Exploiting the MECA/Electrometer for Single Charge Measurements

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TRIBOELECTRICITY: DUST DETECTION

OUTLINE

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EFFECTS OF DUST ON MARS

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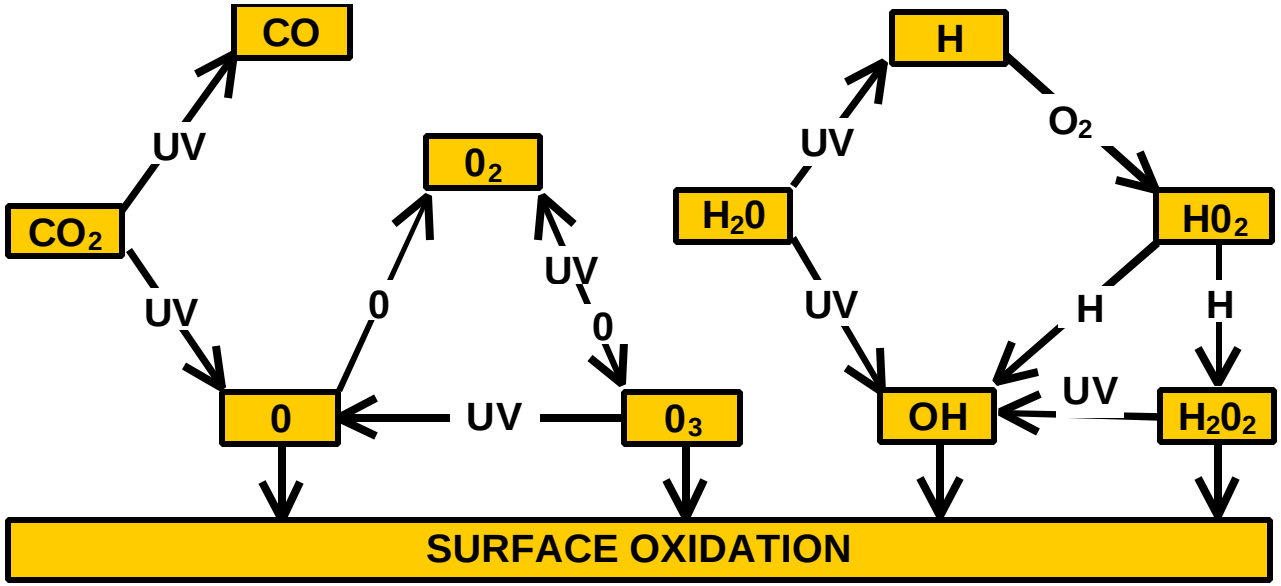
TRIBOELECTRICITY: DUST DETECTION

MARTIAN ENVIRONMENT

Oxygen and Hydrogen Cycles Oxidize the Martian Surface



PEAK WIND VELOCITY:	**80 m/s (178 mi/hr)**
SURFACE TEMPERATURE RANGE:	**140K to 295K (-133 to 22°C)**
DAILY TEMPERATURE SPAN:	**50°C**
PRINCIPAL AEROSOLS:	**Water ice and dry ice**
WATER VAPOR:	**<0.1%**
SURFACE PRESSURE RANGE:	**5 to 10 mb**
SURFACE RADIATION:	**100 rads/year**

- **The Martian atmosphere is full of ions and little water vapor to moderate their effects.**

Ref: A. Hansson, *Mars and the Development of Life* J. Wiley & Sons (New York, 1997).

