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SURFACE SCANNING WITH MICROWAVE MIRCOSCOPE

Křesálek Vojtěch, Navrátil Milan
Faculty of Applied Informatics, Tomas Bata University in Zlín
Nad stráněmi 4511, Zlín, 760 05
Czech Republic

ABSTRACT

The aim of this work was to measure the resonant curves of coaxial resonator during scanning of conducting relief. Relief of surface was created on the basis of measured curves. Resonance response of n.λ/4 resonator was measured with spectral analyser FSH3 (Rohde&Schwarz). User programs were created in MATLAB software. Some trials were carried out for verification of mentioned laboratory microwave microscope kit.
Keywords: microwave microscope, resonator, scanning

1 INTRODUCTION

As a non-contact and non-destructive display technology develops, the frequency of its use significantly increases. It is use especially in nanotechnology area, preparing of new types of material, studying of very thin layers, for non-destructive tests in materiology. Requirements result from needs of developing informatics technology industry.

NSMM (Near-field Scanning Microwave Microscope) is a scanning microscope, which is based on change in impedance between stylus and tested sample in microwave spectrum. During data evaluation the changes in resonance curve of a resonator are monitored (resonator is in interaction with sample) or directly impedance between stylus and surface. Acquired signal is converted into brightness component of a picture. At our workplace we concentrated on use of a resonance method from practical reasons. It is not complicated and is suitable for our applications. Principle of this microscope is very close to optical scanning microscopes with evanescent wave. The first notice describing microwave microscope is about 1972 [1]. Overview about history and its development can be found in [2], [3] and other application possibilities in [4] and [5]. The important part of the microscope is mechanism of movements, which allows scanning measured quantities in defined positions above the sample surface. High demands are put on movements from the point of resolution and hysteresis of mechanisms [6]. There is also need to prevent vibration into measuring system.

Creating suitable software for data evaluation is an essential feature of microwave microscope proposal. Changes in resonance curves are considered as data. Software evaluates maximum of frequency and quality factor of resonator. During our trials we gain from article [7]. High resolution microwave microscope is described in [1] including well arranged present state of this technology development. The reason why we launch into construction such a device was a consequence of necessity clusters control of silicon nano-crystals. These crystals originate by the self-organizing mechanisms and lead to large fluctuations during measurement of ampere volt characteristics of prepared materials (thick layers) on the nc-Si basis.

2 Experimental

2.1 Micro-movements M-110.1DG

For motion of scanned sample were used micro-movements from company PI dealing with piezo and nano-positional systems. Mentioned device has linear motion with 5 mm span. It is M.110.1DG type with resolving ability of 0,5 μm. The minimal declared displacement is 0,0058 μm. Nevertheless, when the minimal displacement requirement is sent, positional error should be considered. This error is in order of hundredth micrometers. Maximal speed of micro-movements is 2 mm/sec and motion span is 5 mm in single axis. Micro-movements can be very simply joined together so that it allows creating of two or three-axial movement system. Controller Mercury by the same producer was used for movement control.

