NON-DESTRUCTIVE TESTING BY ELECTRO-ULTRASONIC SPECTROSCOPY WITH DC ELECTRIC SIGNAL

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ABSTRACT

The new method of non-destructive testing field is presented in this paper. This method consists of two signals. The electric ac signal with frequency f_E and the ultrasonic signal with frequency f_U. The ultrasonic signal changes resistance ΔR of the measured sample by frequency of ultrasonic excitation f_U. Defects in the material are causer larger changes resistance ΔR then in the material without defects for the same amplitude of ultrasonic signal.

1. INTRODUCTION

Electro Ultrasonic Spectroscopy is a method based on the interaction of two signals – electrical ac signal and ultrasonic signal. The ultrasonic signal changes the contact area between the conducting grains in the thick film resistor structure and then resistance is modulated by the frequency of ultrasonic excitation. Resultant intermodulation voltage depends on the value of ac current varying with frequency f_E and on the ultrasonic excited resistance change ΔR varying with frequency f_U, so voltage u_m can be computed using following equation:

$$u_m = I_M \sin \omega_E t \cdot \Delta R_M \sin \omega_U t \qquad (1)$$

where: I_M *- electric current amplitude*

ω_E, ω_U *- angular frequency of electric and ultrasonic excitation respectively*

ΔR_M *- amplitude of the resistance change due to the ultrasonic excitation*

Defects and un-homogeneities in the structure are the sources of the intermodulation signal of frequency $f_m = f_E - f_U$. This method can be used as a diagnostic tool for the quality and reliability assessment of thick film resistors [1, 2, 3]. In our next work we have studied the influence of the ultrasonic signal on the resistor structure. The samples were connected to the DC voltage or shorted, and fixed on the ultrasonic actuator which generates the ultrasonic signal of frequency f_U. We have measured the spectral density of voltage U_S of frequency f_U created on the measured sample. This voltage is proportional to the ultrasonic excited resistance change ΔR and its value depends on the sample structure. We can observe the piezoelectric effect on our samples – the voltage of frequency f_U is measured on the samples even when the sample is shorted.

2. ELECTRO-ULTRASONIC MEASUREMENT SETUP

The block scheme of the electro-ultrasonic measurement setup is shown in Fig. 1. It consists of two parts, the electric and the ultrasonic.

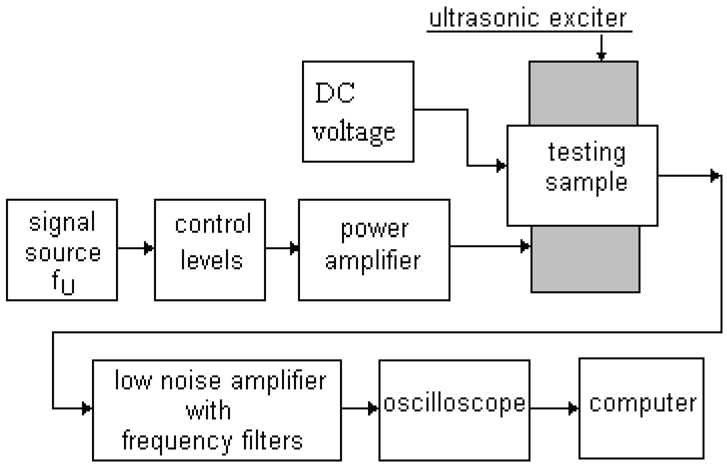

Fig. 1: Electro-ultrasonic measurement setup with DC electric signal.

The ultrasonic part consists of a generator Agilent. The power amplifier consists of the WPD 100 in which it is necessary to have power linear actuating harmonic signal on a ultrasonic transducer. The measured sample was fixed on the power piezoceramic transmitter (HTP05) which is used for ultrasonic signal generation. Electric part consists of a DC voltage source. This signal is led to the measured sample over the protective resistor. The measured signal is amplified by the low noise amplifier with frequency filters (AM 22) with adjustable input gain in the range from -20 to 50 dB by 10 dB step, the frequency band filter with lower frequency 30 mHz, 300 mHz, 0.3 Hz, 3 Hz, 30 Hz, 300 Hz, 3 kHz, 30 kHz and 300 kHz, the high frequency filter adjustable in range 3 Hz, 30 Hz, 300 Hz, 3 kHz, 30 kHz and 300 kHz, adjustable output gain in range from 0 to 50 dB by 10 dB. All parameters are programmed over GPIB or the front panel of the amplifier. The amplified signal is led to the A/D converter. The digital oscilloscope Agilent 54624A with sampling rate 200 Msa / s is used as the A/D converter. The digitized signal is stored in the computer and noise spectral density frequency dependence is evaluated using discrete FFT. The control software was written in Borland C++ Builder and this version is based on Windows operating system. The amplifier AM22 and the exciter HTP05 were produced by 3S Sedlak Company. The power amplifier WPD100 was made with help of Prof. K. Hajek.