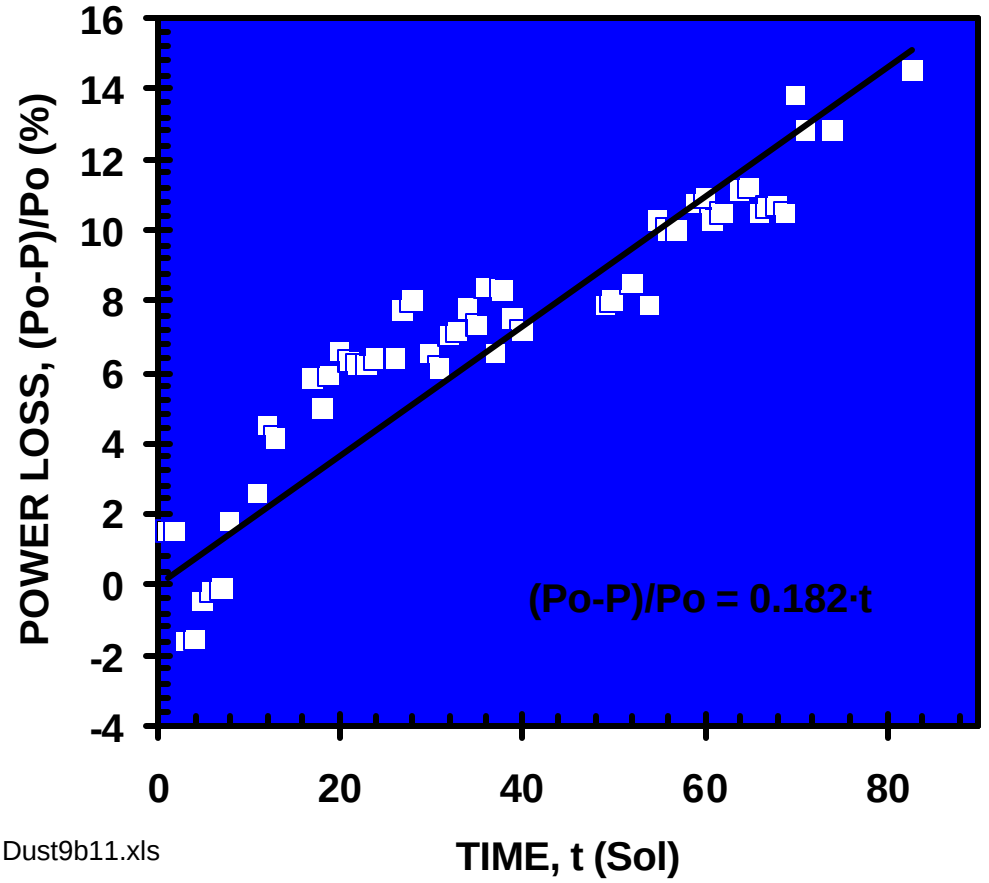
TRIBOELECTRICITY: DUST DETECTION

EFFECTS OF DUST ON MARS

Technologies that have dust problems:

- **Solar Cells**
- **Thermal Radiators**
- **Viewing Ports**
- **Moving Parts**
- **Space Suits**

Pathfinder Solar Cell Degradation



Dust9b11.xls

~ 0.2% power loss/sol.

Ref: R. C. Ewell and D. R. Burger, "Solar Array Model Corrections from the Mars Pathfinder Lander Data", 28th Photovoltaic Specialists Conference, 1997.

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TRIBOELECTRICTRICITY FUNDAMANTALS

