Optically Stimulated Luminescence Dating (Instrument Design for Mars Applications) Marvin Suggs,[1] Derek Sears[2] and Alan Mantooth[2], [1]Arkansas Tech University, Russellville, AR 72801, [2]Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR 72701

Introduction: To examine the geological and climatic history on Mars, we investigate an instrument design for robotic, in-situ, Optically Stimulated Luminescence dating (OSL). In this paper, we discuss the basic concepts of OSL, its benefits, and how this technique can be utilized on Mars. Also presented are the vital electronics needed for an instrument design and some of their basic operational methods. Although much progress has been made in the possibility of creating an instrument to employ this technique, there is still much work to be done to meet the challenges of adapting OSL dating to the Mars surface.

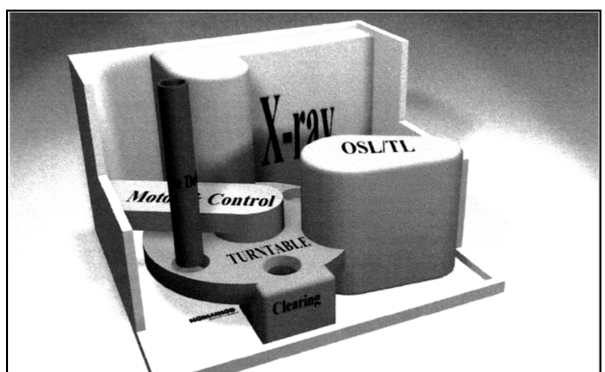
Basic Concepts of Luminescence Dating: Luminescence dating is a dosimetric method used to determine the depositional age of sediments. Ionizing radiation builds up energy as a function of time in defects in the crystalline structure of subsurface sediments. This stored energy can be released in the form of luminescence by either stimulation from light or intense heat. Due to the fact this process is sensitive to light, this phenomenon is exploited to estimate depositional ages of sediments. Different methods of luminescence dating use different stimulation sources, with each offering their own benefits. The focus, optically stimulated luminescence dating, involves the use of light as a stimulation source.

Scientific benefits: The current exploration strategy for Mars is to carry out in-situ measurements by robotic instrumentation and to focus on evidence of life, climatic history and geological evolution. Currently, relative crater densities and the belief that the crater flux has been constant and similar to that of the moon is the only way of ordering events that have shaped the Mars surface *(Kalchgruber et al. 2007).* OSL dating techniques will be beneficial in giving age estimates of younger Martian terrains. From there, a chronology can be established for the geological features observed on Mars' surface and further investigations of the history of water on Mars can be made. Observed features that are often associated with crater or canyon walls appear to show evidence of recent deposition events caused by surface water flow (McKeever et al., 2003). Martian gullies, believed to have been formed by flowing water, are currently a main point of interest. To conclude, OSL dating can be the deciding factor of present and future questions that are inquired about the Martian arena.

[NASA]

Fig. 1. *Martian gullies. Surface features suggest the possibility that water has previously flowed on the surface of Mars.*

Instrument Design: It is widely established that OSL dating techniques can be adapted for utilization on Mars. Main design constraints taken into consideration for all instrument systems on spacecrafts are low power, low weight, low volume and valuable data acquisition. An ideal instrument for OSL dating would only require several watts of power, weigh only a few kilograms and it would be packaged into a container with a volume of about 15 x 20 x 20 cm^3. (McKeever et. al., 2003)



[McKeever (2003)]

Fig. 2. A *conceptual design of an OSL dating instrument.*

Operational Method: To calculate the age of a subsurface sample, the absorbed radiation dose and the rate at which radiation is absorbed by the sample must be measured. A possible method of operation to achieve the instrument objective is briefly described.

Sample transportation: Sample collection will likely be provided by a coring drill. *(McKeever et., at 2003)* Exposure to sunlight must be avoided during collection. Consequently, pre-mature stimulation and age underestimates may occur. After collection, the samples will be deposited onto a turntable where they will be transported to different sections of the instrument. Turntables are usually run by an electric motor. A small 3V, brushed DC motor may be sufficient. An H-bridge motor controller that directs the voltage using four switches will allow the motor to spin in the forward and reverse directions. Position sensitivity will also be required.

Optical stimulation system: After collection and sample preparations, the sample will undergo optical stimulation. The optical stimulation system will consist of LED arrays. Green, blue, and infrared LEDs are possible stimulation light options. Recent studies assert that OSL should not be performed at a temperature below the maximum temperature experienced by the sample in nature (Kalchgruber et al., 2006). For optimum results, a heat source should be considered along with the added electrical power obligation.

Light detection system: To measure the natural luminescence given off by optical stimulation, light detection equipment is needed. A miniature photomultiplier tube that can detect from the near UV to red wavelengths would be best. To detect the low levels of light produced by the natural luminescence signal, the photomultiplier will have to be able to detect individual photons given off by the sample. Photon counting methods implemented in conjunction with Photomultiplier Tubes (PMTs) have been described (Hamamatsu PMT Handbook 2006). Incident light strikes the photocathode and photoelectrons are given off. The electrons are then accelerated across a series of dynode stages where the electrons are multiplied due to the secondary electron emission effect. The electron cluster is gathered by the anode and the output current is sent to a wide band pre-amplifier where it is converted to a voltage and amplified. Next, the pulse outputs into a discriminator for noise elimination. Finally, the pulse feeds into a pulse shaper and then into a photon counter.

Irradiation: To calculate the equivalent dose, we need a means of calibration to set up a ratio between the natural dosage and a known dosage. After bleaching of the luminescence signal by optical stimulation, the sample is then transported to a miniature X-ray tube.. Although frequently used radioisotopes such as $^{90}Sr/^{90}Y$ would have the advantage of size against an X-ray tube, they would require a significant amount of shielding in flight to Mars (McKeever et al., 2003). Several studies have indicated that X-ray sources have been effectively utilized in luminescence dating. *(Anderson et al. 2003)* X-ray tubes produce radiation by accelerating electrons given off by a heated cathode and bombarding them against a target material. The electrons are accelerated by applying a large voltage across the cathode to the anode. By adjusting the tube voltage, the intensity of the radiation can be controlled which allows management of the dose rate. Additionally, a mini X-ray generator would be advantageous in that it will be able to achieve a higher dose rate than $^{90}Sr/^{90}Y$ radioisotopes and can be switched off when not in use.

Dose rate: To calculate age, there needs to be a measure of the amount of radiation per unit time. Using lithium fluoride, an accurate dose rate can be achieved by depositing it on the surface of Mars for a known amount of time and subsequently calculating the equivalent dose.

Challenges: There are several challenges to adapting OSL dating for use on Mars. The main challenges include: using polymineral samples without using the assistance of chemical separation, low wide-ranging temperatures, autonomous fading of the luminescence signal and the dissimilarities of Earth's and Mars' radiation dose rates (Kalchgruber et al., 2006). Furthermore, a proven method for correction of anomalous fading is also needed. Several correctional methods have been discussed in (McKeever et al., 2003).

Conclusions: Development of an OSL dating instrument will be a valuable tool in helping establish a time scale for recent depositional events on Mars. Although knowledge of Mars has come a long way, there is still much to learn Mars' complex mineralogy and environment. Nonetheless, if the challenges are overcome, major breakthroughs can be made and the perception of Mars will change forever. To say the least, OSL dating can help answer some of the most intriguing questions that are raised about Mars today and in the future.

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