ABSORPTION BANDS OF INTRINSIC POINT DEFECTS IN IRRADIATED ZINC OXIDE

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A program has been developed for separating the spectrum of radiation-induced absorption in powdered zinc oxide and reflective coatings based on it into individual components which includes calculations of the parameters of the bands arising from intrinsic point defects, bands from chemisorbed gases, and nonselective absorption by free electrons. Experimental results on the changes in the diffuse reflection spectra of ZnO powder and reflective coatings after the action of various forms of radiation have been found. The experimental spectra have been decomposed into individual components.

INTRODUCTION

Materials used as heat-regulating coatings (HRC) of space flight equipment (SFE) are subject to the action of various factors in space (SF). Since the basic SF can change the composition and structure of their materials due to temperature, high vacuum and cosmic radiation, their action is studied in more detail. However such studies of materials which are exposed to space conditions for a long time involve large technical and scientific difficulties due in the first place to the complexity of the radiation situation in outer space (OS) which usually consists of the simultaneous action of several forms of different radiation, and in the second place the complexity of the composition of TRP, which are heterogeneous systems as a rule.

Experiments under natural conditions using SFE involve large technical and scientific problems. Therefore since 1968 in the laboratory for the study of radiation effects in aerospace materials at Tomsk Polytechnic University we have used special equipment [1] for testing TRP, which imitates the action of SF in a terrestrial laboratory: vacuum, temperature, corpuscular and electromagnetic radiation, etc. The objects of study are powders — ZnO, TiO₂, ZrO₂, and Zn₂TiO₄ pigments used in reflective coatings, coatings based on them, metallized polymer films, ZnO and TiO₂ single crystals, and model alkali halide single crystals.

It is known that the action of SF on TRP changes the diffuse reflection \( \Delta \rho \) and the integrated absorption coefficient \( \Delta \alpha \), which can reveal previous degradation of a system of passive temperature regulation of the SFE. Therefore there are two problems in this area of science: development and production of TRP which have high radiation stability and development of physical models for their degradation which allow a scientifically based prediction of changes in their optical properties under conditions of orbital flight in particular orbits. The solution of these problems is determined by a knowledge of the physical processes which take place under the action of SF and the degradation mechanisms of TRP.

Up to the present time predictions of the operability of TRP have been done from the change in the working characteristics — the integrated absorption coefficient \( \alpha_\lambda \) which in earth experiments is determined from the diffuse reflection spectrum in the solar region \( \rho_\lambda \) before and after irradiation of the samples under forced conditions.

The physical-mathematical or statistical models of TRP degradation used for prediction have been obtained with a certain degree of approximation which is the basis for describing the change in the integrated properties determined by the sum of the absorption bands induced by radiation. It would be best to solve this problem by studying the kinetics of the changes in the absorption coefficients of each defect and then integrating over the whole solar spectrum. For this it is necessary that the change of the diffuse reflection spectrum \( \Delta \rho_\lambda \) of TRP be correctly separated into individual bands. Such work has not previously been done.
The aim of the present work is analysis of methods for separating the optical spectra into individual bands, choice of the optimal method and conditions of separation for zinc oxide (the most widespread pigment for TRP), and expansion of the integrated contour into individual components.

EXPERIMENTAL

The sample included both ZnO pigments and TRP based on them (ZnO + polymethylsiloxane, ZnO + polymethylphenylsiloxane, ZnO + liquid potassium glass). The samples were irradiated in an oil-free high vacuum (P ≤ 10^{-3} Pa) with controlled temperatures in the range 120-420 K with separate or simultaneous electron, proton, and electromagnetic radiations (EMR) with a spectrum close to that of the sun. At the sample irradiation site we detected the spectrum \( \rho_\lambda \) in the range 0.25-2.2 \( \mu \)m before and after irradiation. The error in determining \( \rho \) in the UV and visible regions was 0.2-0.3% absolute and close to the IR region it reached 6%. The method for detecting the spectrum, and the diagnostic methods for the proton, electron, and EMR beams are described in [1].

Figure 1 shows as an example the reduced spectra \( \rho_\lambda \) of TRP based on ZnO + polymethylsiloxane (ZnO + PMS) and the difference spectrum \( \Delta \rho_\lambda \) obtained by subtracting the spectra of \( \rho_\lambda \) in the initial state and after the action of EMR. The irradiation dose \( H \) is given by the product of the radiance \( (E_s)' \) is the equivalent solar radiation (esr); 1 esr = 0.14 W/cm^2) and the irradiation time measured in equivalent solar days (esd):

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H = \frac{t}{24} \cdot (E_s)'
\]

We also found similar spectra of \( \rho_\lambda \) and \( \Delta \rho_\lambda \) for samples irradiated with protons and electrons, and simultaneous protons, electrons, and EMR. The spectrum of \( \Delta \rho_\lambda \) is qualitatively similar to the spectrum of irradiation-induced absorption since transmission and reflection from the surface does not change in the process of irradiation while the changes of the initial spectrum \( \rho_\lambda \) are due only to changes of the absorption coefficient [1].

INTRINSIC POINT DEFECTS

The difference spectrum \( \Delta \rho_\lambda \) of diffuse reflection is a superposition of a series of independent bands which characterize individual color centers (CC). Such bands substantially overlap and the determination of their parameters (absorption energy position \( E_{\text{max}} \), half-width \( H_{1/2} \), and intensity I) is difficult.