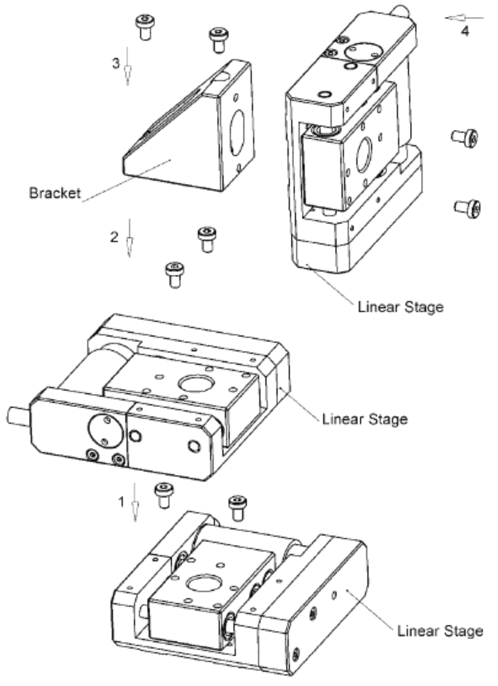

Figure 1. Three-axial micro-movements

2.2 Mercury: DC-motor controller

Mercury utilizes a quadratic feedback signal encoder for determination of a position and it can manage the motion accuracy of 0,05 μm. It provides PID servo-control of position, velocity and acceleration. Mercury is equipped with software including build-in commands which simplify the motor control according to user demands, for example, reaching of requested position.

Figure 2. Mercury controller

2.3 λ/4 Coaxial resonator

λ/4 coaxial resonator supply was realized with two 50 Ω coaxial cables with coupling loops (actuated and scanned magnetic field component). Scheme of mentioned resonator can be seen in Figure 3.

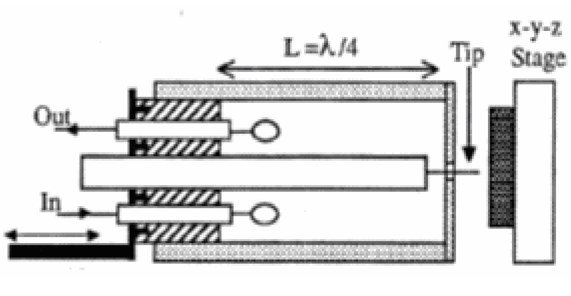

Figure 3. Resonator designed according to [7]

Resonator consists of two pieces: a cavity and a central conductor. The former has three inlet ports (see Figure 4). One port is for cable with exciting coil which generates signal of specific frequency, one port is for another cable collecting signal. Port in the middle of the cavity is designated for central conductor (equipped with threading, see Figure 6).

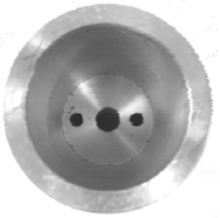

Figure 4. Sideways look at the cavity

Figure 5. Bottom look at the cavity

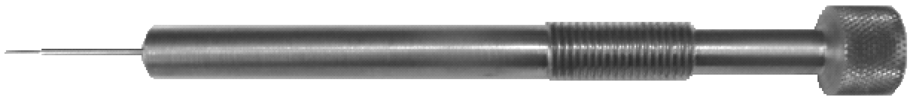

Figure 6. Central conductor with a tip

2.4 Quality factor of resonator

After measurement of resonance curve, the quality factor can be calculated as follows:

1) Finding of maximal peak of resonance frequency
2) Measured maximum to decrease by 3dB
3) Frequency difference f_2-f_1 is called “Band Width” and quality factor is quotient of resonance frequency and band width (see Figure 7).

Dielectric between tip and scanned sample has big influence on quality factor. For that reason it is more sensitive to change in scanned surface then maximum of frequency [1].

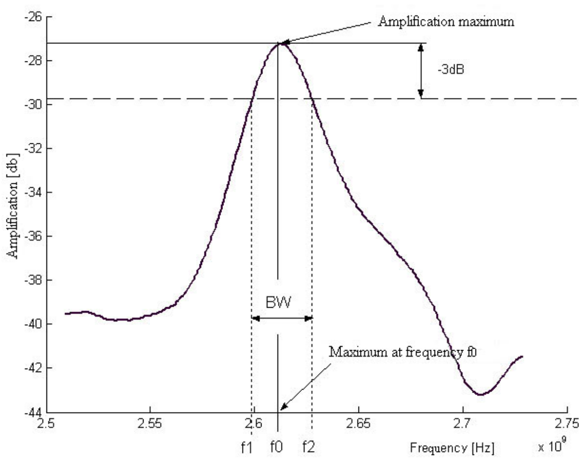

Figure 7. Resonance curve course of used resonator

2.5 Data evaluation

The main principle of all raster microwave microscopes is that a tip or scanned sample is moved along raster and in each point the resonance curve is measured. Individual resonance curves are considered as data. Data evaluation was managed in MATLAB 6.0 software. Signal generator SM 300 and spectral analyzer FS 300 - FSH3 from Rohde&Schwarz were used.