3. EXPERIMENTAL RESULTS

We have measured two samples (denoted: Sample-01 and Sample-03), which were made with different resistive pastes. Samples were rectangular shape with length of 40 mm and width of 5 mm. The thickness of a resistive layer was about 20 μm. Resistance of Sample-01 was 1.5 kΩ and Sample-03 was 270 Ω. We have applied ultrasonic signal of frequency 136 kHz which corresponds to the resonant frequency of the ultrasonic actuator with the fixed sample.

The spectral density of Us measured on the frequency f_U = 136 kHz vs. amplitude of ultrasonic signal for constant DC voltage for the Sample-01 is shown in Fig. 2 and for the Sample-03 is shown in Fig. 4. The value of noise spectral density on the measured resonant frequency f_U was rising even if DC voltage is short. These samples are containing the piezoelectric effect most probably. The spectral density of the voltage U_S vs. DC voltage for constant value of ultrasonic signal is shown in Fig. 3 for the Sample-01 and for the Sample-03 is shown in Fig. 5.

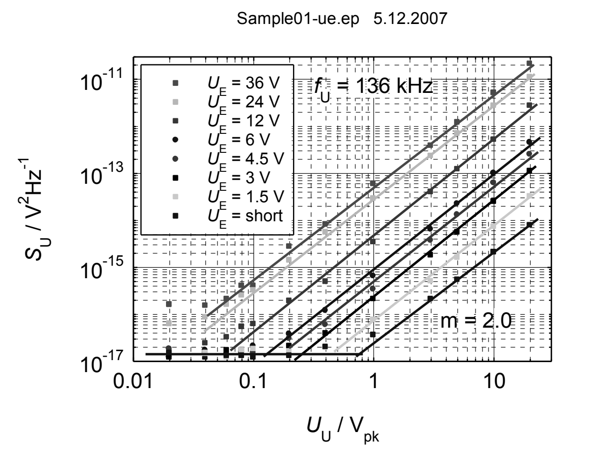

Fig. 2: The spectral density of U_S measured on the frequency f_U vs. the amplitude of the ultrasonic signal for different values of DC voltage for the Sample-01

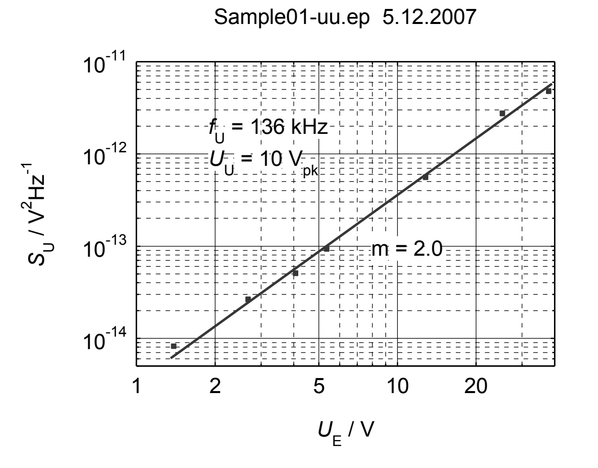

Fig. 3: The spectral density of the voltage U_S vs. DC voltage for constant value of ultrasonic signal U_U = 10V for the Sample-01

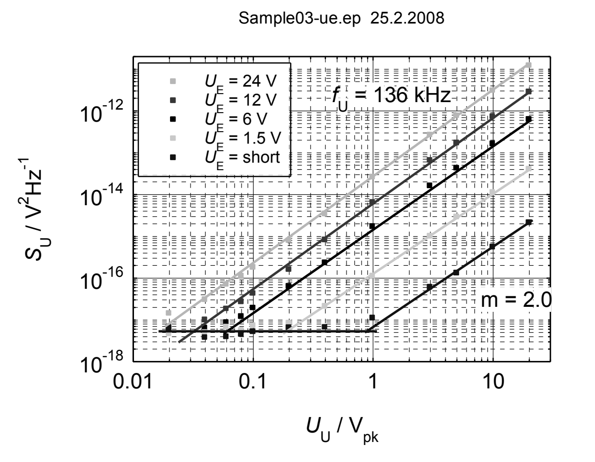

Fig. 4: The spectral density of U_S measured on the frequency f_U vs. the amplitude of the ultrasonic signal for different values of DC voltage for the Sample-03

