LASER TECHNIQUES IN THE STUDY OF MATERIALS.

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Abstract: This article discusses the theoretical foundations and practical application areas of laser techniques in the study of materials. The role of laser techniques in materials science, chemistry, biology, ecology, and nanotechnology is also highlighted. It is emphasized that laser-based methods are distinguished by high sensitivity, rapid analysis, and the ability to perform non-contact measurements.

Keywords: laser radiation, spectroscopy, Raman effect, interferometry, LIBS, plasma, fluorescence, materials science, nanotechnology, optical analysis, molecular structure.

Аннотация: В данной статье рассматриваются теоретические основы и области практического применения лазерных методов в исследовании материалов. Также освещается роль лазерных методов в материаловении, химии, биологии, экологии и нанотехнологиях. Подчеркивается, что лазерные методы отличаются высокой чувствительностью, быстрым анализом и возможностью проведения бесконтактных измерений.

Ключевые слова: лазерное излучение, спектроскопия, эффект Рамана, интерферометрия, LIBS, плазма, флуоресценция, материаловение, нанотехнологии, оптический анализ, молекулярная структура.

Modern science and technology increasingly rely on lasers as one of the most important tools for studying materials. Since the first operational laser device was created by Theodore Maiman in 1960, laser technologies have been widely applied in physics, chemistry, biology, medicine, and materials science. Today, lasers enable high-precision investigations of the atomic and molecular structure of substances, their energy levels, composition, and physical properties. A laser (Light Amplification by Stimulated Emission of Radiation) is a device based on the process of amplifying light through stimulated emission [1]. Laser radiation is characterized by monochromaticity (having a single, well-defined wavelength), coherence (phase correlation of waves), directionality (beam propagation within a very small divergence angle), and high intensity (high energy density). These properties make lasers extremely convenient tools for material studies.

In spectroscopy, laser absorption spectroscopy is based on measuring the laser radiation absorbed by a substance. A laser beam of a known wavelength is transmitted through a sample, and the degree of absorption is determined. As a result, information about the composition and concentration of the substance is obtained [2]. The Raman effect, discovered by C.V.Raman, makes it possible to study molecular vibrations of matter. When laser light interacts with a substance, the frequency of the scattered light changes slightly. This shift is used to determine the molecular structure of the material. Raman spectroscopy is widely used to identify chemical bonds, investigate crystal structure, and analyze biological samples. L Using a laser, a substance can be excited to a higher energy state, and the radiation emitted during relaxation (fluorescence) is analyzed. This method is particularly effective for studying biological molecules and semiconductor materials.

Interferometry is a method based on the phenomenon of interference that occurs when light waves overlap. The high coherence of laser beams allows interference patterns to be recorded with high accuracy. For example, laser interferometry was used at the LIGO observatory to detect gravitational waves. In materials research, interferometry is applied to measure surface irregularities, detect extremely small displacements, and study mechanical deformation of materials. In Laser-Induced Breakdown Spectroscopy (LIBS), a high-power laser pulse is focused onto the surface of a material, resulting in plasma formation. By analyzing the emission spectrum of this plasma, the elemental composition of the material is determined [3]. The main advantages of LIBS include rapid analysis, minimal sample preparation, and the possibility of remote measurements. This method is widely used in geology, metallurgy, and environmental monitoring.

In conclusion, laser techniques have brought revolutionary changes to the study of materials. Using methods such as spectroscopy, interferometry, plasma analysis, and microscopy, the structure and properties of substances at the atomic and molecular levels are being analyzed in depth. In the future, further improvements in laser technologies will open up even broader opportunities in the development of new materials, medical diagnostics, and environmental control.

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