Surface quality control of a thin SiN layer by optical measurements

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Abstract—Fiber optic interferometers have a wide range of applications, including biological and chemical measurements. Nevertheless, in the case of a reflective interferometer setup, standard silver mirrors cannot be used in every measurement, due to their chemical activity. This work investigates the surface quality of a thin optical layer of silicon nitride (SiN), which can serve as an alternative material for silver mirrors. We present measurements carried out with a Fabry-Perot fiber-optic interferometer working in a reflective mode. Measurement results allow us to determine the surface quality of the investigated layer.

The fiber optic configuration of an interferometer has a lot of advantages, like ensuring stable and repeatable measurements. Due to the application of optical fibers, small physical dimensions (hundreds of µm to mm) of the measurement head can be achieved, which allows for their use in hard-to-reach places, performing nearly point-wise measurements. In addition, they are resistant to electromagnetic interference. They can be used in chemical and biological measurements [1]-[3]. Another advantage of using fiber optic interferometers is their lower cost in comparison to other sensors while their construction is relatively simple.

The silver mirrors are usually used as reflective layers in interferometers. Such mirrors have high reflectivity and a wide range of reflected wavelengths, but their lifespan is short. Moreover, they can be easily mechanically damaged, so new materials to replace silver mirrors are needed [4]. One of the possible materials can be amorphous silicon nitride (SiN) as it is more wear-resistant [5]. It is also possible to apply it in biological measurements because SiN does not react chemically with biological samples [6].

Our goal was to investigate the surface quality of a SiN layer [7]. The layer consisted of amorphic Silicon nitride and was 100 nm thick. It was deposited on a silicon wafer, allowing us to conduct measurements using silicon as a main reflecting surface [8].

The measurement setup consisted of a light source (NKT Photonics EXR-20 Supercontinuum Laser with an adjustable optical filter, Denmark), single-mode optical fibers, a 1x2 (50/50) fiber coupler (Cellco, Poland), and an optical spectrum analyzer (Anritsu MS9740a, Japan). The measurement head was built to work as a Fabry-Perot interferometer operating in a reflective mode. Light from the light source was transmitted to the sensing interferometer through optical fibers and the fiber coupler. The signal from the interferometer was then transmitted back to the spectrum analyzer. A simplified measurement setup schema is presented in Fig.1.

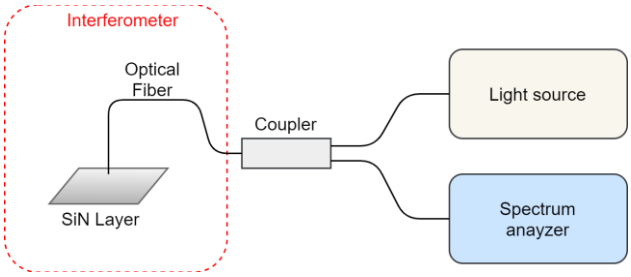

Fig. 1. Measurement setup.

The interferometer was built by placing an optical fiber end-face (acting as a first reflecting surface) in parallel above the investigated SiN layer (acting as a second reflecting surface). The optical cavity between the reflecting surfaces was filled with air. The distance between the fiber end-face and the investigated layer was set to 100 µm by a micrometric screw controlling position of the fiber in the vertical axis.

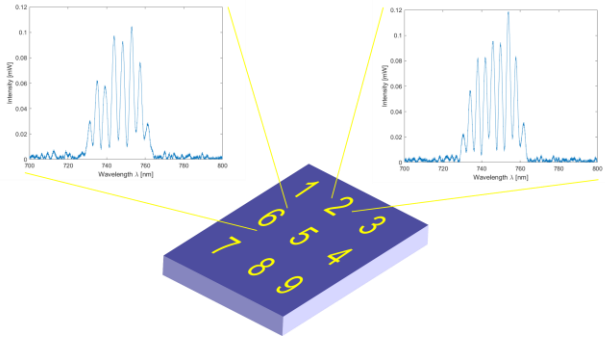

Fig. 2. Position of measurement points on a SiN layer (blue cuboid).

The sample surface quality was investigated by measuring spectra for nine chosen points at the surface of the SiN layer. The position of these points is shown in Fig. 2. The measurement of each point was conducted in a series of 5 measurements to obtain statistical data. Each measurement was made one after another with 15 second

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breaks between them and without changing the position of the measuring head. This method provides that only source fluctuation and investigated layer changes impacted the result of measurement.