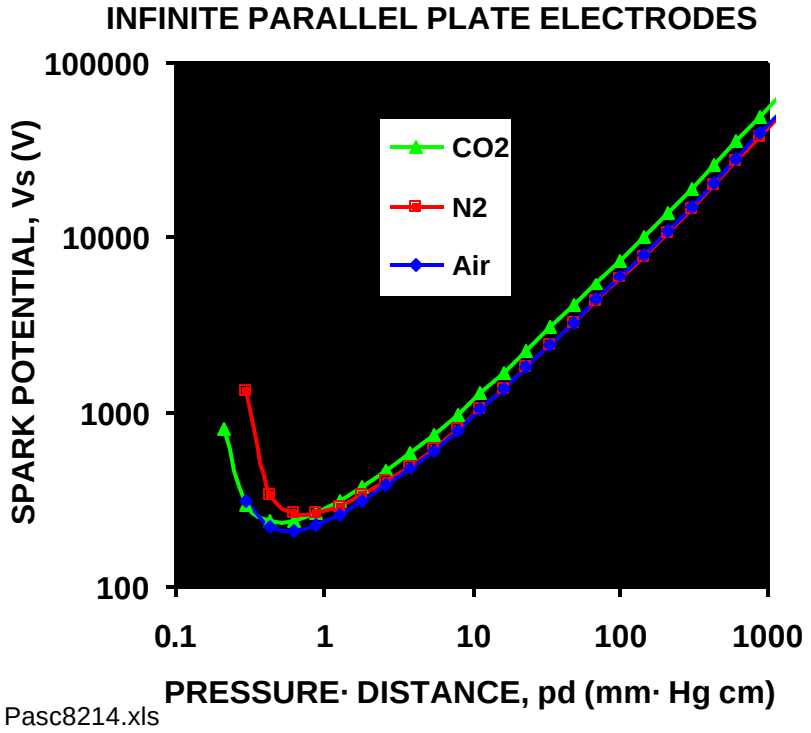
TRIBOELECTRIC SERIES

MATERIAL	CHARGE
EPOXY GLASS, G10	Positive
Plexiglas, LUCITE	
LEXAN	
Glass, Quartz	
Mica	
Nylon	
Wool	
Paper, Cotton	
Steel	
Nickel, Copper	
Brass, Silver	
Gold, Platinum	
Hard Rubber	
Acetate Rayon	
Polyester	
Polyurethane	
Polypropylene	
Polyvinyl Chloride	
TEFLON	
RULONJ	Negative

Refs: O. J. McAteer, *Electrostatic Discharge Control* , McGraw-Hill (1989).
N. Jonassen, *Electrostatics*, Chapman & Hall (1998)

- Capital Letters: MECA/Electrometer insulators

Paschen Curve



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- **Paschen curve predicts a minimum spark potential which depends on the nature of gas, gas pressure, and distance between electrodes.**