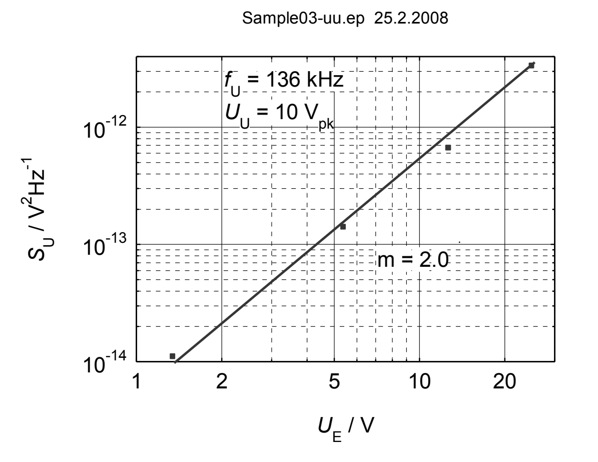

Fig. 5: The spectral density of the voltage U_S vs. DC voltage for constant value of ultrasonic signal U_U = 10V for the Sample-03

The noise background is higher for applied DC voltage U_E = 24 V and 36 V, because there is observed the noise spectrum of $1/f$ type, how is shown in Fig. 6. The spectral density of the voltage Us vs. DC current for the sample-01 and sample 02 is shown in Fig. 7. We can see that for the same ultrasonic excitation and DC current we obtain different values of the spectral density of the voltage Us for both samples.

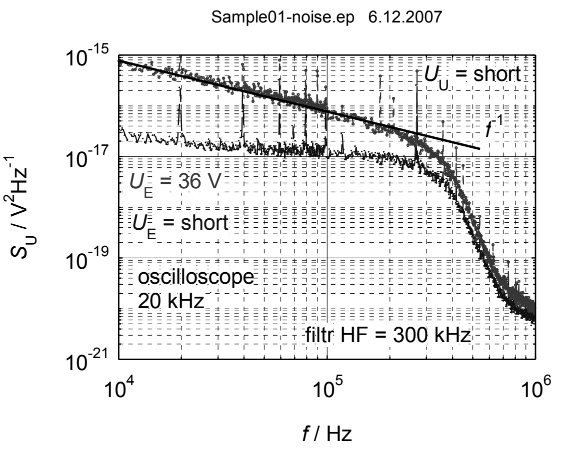

Fig. 6: The noise spectrum of measured resistor Sample-01 for applied DC voltage U_E = 0 V and U_E = 36 V (upper line)

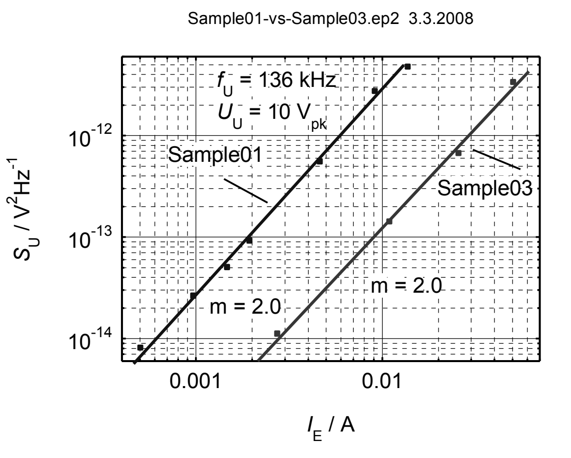

Fig. 7: The spectral density of the voltage U_S vs. DC current for the Sample-01 and Sample-03

4. CONCLUSION

We have measured two samples denoted Sample-01 and Sample-03 which were made from different resistive pastes. For both samples the spectral density of U_S increases with the square power of ultrasonic excitation for constant DC voltage and the spectral density of U_S increases with the square power of DC voltage for constant ultrasonic excitation respectively. We can observe the piezoelectric effect on both samples. We obtain the same peak value of the spectral density *U*s for the Sample-01 as with the Sample-03 if we led higher DC current for the same ultrasonic excitation. It can be an indicator of the sample quality. In our case we can conclude that the Sample-03 is made from better quality resistive past then the Sample-01.

ACKNOWLEDGEMENTS

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REFERENCES

[1] V. Sedlakova, "Electro-ultrasonic Spectroscopy of Polymer Based and Thick Film Resistors", In Proceedings of EMPC 2007, June 17 – 20, 2007, Oulu, Finland, pp. 550-555

[2] V. Sedlakova, J. Sikula, P. Tofel, "Electro-Ultrasonic Spectroscopy of Conducting Solids", In Proceedings of IMAPS POLAND 2007, Sept. 23 – 26, 2007, Rzeszów - Krasiczyn, Poland, pp. 523

[3] V. Sedlakova, J. Sikula, P. Tofel, J. Zajacek "Noise and Electro-Ultrasonic Spectroscopy of Polymer Based Thick Film Layers", In Proceedings of IMAPS POLAND 2007, Sept. 23 – 26, 2007, Rzeszów - Krasiczyn, Poland, pp. 527