Active Solid State Dosimetry for Lunar EVA.

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Introduction: The primary threat to astronauts from space radiation is high-energy charged particles, such as electrons, protons, alpha and heavier particles, originating from galactic cosmic radiation (GCR), solar particle events (SPEs) and trapped radiation belts in Earth orbit. There is also the added threat of secondary neutrons generated as the space radiation interacts with atmosphere, soil and structural materials.[1]

For Lunar exploration missions, the habitats and transfer vehicles are expected to provide shielding from standard background radiation. Unfortunately, the Lunar Extravehicular Activity (EVA) suit is not expected to afford such shielding. Astronauts need to be aware of potentially hazardous conditions in their immediate area on EVA before a health and hardware risk arises. These conditions would include fluctuations of the local radiation field due to changes in the space radiation field and unknown variations in the local surface composition. Should undue exposure occur, knowledge of the dynamic intensity conditions during the exposure will allow more precise diagnostic assessment of the potential health risk to the exposed individual.[2]

Technology Need: An active personal dosimeter for Low Earth Orbit (LEO) EVA use is specifically recommended by NASA JSC's Radiation Dosimetry Working Group, and the National Council on Radiation Protection and Measurements (NCRP) recommends personal radiation monitoring for real-time dose rate and integrated dose in LEO.[3] Compared to the current LEO missions, the expeditions to the Moon will place crews at a significantly increased risk of hazardous radiation exposure.

Current radiation measurement and warning systems may be not adequate for the future Lunar missions, and currently instruments do not exist that can make these measurements and be incorporated into the Lunar EVA suit. However, MEMS devices fabricated from silicon carbide (SiC) to conduct low-noise neutron and alpha particle spectrometry have recently been reported outside of the context of personal dosimetry.[4]

Development Effort: NASA GRC has been leading the world in the development of SiC semiconductor technology, producing SiC semiconductor surfaces of much higher quality than commercially available, as shown in figure 1. These surfaces have demonstrated advantages over standard materials for other sensor applications.[5] In other activities, NASA GRC is attempting to verify claims of nuclear energy in sonoluminescence using thin film coated scintillation detectors fabricated at NASA GRC as part of the Vehicle Systems Program, shown in figure 2.[6]

NASA GRC is leveraging these efforts to investigate small and large area MEMS devices for sensitivity to radiation and to compare with commercial devices. If these initial results look promising as a path for the design and fabrication of a prototype solid state dosimeter, further testing would be required in conjunction with other researchers in the space radiation field over the next few years. The long term objective of this effort is to provide a compact, low power active electronic dosimetry system that would not be adversely affected by radiation, with improved sensitivity and detection capability for real-time monitoring of Lunar EVA conditions.

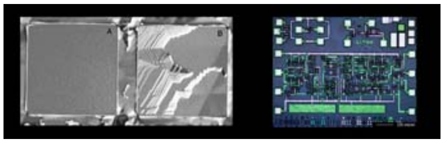

Figure 1: Examples of NASA GRC SiC Fabrication: Defect free (far left) & typical (center left) SiC surfaces, and a SiC circuit (right).

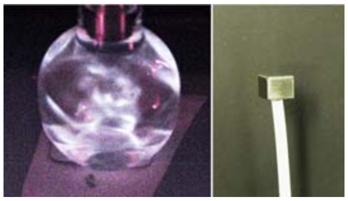

Figure 2: Radiation Detector Development: NASA GRC is attempting to verify claims of nuclear energy in sonoluminescence (left) using thin film coated scintillation detectors fabricated at NASA GRC (right).

References: [1] Johnson A.S., Badhwar G.D., Golightly M.J., Hardy A.C., Konradi A. and Yang T.C. (1993) *NASA TM-104782*. [2] R. Turner (2000) *LWS Community Workshop*. [3] Vetter R.J., et al. (2002) NCRP Report No. 142, 47-49. [4] Ruddy F.H., Dulloo A.R., Seidel J.G., Palmour J.W. and Singh R. (2003) *Nucl. Instr. and Meth. A 505*, 159–162. [5] Hunter G.W., Neudeck P.G., Xu J., Lucko D., Trunek A., Artale M., Lampard P., Androjna D., Makel D., Ward B. and Liu C.C. (2004) *Mat. Res. Soc. Symp. Proc. 815*, 287-297. [6] Wrbanek J.D., Fralick G.C., Wrbanek S.Y. and Weiland K.E. (2005) *NASA TM-2005-213419*, 46-7.

