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Corundum Detector Converter

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Abstract: A study of the energy, spectral, temporal characteristics of corundum (a-Al2O3) with various activators was made to develop a more efficient converter of UV radiation not only in the UV, but also in the VUV spectral regions. Promising activating agents were selected, their concentrations were determined, their optical properties were studied, absorption and luminescence spectra (curves) were obtained, and quantum yields were measured at various impurity concentrations. Luminescence measurements were carried out at several constant corundum irradiation frequencies (dependence of luminescence on radiation power) within the limits of the capabilities of the available equipment. Luminescence is the most important characteristic of crystals in the development of optical detectors based on them.

Keywords: Luminescence, detector, impurities, corundum crystal, converter, dislocation

1. Introduction

It is known that the absorbing and luminescent properties of crystals depend on the activation centers. The study of the luminescent properties is one of the most important methods for elucidating the nature of the activation centers, the kinetics of accumulation, and the generation of the properties of corundum. As is known, many optical properties of crystals, including luminescence, mainly depend on two factors - inclusions (dislocations) and impurities. Naturally, when conducting such developments, it is necessary to accurately determine the qualitative and quantitative composition of impurities, the concentration of which for optical crystals ranges from a few percent to several percent. A significant limitation to the methods used is that the method must be non-destructive.

There are many corundum-based detectors with different impurities that work in the VUV and UV spectral regions [1,2,3,4,5], but you can always improve, develop a detector with a more sensitive converter, find those substances, their concentrations and ratios, which have resonance absorption lines in the VUV spectral region.

We have carried out numerous experiments [7,8]. The experiments were carried out on an AMPTEK X-ray spectrometer. Almost all elements that can be part of optically active crystals $-Fe, Cr, V, Co, Mn, Cu, Sc,$ lanthanum and lanthanides, etc. — were identified. As a result of the research, those substances, their concentrations and ratios that have resonant absorption lines not only in the UV, but also in the VUV spectral regions, were revealed.

2. Experimental Part

Several peaks are found in the luminescence spectra of corundum crystals, which are very difficult to unambiguously identify, since the energy values of their maxima differ quite substantially from the luminescence peaks of most elements. (Fig.1)

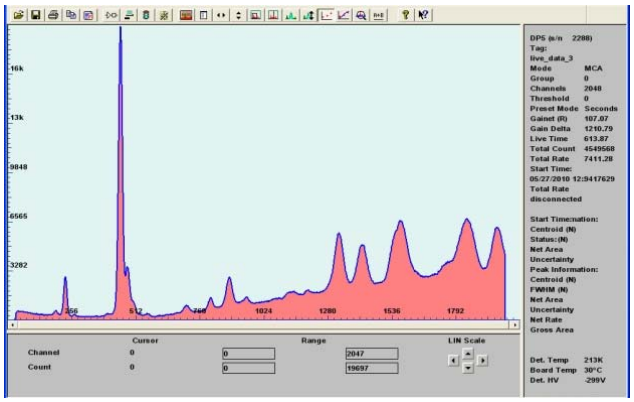


Fig. 1. Spectrum of luminescence of corundum

Moreover, the spectra obtained by irradiating different faces of a crystal differ significantly from each other. (Fig.2), and, as a rule, the intensity and position of such "strange" peaks change.

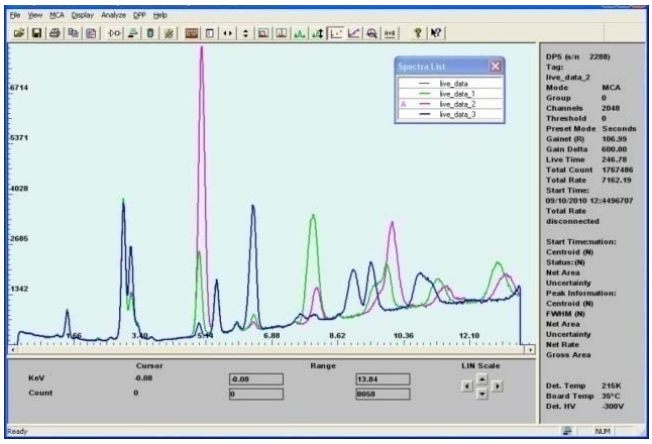


Fig. 2. Offset and extra peaks

To determine the causes of such peaks, we carried out a series of model experiments. The spectra of mixtures of chemically pure salts that mimic the quantitative and qualitative composition of corundum crystals were studied. As shown by the results of these measurements, all the peaks in the recorded luminescence spectra of such mixtures are identified with a sufficiently large accuracy (+ -0.1 - 0.2 keV) (Fig.3)

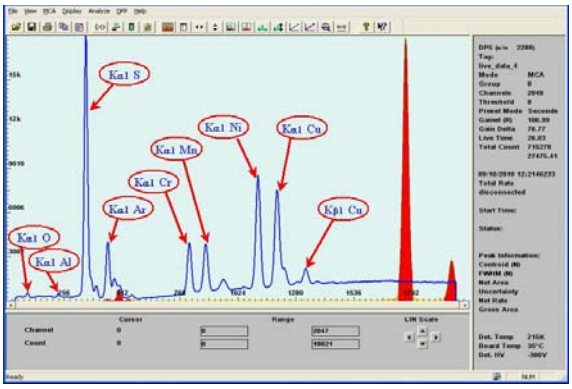
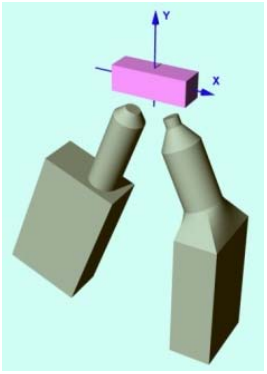