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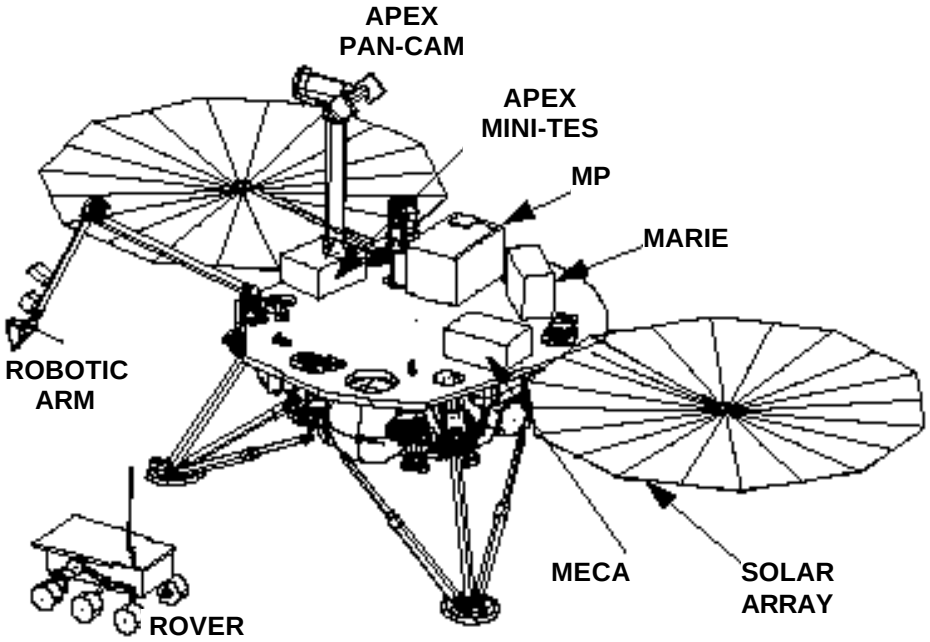
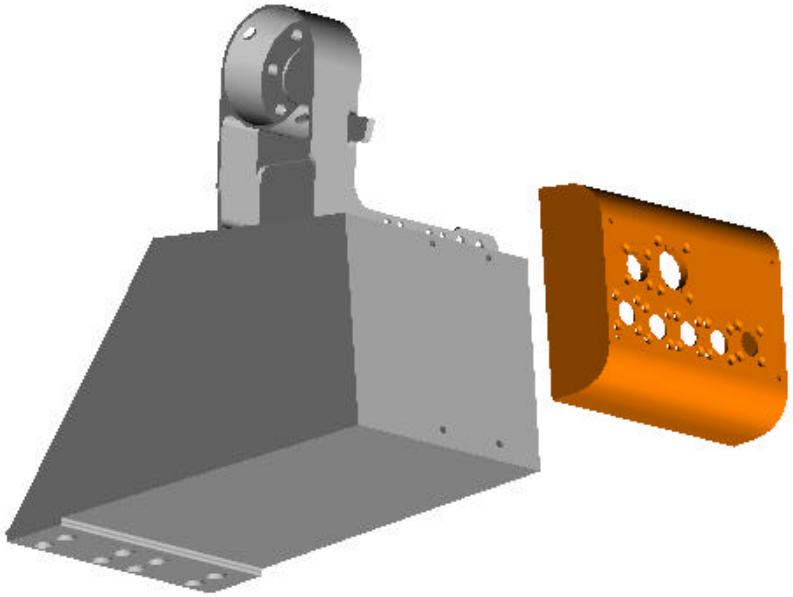
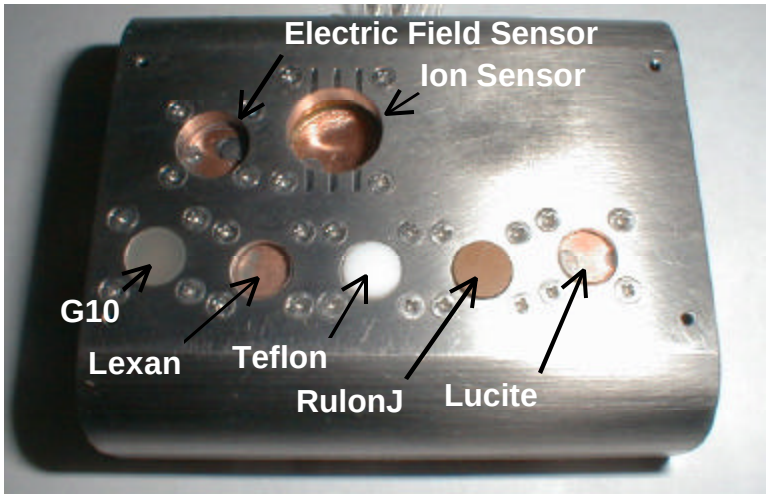
MECA/ELECTROMETER