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Active Solid State Dosimetry for Lunar EVA

- The Radiation Threat
  - Space Radiation Environment
  - Threat to Astronauts
- Radiation Measurement Systems
  - Current Systems
  - Needs & Challenges
- Technology Development
  - NASA GRC Expertise
  - Applications of Aeropropulsion Research

Space Radiation

Space Radiation Environment

- GCR – Galactic Cosmic Radiation (GeV/amu ions)
- SPE – Solar Particle Event (GeV ions from sun)
- Trapped Radiation (GeV/amu ions & electrons)
- Secondary Neutrons (from surface & structures)
- Man-made Sources (RTG’s, etc.)

Aurora Australis from STS-39

The Radiation Threat

Space radiation can cause damage to an astronaut’s DNA.

Damage can be short term (acute) and/or long term (chronic):

- Acute effects typically include radiation burns and/or nausea (“radiation sickness”)
- Chronic effects include cataracts, sterilization, brain damage, and/or an increased risk of cancer

"Strategic Program Plan for Space Radiation Health Research,“
NASA Office of Life and Microgravity Sciences and Applications (1998)

Space radiation can also damage silicon microelectronics by affecting the carrier density and increasing the leakage current, leading to equipment malfunction and failure.

Astronauts are Radiation Workers!

- Radiation exposure to personnel and equipment is a significant health and operational issue.

Radiation Measurement Systems on ISS

EVCPDS: Extra-Vehicular Charged Particle Directional Spectrometer (active telemetry)

IVCPDS: Intra-Vehicular Charged Particle Directional Spectrometer (active telemetry)

TEPC: Tissue Equivalent Proportional Counter (active telemetry)

RAM: Radiation Area Monitor (TLD’s) (passive)

CPD: Crew Passive Dosimeter (TLD’s) (passive)

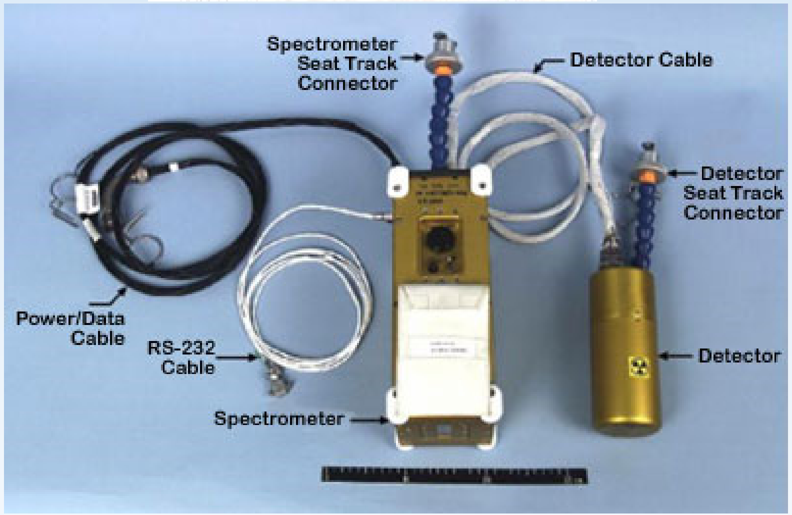
ISS from STS-114

Radiation Measurement Systems on ISS

- RAM / CPD

Pictures from the
Space Radiation Analysis Group
http://srag-nt.jsc.nasa.gov/

- TEPC



- IVCPDS
  & EVCPDS

Mission Need

- Current monitoring of radiation conditions during EVA is limited to post-mission, accumulative information provided by dosimeter badges.
- Active personal dosimeter for Low Earth Orbit (LEO) EVA use is specifically recommended by NASA JSC's Radiation Dosimetry Working Group (2003).
- National Council on Radiation Protection and Measurements (2002) recommends personal radiation monitoring for real-time dose rate & integrated dose in LEO.
- Compared to the current LEO missions, the expeditions to the Moon will place crews at a significantly increased risk of hazardous radiation exposure.

