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«MIST: Aerospace - 2020: Передовые технологии в аэрокосмической отрасли, машиностроении и автоматизации»

«A Method for Measuring Electromagnetic and Geometric Parameters of Thin Films»

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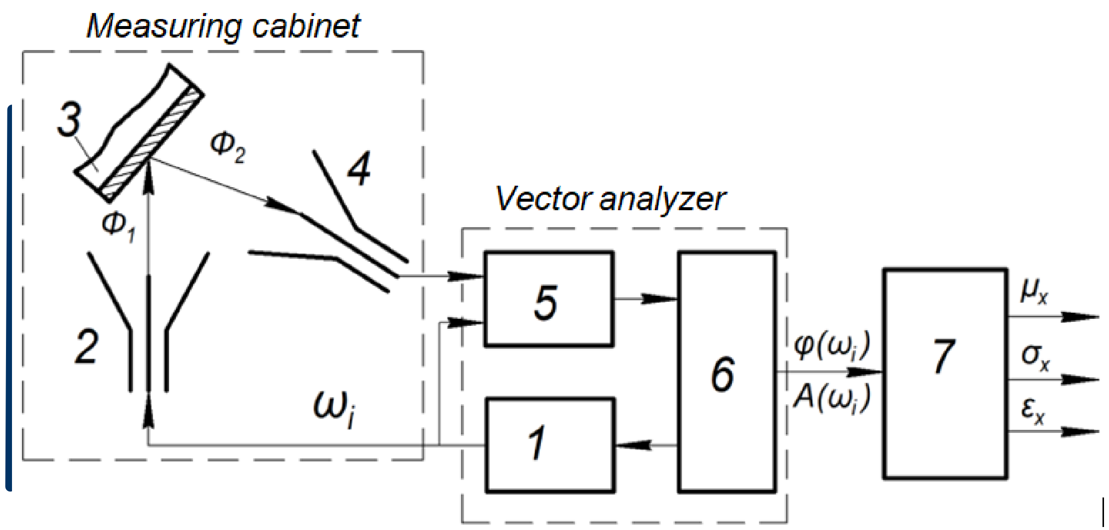
Актуальность

The use of thin films in various fields, such as instrumentation, energy industry and aerospace engineering has become one of the most promising trends in the development of modern instrumentation. Radiation-absorbing properties of thin films largely depend on their electromagnetic parameters (EMP), such as conductivity, permittivity and permeability, resulting in the need to measure the EMP both at the production stage and during operation. Most known contact and non-contact methods do not provide for measuring conductivity, permittivity and permeability at the same time and cannot be implemented within a single integrated device. The paper includes a comparison of the measuring methods each providing a way to measure all three parameters at the same time by the method of electromagnetic probing.

Методы решения



1 - generator, 2 - transmitting antenna, 3 - measured sample containing the film placed on a base plate, 4 - receiving antenna, 5- amplitude and phase analysis unit, 6 - control unit, 7 - processing device, F_1 - probing signal, F_2 - reflected signal

Functional block diagram of the non-contact measuring device

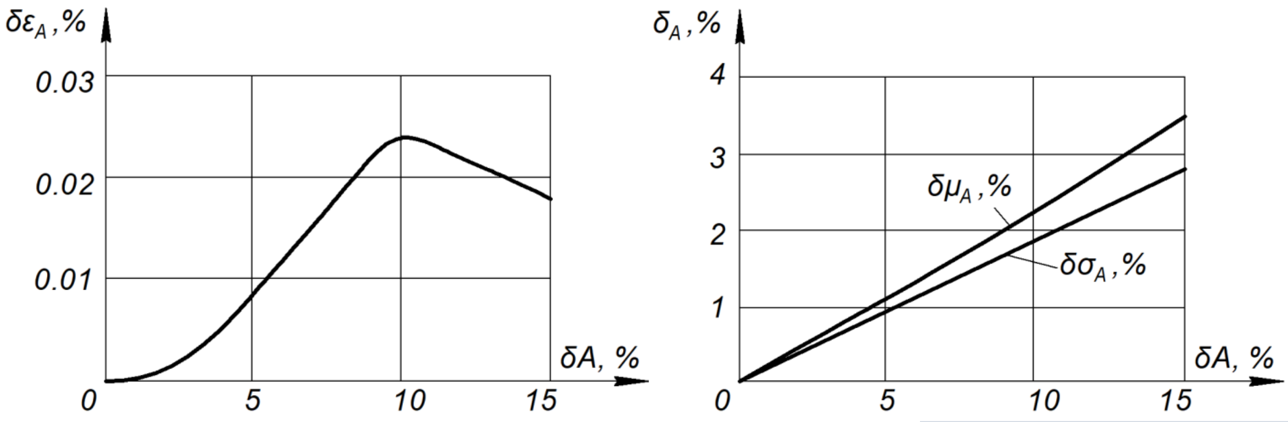
The measuring objective is to determine the current values of conductivity, permittivity and permeability, which can be found by solving the system of equations (1) connecting the amplitude $A\ (\omega_i)$ and phase $\varphi\ (\omega_i)$ of the signal received by the receiver by the corresponding transformation functions $F_A(\omega,\mu_x,\sigma_x,\varepsilon_x)$ and $F_\varphi(\omega,\mu_x,\sigma_x,\varepsilon_x)$ for a specific frequency.

Changes in the amplitude and phase of the reflected signal depend on the electromagnetic parameters of the monitored film through wave impedances $\underline{Z} = \sqrt{\dfrac{j\omega\mu_x}{\sigma_x + j\omega\varepsilon_x}}$

$$\begin{cases} F_A(\omega_i,\mu_x,\sigma_x,\varepsilon_x) = A(\omega_i) \\ F_\varphi(\omega_i,\mu_x,\sigma_x,\varepsilon_x) = \varphi(\omega_i) \\ F_A(\omega_{i+1},\mu_x,\sigma_x,\varepsilon_x) = A(\omega_{i+1}) \\ F_\varphi(\omega_{i+1},\mu_x,\sigma_x,\varepsilon_x) = \varphi(\omega_{i+1}) \end{cases}$$

References

Pulse probing signal is more versatile, since the capability to adjust its shape and duration provides optimization options for the process of measuring. However, the pulse method does not imply a reconfiguration of the generator during the measuring procedure. The processing of a reflected pulse signal requires more computing power in comparison with a continuous probe signal.



Graphs of the dependence of the measurement errors of electromagnetic parameters on the error in measuring the amplitude of the reflected signal

When comparing the methods, it can be concluded that the method error is the same for continuous and pulsed signals. This is due to the fact that this error is caused by the inaccuracy of the solution of the system of nonlinear equations, which was solved by the method of successive approximations. This error can be reduced by decreasing the iteration increments.

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