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Surface Dating of Airless Bodies by Remote Sensing Luminescence

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Abstract

Future planetary missions particularly to asteroids or the outer planet moons need a relatively inexpensive technique to determine from an orbiting spacecraft the relative age, level of "gardening" and rough composition of the surface in relation to its surface features. Optically Stimulated Luminescence (OSL) dosimetry could allow the determination of the age and to a certain extent, composition of an airless body by remote-sensing from orbit. The technique is well known from archaeology and may potentially be adapted to geological timescales.

1. Introduction

The history of the solar system has been frozen into its various members having different characteristics. For instance, some of the existing asteroids have undergone heating and differentiation, whereas others may have preserved their material since their formation. Determining the geological age and collisional history of solar system bodies therefore provides one key to understanding solar system formation and evolution. To date, the age of a body can reliably be determined only by either laboratory measurements of samples or in-situ measurements. However both, in-situ and sample return missions are extremely expensive. A method is outlined here, which provides the possibility to determine the age of the surface of an airless solid body, such as an asteroid by remote-sensing from orbit.

2. Principle

The method is based on the following principle: upon exposure to nuclear radiation such as cosmic rays, some of the bound electrons in a mineral's lattice are detached from their parent nuclei and become freely mobile; they enter the conduction band. Structural defects in the lattice create localized charge deficits, which act as traps for the conduction electrons. Most electrons recombine or are briefly trapped in very shallow traps, but a few are trapped in deep traps and remain there over geological timescales (1-5000 Ma). Heat or light can eject charges from traps back into the conduction band. When an electron recombines with a luminescence centre, a photon is emitted. This phenomenon forms the basis of thermo-luminescence and optical dating. Therefore, if the electrons lying in deep traps can be stimulated to recombine (e.g. with a Laser with associated precision optics), the age of the material relative to surrounding material can be derived. As bodies without atmosphere are subject to a certain degree of "gardening" their surfaces get covered over time with “regolith” which stops the trapping process in the lower layers while restarting it on the new surface. If now electron recombination is stimulated in the lower layers the age of these layers can be determined. Thus the relative age of the surface material of an airless body can be determined by remote sensing from orbit. The measurements would as a side product also provide information on the composition of the surface material with respect to surface geological features, and the degree of gardening that has occurred within the regolith.

3. Technique

The basic technique comprises the luminescence stimulation electromagnetic radiation source, which would be applied as a pulsed narrow beam from an orbiting spacecraft, coupled to an UV-NIR optical detection system (mirror + sensors) to detect the low level luminescence radiation arising from the stimulated pulse.

4. Feasibility

The key milestone in such a project are the detection and measurement of low-level luminescence from the samples as a function of the stimulating de-trapping source. This is also a crucial sensitivity test that must be positive. If this major step is achieved, a number of key results will need to be established largely related to the characterization of the stimulating de-trapping source as a function of sample type and sample dose. To ensure the feasibility of the method the following issues have to be addressed:

1) The dose saturation point and therefore the equivalent limiting age of the surface material
2) The ability to discriminate the stimulated source from the luminescence.
3) Performance of various stimulation sources
4) Flux of luminescence photons
5) Power required in the stimulation source
6) The de-trapping sources temporal characteristics
7) The dependencies of point 1-6 on the expected mineralogy of the asteroid surface material

While the proof of principle will require de-trapping experiments at an acceleration facility, a number of additional studies can be done in parallel, e.g. investigation of the stimulation of trapped electrons by a Laser, effects of input energy, footprint, surface material and morphology, and cross-sections.