MÖSSBAUER SPECTROMETER FOR MINERALOGICAL ANALYSIS OF THE MARS SURFACE FOR THE MARS-96 MISSION

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Introduction: Part of the scientific payload of the Mars-96 mission is a $^{57}$Fe-Mössbauer (MB) spectrometer installed on a small rover to be placed on the surface of Mars [3, 5, 6] having a high abundance of the element iron. The elemental composition of Martian soil was determined during the Viking mission in 1976 but not its mineralogical composition. One believes that it is composed mainly of iron-rich clay minerals, with an iron content of about 14(±2) wt-%. Also the soil contains about 5 wt.% of a strongly magnetic mineral, perhaps maghemite ($\gamma$-$\text{Fe}_2\text{O}_3$). Of extremely great interest is the oxidation state of the iron and the mineral composition of the Mars surface. To both questions MB spectroscopy can provide important information [1, 2].

Experimental Setup: Backscattering geometry allows the rocks and the soil to be studied as found. A preliminary construction scheme of the MB spectrometer [3] is given in fig.1. The main parts are the electromechanical vibrator mounted in the center of the instrument, the detector system consisting of silicon-PIN-diodes, the electronics for the drive and the detectors, the $^{57}$Co MB-source, a multilayered radiation shield, and a $\gamma$- and x-ray window. A $^{57}$Co/Rh-source is proposed with an activity up to 1 Ci, which has to be shielded and collimated to minimize nonresonant background in the MB-spectra and to limit the increase of linewidth due to cosine smearing. The total weight of the system is less than 400g, with a maximum power consumption < 2 W. The total volume will be below 700 cm³ (comparable to a coca-cola can).

Drive system: An electromechanical velocity transducer is chosen. In comparison to the very heavy standard system weight and dimensions are drastically reduced [3]. Diameter and length of the drive are about 20mm and 45mm, respectively, and it weighs about 50g. The frequency response shows as expected $1/f$ dependence to the left and to the right of the 15 Hz resonance. A position feedback circuit stabilizing the position of the drive tube within a few μm is included. The accuracy of the drive is found to be better than 0.3% for a triangular wave form and will be considerably improved using a smoothed triangular wave form. A maximal velocity of ±15 mm/s can easily be achieved, sufficient to detect magnetically split Fe$_2$O$_3$. Velocity calibration and control of linearity will be done by recording simultaneously a calibration spectrum using a second source and a combination of reference absorbers [3].

Detector system: Our proposed detector system consists of at least 4 Silicon-PIN-diodes (fig.1), with active areas of about 1 cm$^2$ and a wafer thickness of about 500μm. The operating voltage is (30-100)V. Cooled to about 0°C the energy resolution is about 2.3 keV at 6.4 keV. Using standard PIN-diodes the useful energy range is limited to photon energies above (3-4) keV and below about 150 keV, sufficient for MB applications. Besides MB-spectroscopy this system also allows simultaneously x-ray fluorescence measurements.
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Electronics: Each of the 5 detectors has its own preamplifier-amplifier-ADC circuit (see fig.1) for noise reduction, high energy resolution and redundancy. With each detector an energy spectrum and two MB-spectra will be measured, at 6.4 keV and 14.4 keV, respectively. The data handling is done by a transputer (microprocessor), which also has to act as function generator for the drive. Position and velocity are controlled by analog feedback circuits. The velocity error signal will be measured during the experiment and/or after the drive is switched off, to investigate the influence of vibrations caused for instance by martian wind and dust storms.

First experimental results: Using the setup shown in fig.1, but with only one diode, we have recorded MB-spectra at 14.4 keV for two samples [3]: (a) 80% iron rich clay (Nontronite; SWa-1) and 20% γ-Fe₂O₃, and (b) a Mars sample analogues [2]: 80% iron rich clay (Nontronite; SWa-1), 5% iron oxide (γ-Fe₂O₃), 10% MgSO₄ and 1 ⅔% of CaSO₄, Ca-Carbonat and Fe₂(SO₄)₃ respectively (composition given in weight-%). From these measurements we conclude that spectra with sufficient statistical quality can be recorded within about 1-2 hours using a fully equipped spectrometer with 4 diodes, a 200 mCi source and a maximum emission angle of 20°. These results demonstrate that this MB spectrometer can be used in space research.


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