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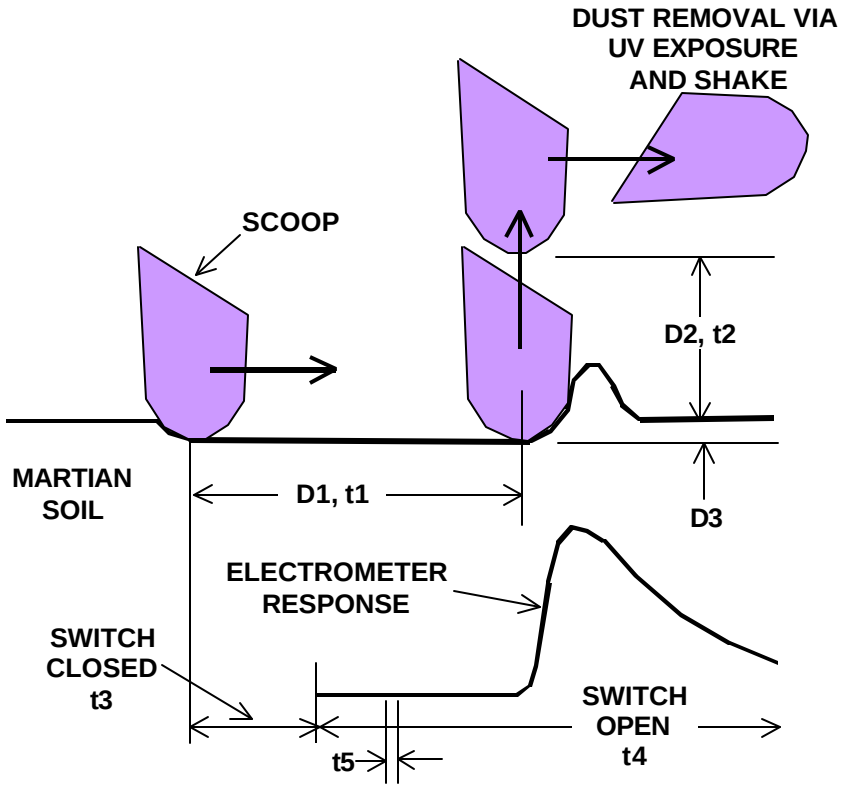
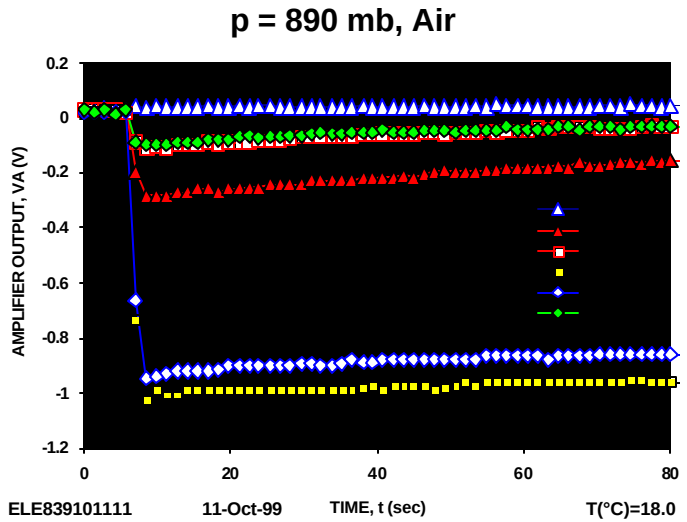
MARS RUBBING EXPERIMENTS

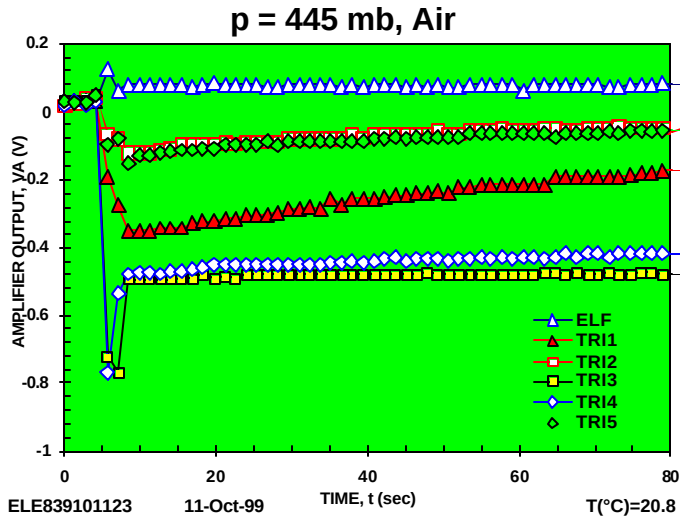
PROPOSED SCOOP OPERATION



- **Results show that high triboelectrically generated voltages discharge at lower pressures.**

