Martian Soil Biosensors Based on Dielectric Spectroscopy

New biosensing techniques need to be developed to test for the presence of living organisms in soil samples from outer terrestrial bodies, such as Mars. The basic idea is to use dielectric spectroscopy, which covers frequencies ranging from a few microhertz up into the gigahertz region. Live organisms exhibit several distinct dispersion characteristics, including alpha-, beta-, and gamma- dispersions, at different frequency ranges. For example, the alpha-dielectric response, unique to live organisms, leads to enormous dielectric constants (as high as 108) at low frequencies and results from the finite membrane potentials of live cells. Martian soil simulants from various regions on Earth, known to be Mars analogues, will be used to test and implement this revolutionary detection technique. Furthermore, the composition and concentration of microorganisms will be validated by well-established molecular biology-based techniques.

Project Rationale

The question of whether or not life once existed on Mars, or perhaps still exists today, has profound scientific implications for the evolution of life on Earth and the distribution of life in the cosmos. Recent studies of the Martian meteorite Allan Hills 84001 (ALH84001) suggest that microbial life existed on Mars about four billion years ago. Perhaps the most compelling evidence is the presence of magnetite (Fe_3O_4) crystals found within carbonate globules and their associated rims in the meteorite. About one fourth of these tens-of-nanometer sized magnetites are nearly identical to those produced by magnetotactic bacteria on Earth; they are not known or expected to be produced by abiotic means. It has, therefore, been argued that these Martian magnetite crystals are, in fact, magnetofossils, which, if true, would constitute evidence of the oldest life forms known.

Additional findings suggest that subsurface Martian life could potentially survive even today. There is abundant geological evidence that ice was once deposited in the regolith, where it should still be present above mid-latitudes. This ice, which probably extends several kilometers below the surface, could be a source of liquid water near magmatic intrusions. Periodic or episodic partial melting of ice or permafrost could revive microbial life that exists as spores or other dormant forms during colder periods. For these and other reasons, there is considerable interest in developing new techniques of detecting subsurface life on Mars. A detector based on dielectric properties of regolith soils could conceivably be produced as a small, light, low power instrument package suitable for robotic mission opportunities by the year 2011 or 2013 and for human missions beyond that time.

Experimental Tasks

A post-doctoral fellow selected to conduct these studies will characterize Martian soil simulants using dielectric spectroscopy, which is a powerful method for detecting and studying live organisms. Experiments on low-frequency linear dielectric response will employ a Stanford Research SR780 Vector Signal Analyzer, which measures complex admittance at low frequencies (up to 100 KHz), while a variety of HP/Agilent network analyzers will be used for higher (rf and microwave) frequencies. In addition, time-domain dielectric response measurements will be explored with a 500-MHz Agilent MegaZoom digital oscilloscope. Controlled studies will be carried out on Martian soil simulants (mainly MS-1) with both known and unknown concentrations of live organisms. These studies will be validated by well-established molecular biology techniques. Dielectric spectra will be measured for both dry and aqueous suspensions of these soil simulants, including sterilized samples, samples with introduced, known concentrations of organisms (cells, usually bacteria, or spores), and original samples (e.g., from Devon Island) which have been analyzed using molecular biology methods. A major objective will be to determine whether dielectric spectroscopy provides a rapid, easy-to-use method of detecting signatures of living organisms from among the background of inanimate material.

Facilities

Electronic instrumentation for the project is available in the Texas Center for Superconductivity and Advanced Materials at the University of Houston (TCSAM). The post-doctoral fellow will be supplied with office space and a personal computer at the NASA Johnson Space Center (JSC). The post-doctoral fellow will work with UH investigators and with JSC investigators in Astromaterials Research and Exploration Science (ARES) and in the Life Sciences Research Laboratories. Appropriate lab space is available in the existing Astrobiology Laboratory and in the Life Sciences Research Laboratories. All testing and operations conducted by the researchers shall be in accordance with the Medical Sciences Division General Operating Procedures. JSC will also provide any prerequisite training required in order for the researcher to perform the project task in accordance with applicable safety, ISO-9000, and/or General Operating Procedures. The JSC collaborators also have access to a variety of Martian soil simulants, such as those obtained on recent Devon Island expeditions.

Publications

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PRINCIPAL INVESTIGATORS

John H. Miller, UH / Jaroslaw (Jarek) Wosik, UH / David S. McKay, NASA-JSC / Jeffrey A. Jones, NASA-JSC / Fathi Karouia, NASA-JSC

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