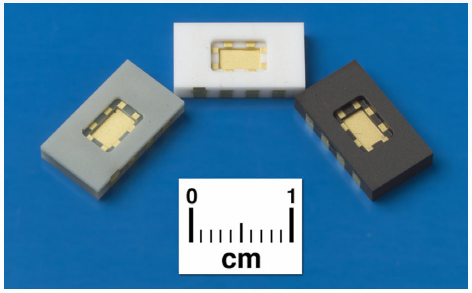
Technology Development Challenges

- Astronauts need to be aware of potentially hazardous conditions in their immediate area on EVA before a health and hardware risk arises.
- Real-time feedback of personal dosimeter information regarding astronaut conditions is currently not available.
- Real-time dosimeters based on silicon electronics could provide real-time information but silicon lacks the desired sensitivity and is itself affected by radiation, decreasing the effectiveness of this technology.
- Improvements in the basic dosimeter design would provide a valuable tool to improve astronaut safety and provide better awareness of the external situation.

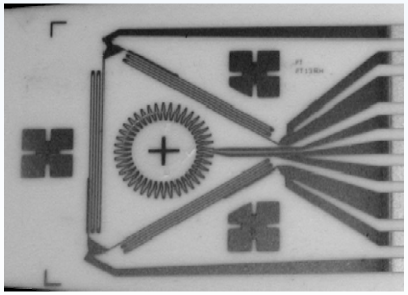
NASA GRC Instrumentation & Controls Division

Conducts basic and applied research on advanced instrumentation and controls technologies for aerospace propulsion and power applications:

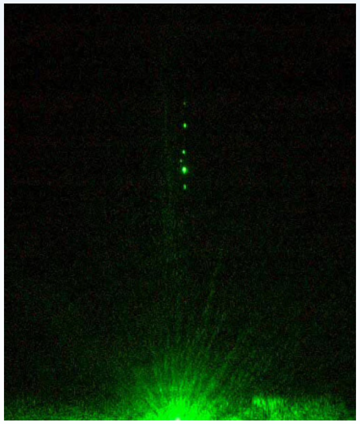
- Harsh environment sensors
- High temperature high power electronics
- MEMS & nanotechnology based systems
- High data rate optical instrumentation
- Active and intelligent controls
- Health monitoring and management



Harsh Environment Packaging
(L.Y.Chen)



Thin Film Physical Sensors
(G.C.Fralick & J.D.Wrbanek)



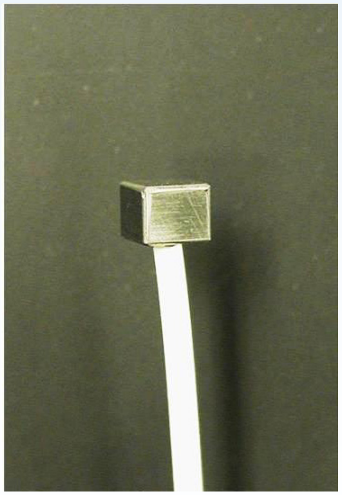
Optical Micromanipulation
(S.Y.Wrbanek)

Radiation Detector Development

- Claims and theories are being examined that predict a net gain of power resulting from atomic interactions at the high temperatures and pressures present in sonoluminescence.
- Sonoluminescence-based power generation has been only recently reported in the main-stream academic press.
- NASA GRC is attempting to verify these claims using thin film coated scintillation detectors fabricated at NASA GRC.

MBSL in Water (left)

Fiber Optic Scintillation Detector (right)