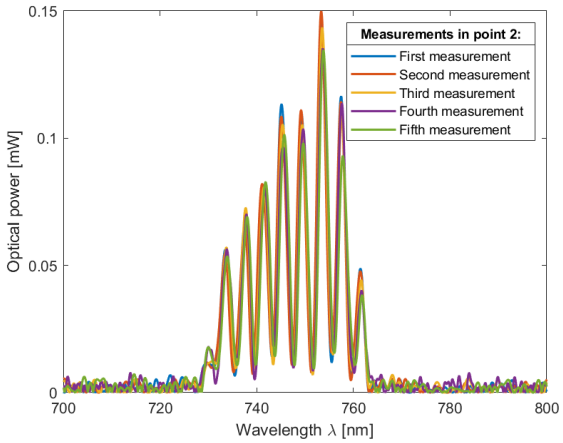

Fig. 3 Comparative signal spectrum for measured point 2.

Figure 3 shows five spectral characteristics. They were captured for the point 2 marked in Fig. 2 and investigated one by one. This method provides the opportunity to observe the change of signal and define surface quality of the SiN layer. Spectral characteristics in Fig. 3 are similar to each other, overlapping nearly perfectly. They have the same shape and the number of peaks in the spectrum remains stable in the following measurements. Maximum intensity of the signal and the corresponding central wavelength in each characteristic have changed insignificantly. These changes are caused by the source instability and are independent on the examined layer. The only parameter shown in Fig. 3 that is dependent on the SiN layer is the positions of peaks in the measured spectrum.

The position statistics of a selected peak in the spectrum can be used to determinate surface quality. We decided to use a box plot technique. This method is used to show statistics of measurements with less data available than in other methods, e.g., histogram. To use a box plot it is enough to have five measurements for each point to receive reliable data [9]. Additionally, box plots allow to present data in a more transparent way, which makes it easier to compare them and draw conclusions. The single box plot is a rectangle, which consists of three elements: lower quartile (25 percentile), median (50 percentile) and upper quartile (75 percentile). Between the lower and upper quartile is an interquartile range. This is a 50% of the central data. Quartiles are not sensitive to outliers, so they keep information about the center of data and distribution. The box plot can have whiskers which connect the rectangle with maximum or/and minimum value of data. If the outlier appears, it is shown individually. [9]

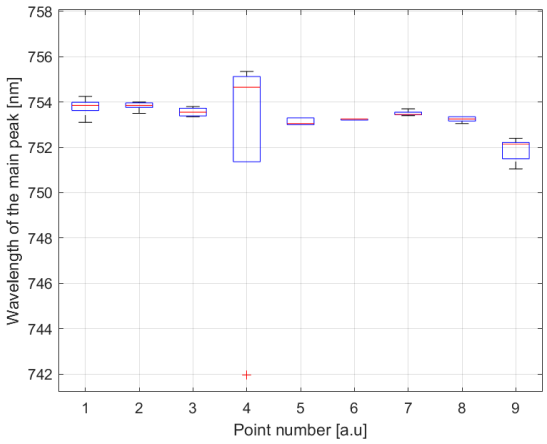

Fig. 4. Statistics of the wavelength of the main peak.

Figure 4 shows the position statistics of main peak in the measured spectra. It was calculated as the position of maximum closest to 754 nm. Because the layer thickness should not vary in a significant way, the position of a selected peak should only shift by single nanometers or less. This can be observed in all points except points 4 and 9. As they are positioned on the edge of an examined sample this can mean that this part was damaged. Layer thickness cannot be calculated from the position of a selected peak, but differences in thickness between the measured points can be calculated. To determine how a change in the layer thickness influences the position of a selected peak, computer simulation was used. The measured setup was simulated as a Fabry-Perot interferometer with three reflecting media boundaries: fiber-optic-air, air-SiN and SiN-Si. Based on simulation results, estimated layer thickness distribution was calculated. The results were shown in Fig. 5.

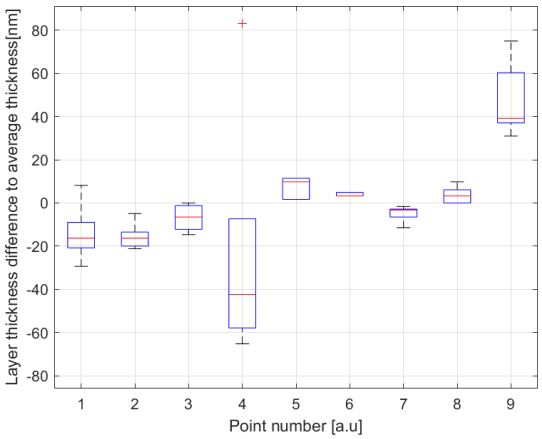

Fig. 5. Layer thickness distribution.

The results in Fig. 5 showed that the examined layer has acceptable surface quality. In points 1, 2 and 3, the

layer was thinner, while in 5, 6, 7 and 8 - thicker. As already mentioned, the results gathered from points 4 and 9 indicate the damage of the layer and the obtained thickness results can be different from real values.

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