



Ionoluminescence investigation of a Natural fluorite sample

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Abstract

The ionoluminescence spectroscopy and imaging of a natural fluorite sample was performed, using high energy proton beam. Three luminescence bands were detected for the sample, which are located in the UV and red parts of the electromagnetic spectrum. Moreover, the distribution of the red luminescence of the sample is investigated based on its ionoluminescence image. The results of this research work provide information regarding the structural defects and impurities of the sample, which are required for the dosimetry applications of the natural fluorite.

Keywords: Ionoluminescence Spectroscopy; Ionoluminescence Imaging; Natural Fluorite

Introduction

It is well-known that minerals, such as quartz, feldspar, and recently fluorite, can be employed as natural dosimeters, particularly for dating of archaeological materials [1-3]. In this regard, normally thermoluminescence (TL) and optically stimulated luminescence (OSL) techniques are applied to reveal the irradiation history of these minerals. In order to interpret the experimental results of these techniques, it is necessary to identify the luminescence centers in these minerals. Therefore, complementary techniques to TL and OSL, especially luminescence imaging techniques, such as cathodoluminescence (CL) and ionoluminescence (IL) [4], are used to provide the required information for identification of the samples' defects.

Considering the few laboratories in the world which have implemented the IL spectroscopy and imaging setup, it has not been commonly applied for revealing the defects in minerals [5]. However, usually high energy proton beam are applied for this purpose, which imposes the minimum damage to the crystal lattice and, on the other hand, due to its larger penetration depth in comparison to CL, is much less sensitive to the surface conditions.

In this research work, the results of ionoluminescence spectroscopy and imaging of a natural fluorite sample are provided, which are compared with the corresponding available CL results in the literature.

Experimental

Preparation of the materials

After cutting the sample in a small size of ~ 2 cm, it was mounted and polished, using sand papers and diamond compounds of different sizes to provide a smooth surface.

The experiments were performed in air-pressure conditions at the Van de Graaff laboratory, using 2 MeV proton beam of ~ 4 nA. The IL spectrum and image of the sample were collected via an AvaSpec-ULS2048L spectrometer of 1.4 nm resolution and a CCD, respectively. A fiber optic was used to transfer the emitted light from the sample to the spectrometer [5]. The integration time of the IL spectrum was 5 seconds.

Results and discussion

The fluorite sample with smoothed surface is shown in Fig. 1. The IL image of the sample which is exhibited in Fig. 2, presents the distribution of luminescence centers in the sample. Such IL images which represent the density of structural defects and impurities in the samples, can be applied e.g. for understanding the variations of OSL intensities from grain-to-grain [2]. In order to illustrate this, using ImageJ software, the variation of IL intensity along the dashed black line in Fig. 2, is plotted in Fig. 3. Micrometer-scaled variations of the IL image of the sample are easily recognizable.



Figure 1. smoothed surface of the mounted fluorite sample of ~ 1×1 cm².



Figure 2. Ionoluminescence image of ~ 1×2 mm² of the fluorite sample.

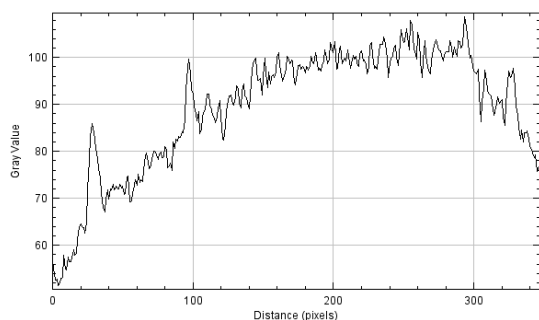


Figure 3. Variations of ionoluminescence intensity along the dashed black line in Fig. 2.

The IL spectrum of the fluorite sample is provided in Fig. 4. Two main peaks are recognisable in the spectrum which are located in the UV and red part of the electromagnetic spectrum. In order to distinguish the bands constituting the spectrum, it was deconvoluted into three main bands (Fig. 5). Such spectra reveal information regarding the nature of the luminescence centers, including impurities and defects of the lattice and their relative concentrations in the sample.