SiC Semiconductor Technology Development

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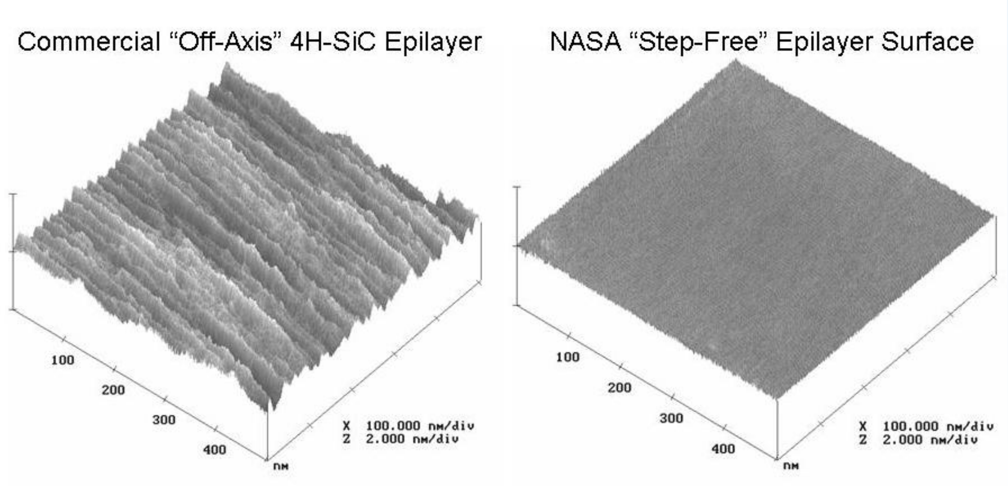
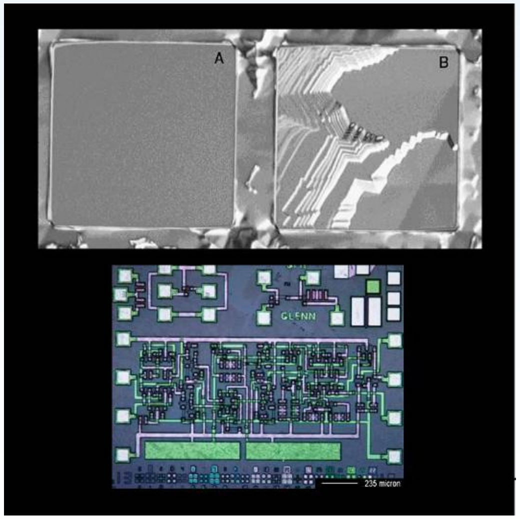
- NASA GRC produces SiC semiconductor surfaces of much higher quality than commercially available.
- These surfaces have demonstrated advantages over standard materials for sensor applications.



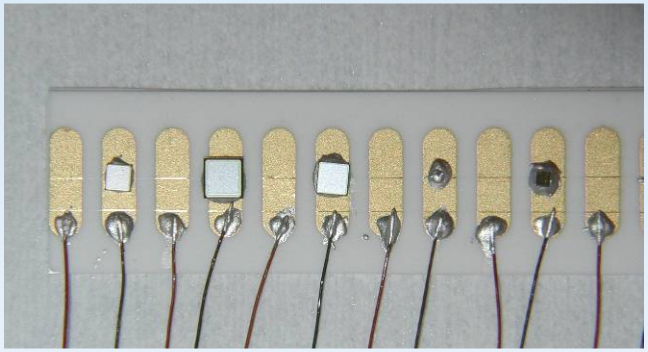


Technology Development Plan

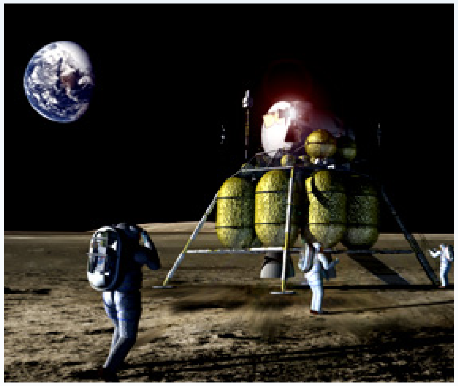
- Leverage significant experience in silicon carbide (SiC) technology to provide reliable real-time EVA dosimetry by replacing the silicon with a significantly more rad-hard SiC semiconductor technology with improved sensitivity and detection capability.
- Apply unique, patented NASA technology improving the quality of SiC semiconductors.
- Leverage ongoing activities of the NASA Low Emissions Alternative Power (LEAP) project in radiation detector technology development.

Technology Development Objectives

- The task will first validate basic SiC approach using SiC devices and compare with silicon diodes and compact scintillation detectors.
- <u>Long-term Objective:</u> Provide a wearable, electronic dosimetry system which would not be adversely affected by radiation with improved sensitivity and detection capability for real-time monitoring of EVA conditions.



SiC Devices for Testing



Lunar EVA Concept