Bulgarian Chemical Communications, Volume 45, Special Issue B (pp.194-197) 2013

Film thickness measurement by optical profilometer MicroProf® FRT

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Received October 17, 2013; Revised November 25, 2013

This paper compares Chromatic white light (CWL) and stylus profilometer measurements. Standard samples with vacuum deposited aluminum films of different thicknesses in the range of 50-300 nm were prepared and measured by both methods. It was found that the CWL technique is proper for a measurement of thin organic films with higher than 40-50 nm film thicknesses.

Keywords: thickness measurements, chromatic white light, stylus profilometer

INTRODUCTION

Thickness measurement is of a main importance in both the first stage of the thin film deposition and the final steps of testing and failure analysis in the microelectronics and MEMS [1]. Usage of the organic semiconductors in the microelectronics causes specific new problems, concerning the film deposition and measurement.

Organic semiconductors are more recently investigated due to their low price and easy processing at room temperatures and atmospheric pressure [2], with low cost "wet" techniques – spin and dip coating [3], electrophoretic deposition [4] and ink-jet printing [5]. They are promising materials for a thin film application as electrode, insulator or semiconductor films in the future microelectronic devices [6] – OLEDs, solar cells, OFETs and gas sensors. But some problems as film softness, bad adhesion and the presence of impurities result in low reproducible parameters and impede the organic microelectronics development. In general the film softness could considerable affect the organic film thickness determination.

The film thickness could be measured by forming a step between the film and the uncovered substrate. In a case of "wet" film deposition techniques used, the step is usually formed by a scratching [7]. The film delamination and removal depends on the stylus material and shape, the force applied, the film and substrate properties [8].

The most used tool for a thin film thickness measurement is the stylus profilometer. It is capable to scan area of tens of millimeters with a vertical range starting from several nanometers up to hundreds of microns. Its main disadvantage is the contact with the surface, which can cause a destruction of the organic film surface and a misrepresentation of the data measured. Due to this, the stylus profilometer is not always the best tool for a thickness measurement of thin soft organic films.

Chromatic white light (CWL) method is a non-contact technique for 3D profiling of the surface roughness [9]. It allows scanning of a wide area surfaces with a lateral and vertical resolution of 1 μm and 10 nm, respectively. It is successfully utilized for a surface topography evaluation in mechanical engineering, electro-technical industry and bioengineering [10]. CWL method was originally developed mainly for surface scanning. The software for data processing in fact has all capabilities, (e. g. digital processing and Fourier filtering) available in AFM measurement. The main

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disadvantage of the method is the influence of the optical inhomogeneity of the film on the accuracy of the measurement.

This paper compares two different measurement techniques – CWL and stylus profilometer to determine the capabilities of the non-contact CWL method for thickness measurements of thin organic films.

EXPERIMENTAL

Standard samples with vacuum deposited aluminum films of different thicknesses in the range of 50-300 nm were prepared. The different thicknesses were obtained by placing the substrates at different distances from the evaporation source. Al was used because of both good mechanical and excellent light reflectance properties fulfilling the requirements for both contact and non-contact thickness measurement.

Thicknesses of the standard samples with Al films were measured by CWL and stylus profilometer methods. The reliability of both methods was estimated.

The CWL measurement with CWL MicroProf® FRT (Fig. 1) is based on the chromatic aberration of the optical sensor CHR 150 N. A white light from a polychromatic source is passed through a semitransparent mirror and splits spectrally in the chromatic aberration lens. The optical aberration effect causes each wavelength to be focused at a different Z height. As a result of the chromatic "splitting" the film thickness is measured [11].

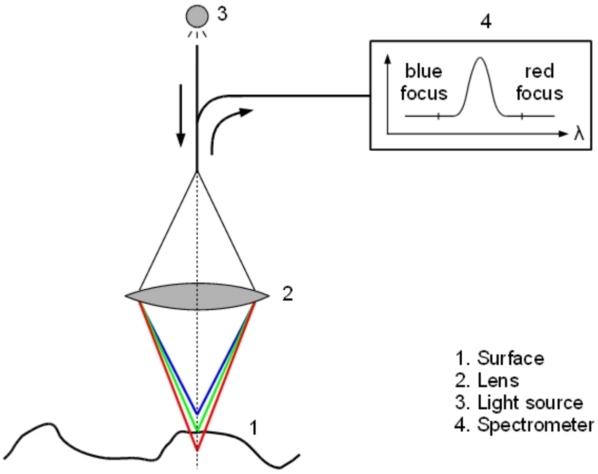

Fig. 1. Principle of Chromatic White Light (CWL) measurement.

The thickness of the films was measured using a contact profilometer, Talystep. (Taylor Hobson Talystep, Model 223-7.)

RESULTS AND DISCUSSION

CWL thickness measurements

In Fig. 2 a typical step profile, formed between two thin Al films on a standard sample is measured by the CWL method in 1D mode. The measurement was performed after leveling of the sample. A distinguishable step between the Al films is formed allowing determining the film thickness. It could be seen that the noise is 2-3 times the device resolution. The minimum value successfully measured with the CWL technique under the aforementioned conditions was 49 nm, which is about 5 times the device resolution.