Fig. 3. Luminescence spectra of mixtures of chemically pure salts

Naturally, corundum crystals can be non-uniform and, therefore, different parts differ from each other in composition, but it is impossible to explain the picture presented in fig. 2 base only on composition difference. In our opinion, the only acceptable explanation for such a pattern is the diffraction nature of these anomalous peaks. To test this assumption, the same region of the crystal was investigated for its different orientations. The following figure shows the results obtained. It is clearly seen that part of the peaks is reproduced with great precision both in energy and in intensity. It is characteristic that all of them are also uniquely identified. These are the peaks corresponding to Al, V, Cr, Ni. Such an approach makes it possible to identify diffraction peaks and exclude them from further analysis of the data obtained.



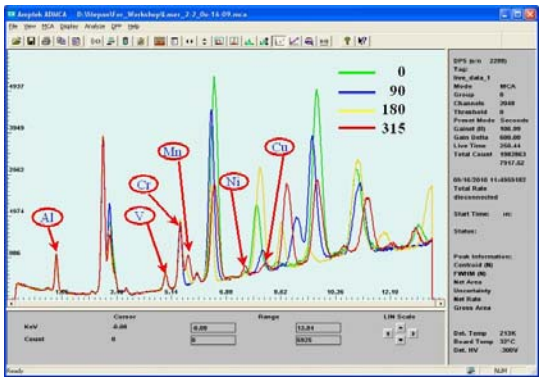


Fig. 4. Luminescence spectra at different orientations of the sample

However, such a direct exclusion of mismatched peaks may not always give the expected result. In some cases, they more or less overlap the peaks corresponding to certain elements. The following figure shows a small area of the spectra with such peaks. Both of the peaks presented (maximums 6.37 and 6.49) are fairly close to the peak of iron (6.43) and can be interpreted as iron with equal success. However, the area of their overlap, which is highlighted in solid color in the figure, corresponds to iron much more precisely in terms of energy. In such cases, in order to obtain more reliable information, it seems that in the quantitative analysis the difference spectrum of such areas should be used. Unfortunately, the installation software, which analyzes the recorded spectra, does not have such a function, however it can be done quite easily with other software products, especially since the installation program stores data on the intensity of the peak in a simple text file.

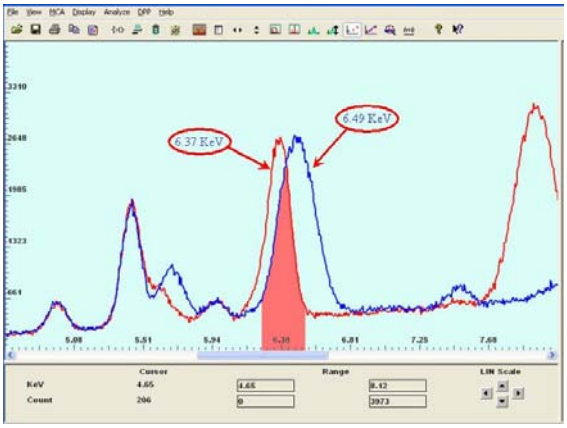


Fig. 5. Offset and additional peaks

Thus, during the study of crystalline samples, it is possible to register the luminescence spectra at different crystal orientations, a comparison of the obtained spectra will make it possible to eliminate diffraction peaks and to obtain more reliable information about the sample composition. The crystals, which were investigated during the work, are in Fig. 6.

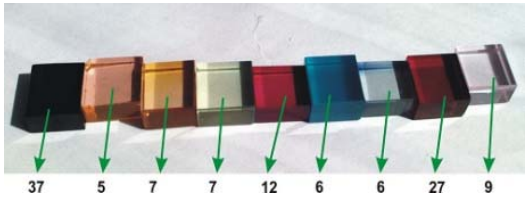


Fig. 6. Some samples of single crystals of corundum

The luminescence of these selected crystals is presented in Fig. 7.

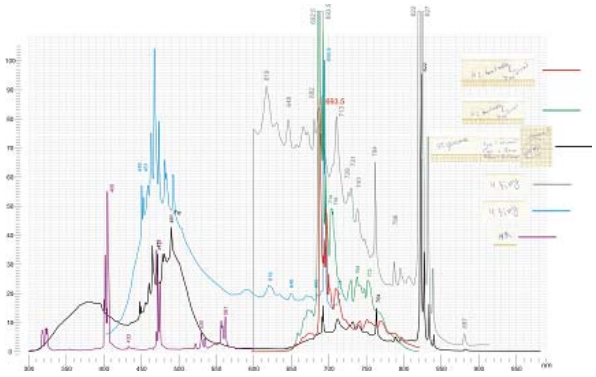


Fig. 7. Relative luminescence intensities of crystals when excited by a UV spectrum in the range of 250-350 nm

3. Conclusion

Single-crystal corundum samples with various doping impurities were investigated, their optical properties were studied, and luminescence spectra (curves) were obtained. The luminescence measurements were carried out at several constant corundum irradiation frequencies within the capabilities of the available equipment. . The differences between them, depending on the composition of the alloying substances and their concentration, are obvious even at first glance. Concentrations of the available alloying substances were measured. Further studies should be performed to identify and divide the resonance lines corresponding to each specific element of the doping substance, to study the role of the doping substance in the formation of the overall absorption spectrum, to assess the possibilities of the forced formation of the absorption spectrum in the wavelength range of interest.

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