TRIBOELECTRIC CHARGING BY WOOL





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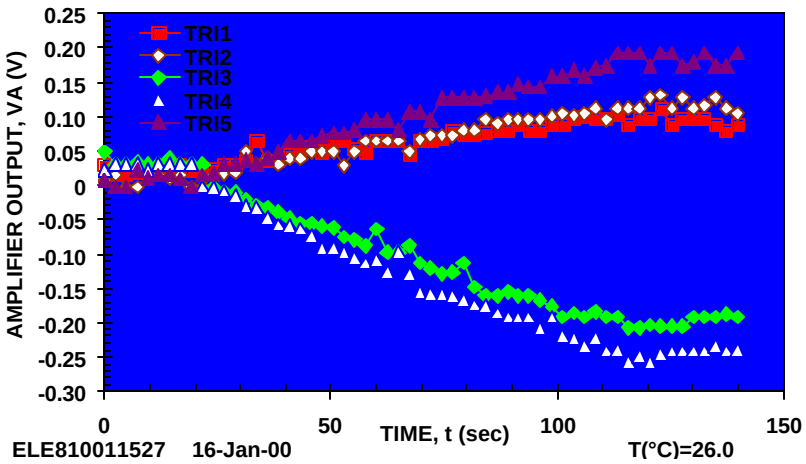
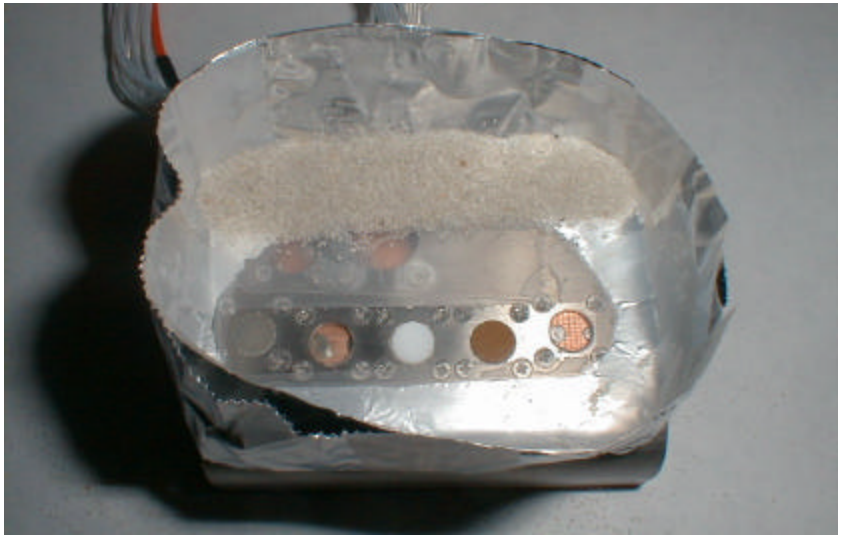
ROCK AND ROLL EXPERIMENTS

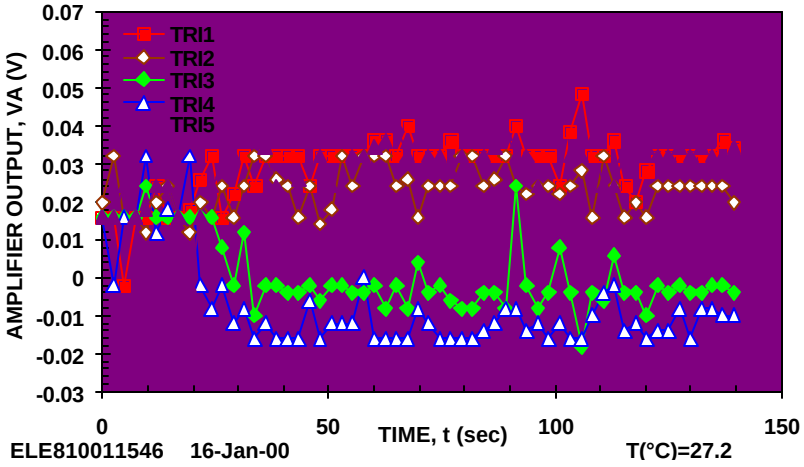
OTTAWA SAND





• Sand charges but does not coat the insulators.

