passing through each of the standard pin-holes gives a sharp spike of different width on the CRO screen (Fig. 4). The widths of the spikes are measured at the of the time-base scale for all the standard pinholes. By plotting the pinhole size vs. width of the spikes in time-base scale of CRO of respective standard pin-holes a calibration curve (Fig. 5) is obtained which is found to linear in nature. From the calibration curve, a linear equation relating the pin-hole size (x) and the spike width (y) is obtained which can be written as:

$$y = 0.0136x + 0.0819 \qquad (1)$$

Table 1. Measurements of the standard pinholes made with optical microscope.

Sl. No.	Pinhole No.	Micro s-cope Div^{n}s	Diameter (in μm)	Spike width in (in ms)
1	Pinhole 1	66	660	9
2	Pinhole 2	58	580	8
3	Pinhole 3	52	520	7
4	Pinhole 4	46	460	6.5
5	Pinhole 5	37	370	5
6	Pinhole 6	24	240	3.5

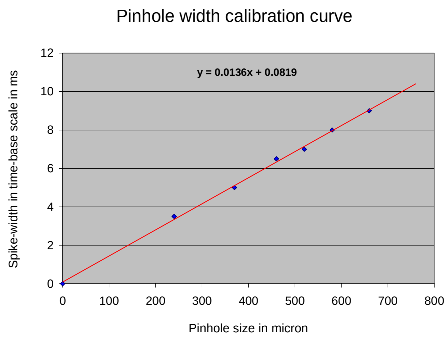

Fig. 5. Pin-hole width calibration curve.

Equation (1) is used to measure the size of unknown micro-holes present in a thin film from the corresponding spike width as measured from the time-base scale.

4. Results

Measurement with calibration curve:

If, x = pinhole size in micron, and y=Width spike in time base scale of CRO,

Then from the calibration curve x and y are found to be related by the equation,

$$y = 0.0136x + 0.0819$$

$$\therefore x = \frac{y - 0.0819}{0.0136} \quad (2)$$

Width-measurement of some unknown micro-holes in Fig. 3 using equation (2) are as follows:

Pinhole 1[Fig.3 (a)]:
Width of the observed spike = 2.5 ms.
∴Width of the respective pinhole,

$$\therefore x = \frac{y - 0.0819}{0.0136}$$

= 177.8 micron.

Pinhole 2[Fig.4 (b)]:
Width of the observed spike = 4 ms.
∴Width of the respective pinhole,

$$\therefore x = \frac{y - 0.051}{0.0441}$$

= 288.09 micron.

5. Conclusion

The present research work has been carried out in designing a modest laser based optoelectronic system which is simple enough to be used as a first hand tool for the study of thin films as well as characterization of semiconductor devices. Although various sophisticated characterization techniques such as AFM, STM, SEM, TEM etc. are available nowadays for surface studies, they are costly and not easily available in laboratories. They are also complex to operate and maintain. Taking into account the above factors, a simple laser based optoelectronic system for studying surface properties of thin films has been designed and fabricated. Utmost efforts have been put to make the system flexible, user-friendly, compact as well as cost-effective at the time of designing. Also, work was concerned with the designing of the optoelectronic system with high resolution at a lower cost with as many as locally available materials and components without compromising the quality of the system.

The designed optoelectronic system is found to be excellent for detecting the presence of micro-holes on the surface of thin films and the size of such hole can be measured in micro-meter range by comparing with holes of known size. The width of the spike directly provides the size of the micro-hole as they are related by a linear equation.

References

[1] Jean M. Benett, Thin Solid Films, **220**, 227 (1992).
[2] Om Prakash, Mohan Lal, J. Instrum. Soc. India, **35**(4), 392 (2005).
[3] S. Tolansky, Wiley (Interscience), New York (1960).
[4] S. Tolansky, Oxford Univ. Press, London and New York, (1948).
[5] A. Kadyshevitch, R. Naaman, Phys. Rev. Lett., **74**(17), 3443 (1995).
[6] D. K. Hamilton, T. Wilson, J. Appl. Phys., **53**(7), 5320 (1982).
[7] R. K. Bordoloi, Ph. D. Thesis, Gauhati University, India, (2007).
[8] K. K.Baruah, Ph.D. Thesis, Gauhati University, India, (1999).
[9] K. K. Baruah, K. C. Sarma, A. Choudhury; J. Instrum. Soc. Ind., **26**(4), 159 (1996).
[10] K. K. Baruah, K. C. Sarma, A. Choudhury; J. Instrum. Soc. Ind., **26**(6), 581 (1996).

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