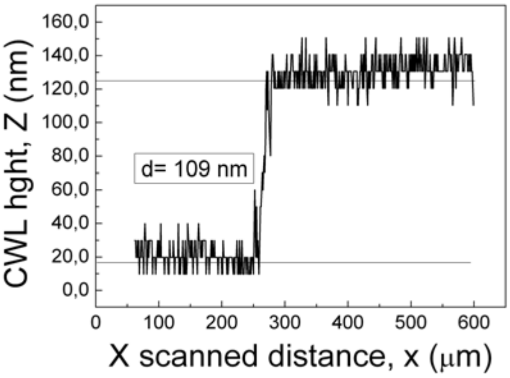

Fig. 2. Step profile formed between two Al layers, measured by CWL method in 1D mode.

This measurement shows the limits of the method for thin film thickness measurements. When the measured value is close to the device resolution, the measurement needs a statistical processing. Hereafter all data from at least 10 CWL measurements are presented after statistical processing in the form of mean value and standard relative error. The standard relative error was chosen to make possible the comparison of errors obtained from different film thicknesses.

Stylus profilometer thickness measurements

In Fig. 3 typical contact profilometer measurement of the step between two Al layers on a standard sample is presented. The measurement was carried out at the maximum possible magnification after a precise sample leveling in a way to extend the step over the full scale of the range. In this case it was assumed that the resolution of the measurement is equal to or less than the resolution of the scale on the paper of 1 mm (1.6% from the full scale). The picture presents a smooth curve resulted from the low speed of scanning. Moreover the relatively heavier tip facilitates the integration of the noise during the scanning.

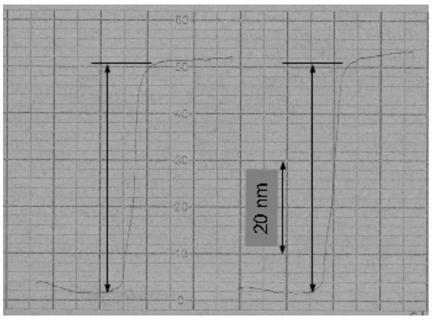

Fig. 3. Measurement of a step between two Al layers of a standard sample with stylus profilometer.

It could be seen from the figure that a clear distinguishable step is measured. Obviously the stylus profilomenter has the advantage of smooth measurement with higher resolution. It has the disadvantage of a mechanical contact between the stylus and the measured surface. In case of soft thin films it could vitiate the measurement.

Comparison of the methods

Summarized results of the CWL and stylus profilometer are presented in Table 1.

Table 1. Comparative thin film thickness measurements with CWL and stylus profilometer methods.

Sample No	CWL thickness [nm] (Relative error [%])	Stylus thickness [nm] (Relative error [%])
s1	49 (8)	50 (7)
s2	109 (7.5)	98 (3)
s3	275 (4)	275 (3)

Comparing the CWL measurements on samples with different thicknesses, standard relative error less than 8% was obtained. The variation of the standard relative error from one to the other sample could be related to the sample properties - presence of dust or film inhomogeneity. Measurement of samples with thicknesses bellow 50 nm is not proper; the values measured are close to the device ADC resolution.

Stylus profilometer produces smoother and distinguishable step. It has the capability of measurement in the range less than 50 nm. But the standard relative error of the measurement for ranges higher than 50 nm is similar to that obtained by the CWL method.

Comparing measurements with both methods on the same sample, it could be seen that the differences are close or within the relative standard error, i. e. no apparent constant error related to the measured device was observed.

CONCLUSION

The CWL method is proper for a measurement of thin soft organic films with higher than 40-50 nm film thicknesses. Measurement of lower thicknesses could be affected by the limit of the device resolution. In a case of optical inhomogeneity the method requires covering the film with a uniform high reflective coating (for example Al).

For films thicker than 50 nm both CWL and stylus profilometer methods give comparable results with comparable standard relative error.

Acknowledgements: This work was supported by Ministry of Industry and Trade of the Czech Republic project No FR-TI1/144, Grant Agency of the Czech Republic projects No. P205/10/2280 and 13-29358S and by project "Centre for Materials Research at FCH BUT" No. CZ.1.05/2.1.00/ 01.0012 supported by ERDF.

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ИЗМЕРВАНЕ НА ДЕБЕЛИНИ С ОПТИЧЕН ПРОФИЛОМЕТЕР MICROPROF® FRT

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Постъпила на 17 октомври 2013 г.; коригирана на 25 ноември, 2013 г.

(Резюме)

Тази статия сравнява измервания с методите хроматична бяла светлина (CWL) и контактен профилометър. Приготвени са еталонни образци с отложени тънки слоеве алуминий с дебелини в интервала 50-300 нм и с гореспоменатите методи са измерени техните дебелини. Установено е, че CWL техниката е подходяща за измерване на тънки слоеве с дебелини, по-големи от 40-50 нм.