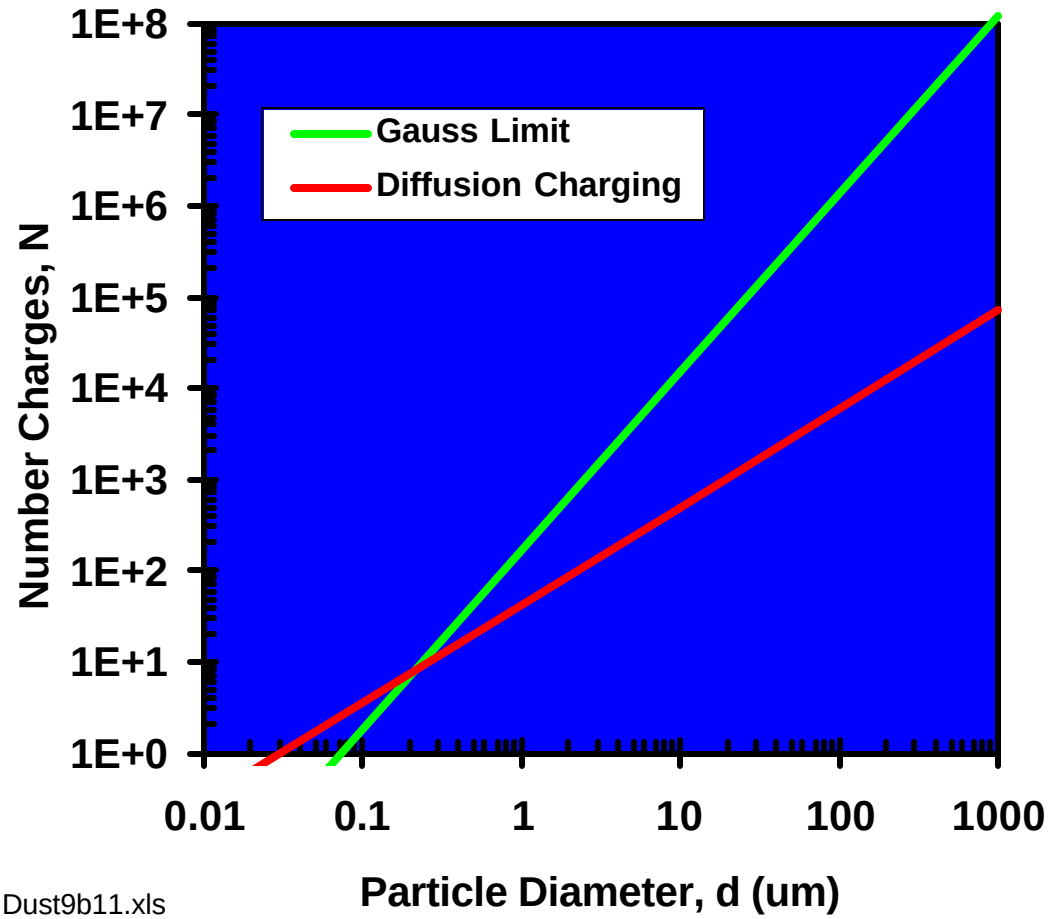
HEMATITE



• Hematite charges and coats the insulators

TRIBOELECTRICITY: DUST DETECTION

MAXIMUM CHARGE ON PARTICLE



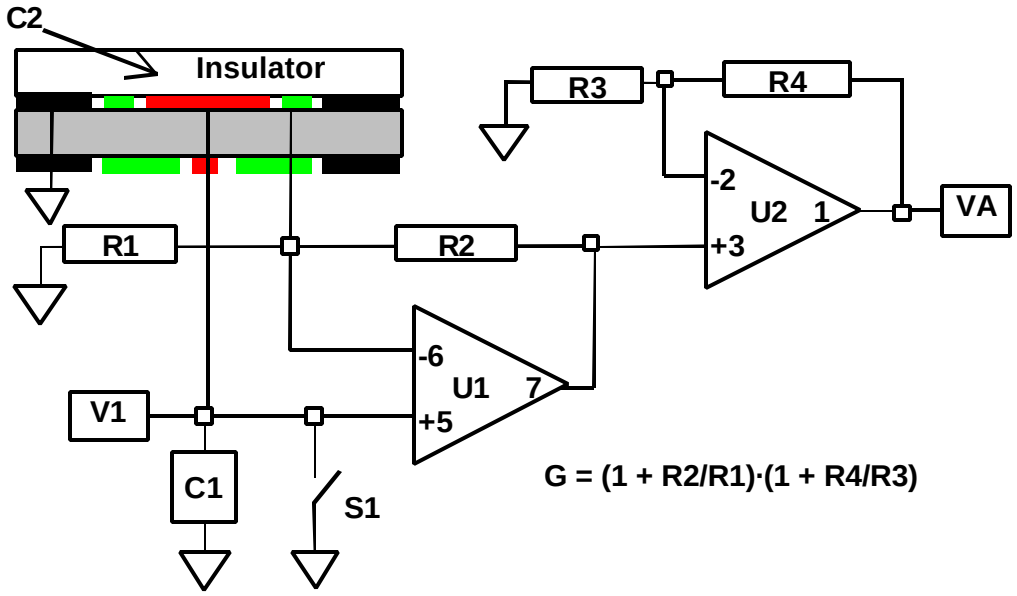
Dust9b11.xls

- **Gauss limit is maximum charge on a particle due to atmosphere breakdown.**
- **Gauss limit calculation based on $N = e_0 \cdot E_b \cdot A/q$ where E_b = 30 kV/cm.**
- **Results depend on pressure so for a given d, Mars N-values should be ~200X lower.**

Ref: J. A. Cross, *Electrostatics: Principles, Problems and Applications*, Adam Hilger (Bristol, UK).

TRIBOELECTRICITY: DUST DETECTION

TRIBOELECTRIC CIRCUITRY: CHARGE SENSITIVITY



GAIN, G	C1(pF)	BITs	Nfull	Nfull/A (1/cm^2)	Nres	Nres/A(1/cm^2)
4	**1000**	**12**	**6E9**	**2E+10**	**3E6**	**1E+7**
100	1	16	3E5	9E+5	8	27
500	100	20	5E6	2E+7	10	34

Amplifier output VAfull = ±4 V and insulator area A = 0.28 cm^2

- **Single digit charge detection feasible by adjusting circuit values.**
- **The number of teflon surface atoms is about 4x10^{14} cm^2 thus the number of triboelectrically induced surface charges on a teflon surface is very small.**

Ref: M. Buehler, L-J. Cheng, O. Orient, M. Thelen, R. Gompf, J. Bayliss, and J. Rauwerdink, "MECA Electrometer: Initial Calibration Experiments," Electrostatics 1999, Proceedings of the 10th International Conference, Institute of Physics Conference Series No. 163, pp. 189-196 (Institute of Physics Publishing, Bristol, UK, 1999)

TRIBOELECTRICITY: DUST DETECTION

CONCLUSIONS

- Electrometry is applicable to the detection of:

- ***Dust accumulation*** **as illustrated by the Hematite example.**
- ***Surface charging*** **as illustrated by the Sand example.**

- An effective method for introducing dust (minerals) onto insulator surfaces has been discovered using the *rock and roll* approach.

- Calculations show that single digit charge detection is feasible so small amounts of dust can be detected.

- It appears that electrostatic measurements are applicable to detecting dust accumulation on:

- **Solar Cells**
- **Thermal Radiators**
- **Viewing Ports**
- **Moving Parts**
- **Space Suits**