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Preliminary results on time-resolved ion beam induced luminescence applied to the provenance study of lapis lazuli

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ABSTRACT

This work will present preliminary results concerning the use of time-resolved ion beam induced luminescence applied to provenance studies of lapis lazuli. Measurements were performed at the pulsed beam facility at LABEC laboratory in Florence. Lapis lazuli is a semi-precious gemstone, used as ornament since the early civilizations that can be found in few places on Earth. The importance of this work lies in understanding the origin of various samples of lapis lazuli, from which it may be possible to gain insight into trade routes from ancient times. The samples studied in this work originated from Chile, Afghanistan, Tajikistan, Myanmar, and Siberia. The stones were irradiated with 3 MeV protons and the resulting luminescence was detected by a photomultiplier tube, whose output was acquired using a sampling digitizer VME module (CAEN/V1720). Wavelength discrimination was performed at 430 nm utilizing a range of beam currents. The results showed that, by changing the beam current intensity, one can study different features of lapis lazuli, and this may aid in distinguishing lapis lazuli from different provenances.

1. Introduction

When studying insulators and semiconductors, luminescence techniques can be extremely powerful as they give information about structural defects and impurity sites [1]. Among the possible excitation sources such as photons and electrons, ion beams can offer particular advantages. Ion beam induced luminescence (IL) technique [2] allows for the changing of the excitation depth profile by varying ion energy and mass. Moreover, the rate of energy deposition along the ionization track can also be changed. Although it is still not fully understood, the process behind IL can be comprehended in terms of basic notions. When an ion beam collides with a crystalline material it generates an excited lattice and excited impurities. Through different relaxation mechanisms the material can return to the ground state, with non-radiative and radiative emissions.

Techniques based on luminescence detection can be very sensitive to the presence of d-transition metal ions and rare earth elements because IBIL depends on the chemical state of the emitting atom, as well as local symmetry, the covalent character of the bonds it forms, and the spatial symmetry of the crystalline lattice [3]. In fact, these techniques have been applied to the characterization of minerals with interesting results [4]. The LABEC laboratory in Florence, with a long record of cultural heritage studies [5,6] and environment [7,8], has applied ionoluminescence spectroscopy to the provenance studies of lapis lazuli [9–14]. This very heterogeneous material has been a matter of study in several laboratories [15–19]. It consists of many minerals such as, for example, lazurite, diopside and pyrite, whose crystals have a size ranging from few micrometers to millimeters. Lapis lazuli has been traded since early civilization and can only be found in few places on Earth like Chile and Siberia. The importance of being able to characterize lapis lazuli from different origins comes with the fact that it can help in understanding different trade routes in ancient times [20]. The results from previous studies have offered a strong marker that can help distinguish Chilean lapis lazuli from other

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