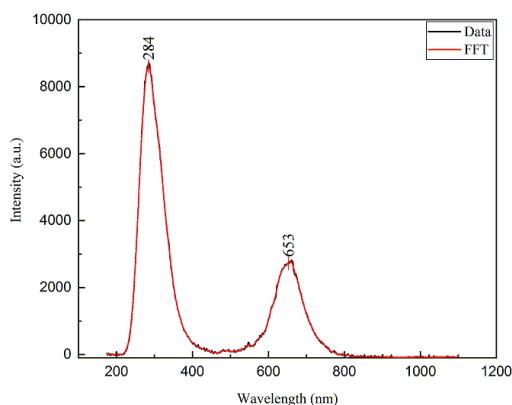


Figure 4. The IL spectrum of the fluorite sample. The peak positions are remarked.

According to Fig. 5, the main part of the IL spectrum is formed from two UV bands of 3.87 and 4.47 eV, which the latter is significantly intense. Such intense violet band has been previously observed in the CL spectrum of white fluorite sample, which has been ascribed to the structural defects [1]. It should be noted that the wavelength shifts of the bands in the IL spectra, in comparison to the other luminescence techniques, has been frequently observed. A less intense red band at 1.92 eV also exists in the spectrum. It should be noted that this band is the only visible one, which forms the corresponding IL image (Fig. 2). The origin of the red band likely is the color centers of the mineral [6,7]. It should be mentioned that although it is common to observe the narrow bands of the rare earth elements in the luminescence spectrum of fluorite, they are not detected for the current sample.

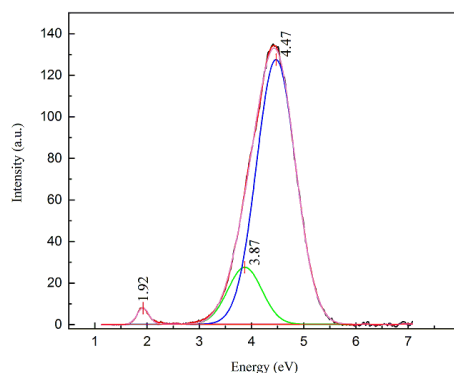


Figure 5. The result of deconvolution of the IL spectrum of the fluorite sample. The bands' positions are remarked.

Conclusions

In this research work, the IL spectrum and image of a natural fluorite sample was investigated for the first time. According to the results of the current work, IL is capable of extracting information regarding the nature of the structural defects and impurities, and their distributions in minerals. Despite differences between the excitation of the dosimetry techniques of OSL and TL with that of IL, they provide similar spectra, which reveal the nature of luminescence centers in the mineral that could be useful for deciphering the origin and thermal history of the mineral. Considering valuable information obtainable by IL technique for dosimetry applications of natural minerals and the limited works performed in this field, it is recommended to perform further comprehensive researches in this field.

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References

- [1] M. Topaksu, V. Correcher, J. Garcia-Guinea, *luminescence emission of natural fluorite and synthetic CaF₂:Mn (TLD-400)*, *Radiat. Phys. Chem.* 119, 151 (2016).
- [2] F. Preusser et al., Quartz as a natural luminescence dosimeter, *Earth Sci. Rev.* 97, 184 (2009).
- [3] M. Gaft, R. Reisfeld, G. Panczer, *Modern Luminescence spectroscopy of minerals and materials*, Springer, Sec. Ed., Switzerland (2015).
- [4] J.R. Huddle et al., Ion beam-induced luminescence, *Nucl. Instrum. Methods B* 261, 475 (2007).
- [5] T. Nikbakht, O. Kakuee, M. Lamehi-Rachti, Study of the ionoluminescence behavior of the gemstones: Beryl (aquamarine variety), opal, and topaz, *J. Lumin.* 171, 154 (2016).
- [6] W. Bontinck, Colour centers in synthetic fluorite crystals, *Physica XXIV*, 639 (1958).
- [7] M. Gaft et al, Red luminescence and purple color of naturally irradiated fluorite, *Phys. Chem. Miner.* 47, 46 (2020).