2.6 Measurement

A coin was used as a preliminary testing sample. Letter „K“ on the coin has chosen for detailed examination (see Figure 8). Unprocessed measured data can be seen in Figure 9, where a slant of scanned sample can be observed. The slant was numerically eliminated. Colour draw of data is represented by different measured values. Individual points of raster grid are draw by red square (see Figure 10).

Figure 8. Look at scanned sample

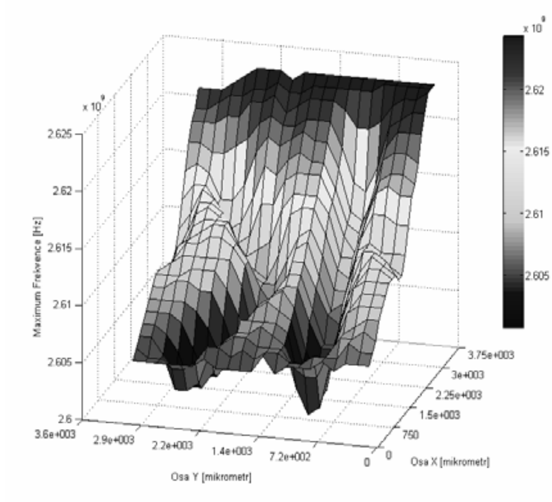

Figure 9. Unprocessed data display

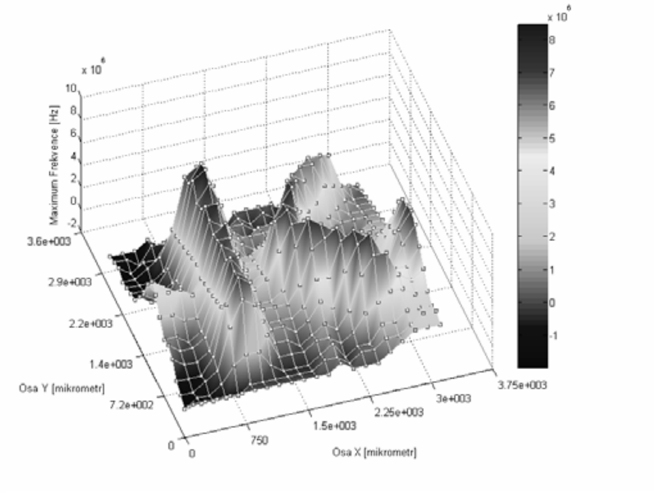

Figure 10. Data display after slant elimination with scanning raster

2.7 Evaluation of scanned sample with quality factor

The relief height of letter "K" from coin surface was measured (with micrometer) for approximation of vertical sensitivity of microscope. It was 100 μm and it was corresponding to frequency change $3,5.10^6$ Hz so that the sensitivity is 35 kHz/μm.

However, the question of transfer function determination is very complicated and we still do not have sufficient experimental data for rational approximation of that.

3 CONCLUSION

Results of experiments concerning our microwave microscope proposal were shown in this article. This device can expand our possibilities during study of either nano-silicon structures in longer time horizon or surface modification of biopolymer composite materials in laboratory conditions at atmospheric pressures and moistures. It is quite complicated problem which requires considerable interdisciplinary cooperation. During problem solving it arose substantially more questions and problems then results which we expected. We can not expect that mentioned microscope principle dramatically will change available commercial display techniques. However, in specific cases it can be quite useful. This work was accomplished with financial support by Czech Science Foundation under no. 202/03/0789 called "New silicon nano-materials for optoelectronics".

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