PHOTOLUMINESCENCE OF CHELYABINSK LL5 CHONDRITE WITH LIGHT-COLORED LITHOLOGY IN 7 – 300 K TEMPERATURE RANGE

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Introduction: Recently it was shown that fragments of Chelyabinsk LL5 chondrite, in which lithologies of various types dominate, had dissimilar physical and chemical properties [1 – 4]. On the one hand, this makes it possible to use relevant experimental methods to characterize such samples. On the other hand, we can talk about a more rigorous methodological and classification approach in studying the fundamental mechanisms responsible for the formation of observed feartures of the Chelyabinsk meteorite. It was found earlier [3, 4] that optically induced and luminescence processes occur more intensively in samples with light-colored lithology. The high content of inhomogeneous optically active centers, the variety of radiative and non-radiative transitions, the presence of competing systems of discrete and quasicontinuous levels of charge carriers capture in the energy gap lead to a complex kinetics of the observed processes and microscopic mechanisms of radiationally and thermally stimulated responses Chelyabinsk meteorite under different excitations. The purpose of this work was to study the temperature behaviour of the photoluminescence (PL) spectra in the 7 – 300 K range of Chelabinsk LL5 chondrite samples with predominantly light-colored lithology.

Experimental: The fragment of Chelyabinsk LL5 chondrite characterized by light-colored lithology predominantly was selected. The core of the meteorite was separated from fusion crust and crushed into micropowder, which was treated in hydrochloric acid to remove metal particles. PL was excited by ultraviolet pulsed radiation from the DTL-389QT solid-state laser (Laser-Export, LLC) with a wavelength of λ = 263 nm and with pulse repetition frequency of 1 kHz. The laser radiation power was 12 mW at the sample location. PL signal was registered using a Shamrock SR-303i-B spectrograph (Andor, Inc.) with a diffraction grating of 150 mm^{-1} stroke number and with efficiency maximum at λ = 500 nm, as well as a cooled Newton EM DU970P-BV-602 CCD matrix (Andor, Inc.). The temperature of the matrix during the measurements was stabilized by 193 K. The width of the spectrograph entrance slit was 50 μm. To eliminate the influence of the laser radiation scattered by the sample, BS-8 optical filter (Electrosteclo, LLC) was used. Data from the CCD were read in full vertical binning mode under 3 s exposure time. The experimental spectra were averaged over 20 independent measurements. The temperature of the sample was changed by means of a CCS-100/204N helium cryostat (Janis Research Company, LLC) with a closed loop equipped with DT-670B-CU sensor, HC-4E compressor and 335 Model controller (Lake Shore Cryotronics, Inc.). The pressure inside the cryostat was maintained by HiCube 80 Eco vacuum pumping station (Pfeiffer Vacuum, LLC) at a level of $P \leq 10^{-4}$ mBar. PL spectra were recorded in the range of λ = 350 – 900 nm at different temperatures: 7 K, in 10 – 100 K range in steps of 10 K and from 100 to 300 K in steps of 20 K.

Results and Discussion: The measurement results of the PL emission spectra at different temperatures are presented. It is shown that the PL dependences are characterized by two wide bands with maxima at ≈ 2.5 eV (490 nm) and ≈ 1.8 eV (680 nm) in the spectral range under study. It is found that the ratio of the maximum intensities of the registered bands has a complex dependence upon temperature change in the range 7 – 300 K. Thus, the luminescence intensity in the band 2.5 eV first increases by ≈ 1.2 times, reaches a maximum at ≈ 240 K and then falls to ≈ 2.1 times with decreasing temperature. At the same time, the intensity in the 1.8 eV band remains practically unchanged from 300 K down to 160 K, and then increases by ≈ 1.9 times with a further decrease in temperature. The deconvolutions of all experimental PL spectra into several Gaussian components are performed. It is demonstrated that the spectrum observed at 300 K is quite accurately approximated (determination coefficient of $R^2 > 0.998$) by single Gaussian with the maximum energy at $E_{max} = 2.48 \pm 0.01$ eV and the halfwidth of $\omega = 0.96 \pm 0.01$ eV, and the spectrum measured at 7 K is numerically described ($R^2 > 0.995$) by three components with E_{max} = (2.81, 2.37 and 1.79) ± 0.01 eV and ω = (0.64, 0.53 and 0.42) ± 0.01 eV, respectively. The spectral positions of the obtained luminescence bands are in satisfactory agreement with the earlier studies [1, 3 – 5]. The temperature dependences of the maximum PL intensity in the investigated bands are analyzed in the framework of the Mott and Street models [6, 7] with various non-radiative channels. It is evaluated that the activation energies of the PL thermal quenching are E_q = 330 ± 30 meV (T > 240 K range) and 28 ± 7 meV (50 < T < 240 K) for the bands of 2.5 and 1.8 eV, correspondingly. The possible quenching mechanisms and origin of responsible optically active centres are discussed.

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References: [1] Popova O.P. et al. 2013. *Science* 342: 1069–1073. [2] Kohout T et al. 2014 *Icarus* 228: 78–85. [3] Weinstein et al. 2014. *Meteoritics & Planetary Science* 49: A428. [4] Weinstein I.A. et al. 2015. *Meteoritics & Planetary Science* 50: 5175. [5] Vokhmintsev A.S. and Weinstein I.A. 2017. *Meteoritics & Planetary Science* 52: A371. [6] Weinstein I.A. et al. 2006. *Techn. Phys. Lett.* 32: 58–60. [7] Street R.A. 1976. *Adv. Phys.* 25, 4: 397–453.