Cathodoluminescence microscopy and spectroscopy of plagioclases from lunar soil

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ABSTRACT

Cathodoluminescence (CL) microscopy and spectroscopy of single plagioclase grains from lunar soil show that plagioclases from Luna 20 (highland) have more or less homogeneous CL with both blue or green colors, whereas plagioclase grains sampled by Luna 24 (mare) luminesce predominantly green with partially distinct oscillatory zoning. The three main emission bands in the blue (~450 nm), green (~560 nm), and red-IR (~690 nm), mimic the most common emission bands in terrestrial feldspars. Mn2+ is the most important activator element in lunar plagioclases. Variations in the amount of structurally incorporated Mn2+ cause variations in the intensity of the green emission band at 560 nm, in some cases resulting in zoning of the CL intensity within single crystals. Calculations by a combination of quantitative spectral analysis of CL emission and PIXE measurements yield Mn concentrations of 7–47 ppm. The intense intrinsic emission band at 450 nm (probably an Al-O–Al center), which was especially prominent in Luna 20 plagioclases, causes their blue CL color. The occurrence of a CL emission band at ~690 nm in plagioclases from Luna 24 samples confirms that Fe3+-activated CL is common in these grains. The results indicate that at least some of the Fe in Luna 24 plagioclases is Fe3+, whereas all Luna 20 plagioclases have Fe3+-near the CL detection limit of about 0.1 ppm.

INTRODUCTION

Plagioclase is a principal mineral in lunar rocks and soil. It is generally assumed that Fe, the most abundant transition element in calcic plagioclases of lunar rocks and soil (regolith), occurs predominantly as Fe2+, because Mössbauer measurements, optical studies, and wet chemical analysis did not detect Fe3+ (e.g., Herzenberg and Riley 1970; Forester 1973; Burns et al. 1973; Bell and Mao 1973). However, electron spin resonance (ESR) and luminescence excitation spectroscopy studies have indicated the presence of Fe3+ along with Mn2+ (Weeks 1973; Niebuhr et al. 1973; Telfer and Walker 1975). To further constraining concentrations of Fe3+ on the moon, single plagioclase grains from Luna 20 and Luna 24 samples, which represent material of predominantly highland origin and material mostly consisting of pure mare soil, respectively, were characterized by spatial resolved CL spectroscopy and spectral analysis of CL emission. In addition, attempts were made to quantify the concentration of the most important activator for CL (Mn2+) in these lunar plagioclases.

MATERIALS AND METHODS

Sample material

The landing site of Luna 20 is located in the highland region between Mare Fecunditatis and Mare Crisium (3°32′N and 56°33′E). The Luna 20 soil consists of loose-grained, light grey regolith with about 50% <0.083 mm. The sample material consists of about 50% degraded bedrock and thus is mature soil (Taylor et al. 1973). Lithic fragments are mainly anorthositic norite and troctolite with calcium plagioclase, pyroxene, olivine, and only minor basaltic constituents (Cameron et al. 1973).

The landing site of Luna 24 is located in the south-eastern part of Mare Crisium, which fills most of the Crisium multiringed basin (Vinogradov 1972). The Luna 24 regolith is a relatively immature, pure mare soil with minor exotic components and a near bimodal size distribution with maxima at the 200–94 and 40–10 µm fractions (Laul et al. 1987). The soil is dominated by monomineralic particles (Ca-rich feldspar, Fe-rich pyroxene of mare origin, olivine) with low agglutinate, lithic, and glass contents. Whereas the monomineralic population has a minor highland component, the fraction of glass fragments contains a significant proportion of clasts that are of highland origin (Laul et al. 1987).

Monomineralic grains of plagioclases investigated here mainly consist of transparent, pure plates and splinters with a grain-size of 100–300 µm. All investigations were carried out on polished thin sections of the separated single plagioclase grains, which were produced using low-fluorescing epoxy resin.

Experimental methods

We used a “hot cathode” CL microscope at 14 kV and with a current density of ~10 µA/mm². To prevent the build-up of electrical charge, the thin sections were coated with carbon. Luminescence images were captured “on-line” during CL operations by means of an adapted digital video-camera (KAPPA 961-1138 CF 20 DXC with cooling stage). CL spectra were...