Dusty Spacesuit Charging/Discharge: Numerical Simulation of Possible Damage

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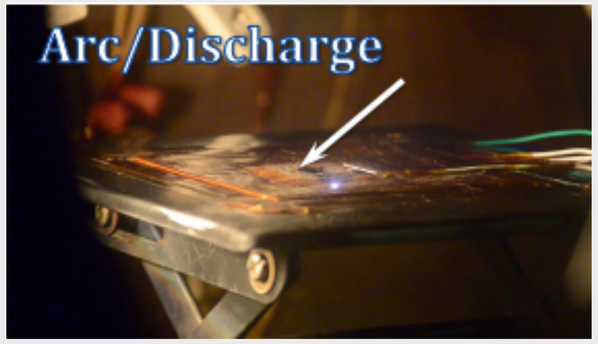
Introduction

- Surface charging was not considered a serious risk during the Apollo mission because the astronauts always stayed under sunlit
  - No significant charging (typical potential: a few volts positive) due to photoelectron emission
- Future lunar missions will explore the lunar terminator and far side where high voltage charging occurs
  - Hundreds to thousands of volts negative due to the hot electrons from ambient plasma
- Lunar surface is a dusty plasma environment
  - Dust accumulation on spacesuit leads to differential surface charging. Large differential charging may lead to electrostatic discharge/arcing or breakdown
- Laboratory experiments [Chou et al., 2019] showed that electrostatic discharge occurred on differentially charged dusty spacesuit samples



Methods

This paper presents a modeling study of plasma-dust-spacesuit interactions. The focus is on the consequences of dusty spacesuit charging. The simulation study utilizes an Immersed-Finite-Element Particle-in-Cell (IFE-PIC) code to simulate plasma interactions and spacesuit charging, a Direct Simulation Monte Carlo (DSMC) code to simulate neutrals from electron simulated desorption (ESD). The arcing process and will be simulated by a high order accuracy Monte Carlo Collision (MCC) method. A Molecular Dynamics(MD) model will be used to investigate the breakdown of spacesuit material under strong electric field

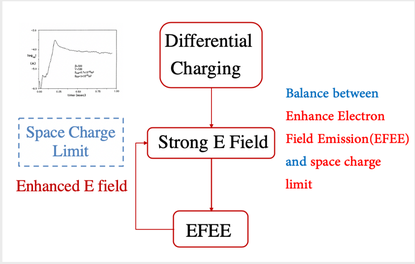
Simulation Model

Charging:

- Fully kinetic PIC with Immersed Finite-Element(IFE) field solver (*Han and Wang, 2018*)
  - Immersed Finite-Element (IFE) field solver to resolve complex surface feature and surface/internal charging
  - Charging determined self-consistently from local charge deposition.
  - Non-uniform mesh
  - Kappa distribution for SW

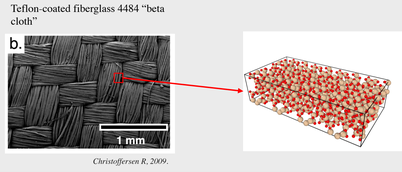
Breakdown :

- Direct Simulation Monte Carlo (DSMC) and Monte Carlo Collision (PIC-MCC)



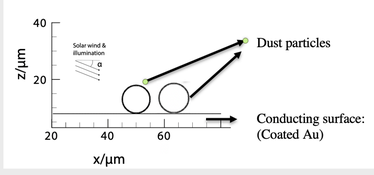
Possible Damage:

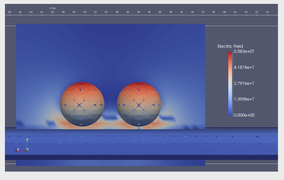
- RXMD: Parallel reactive molecular dynamics (RMD) simulator (*K.Nomura,2020*)



Simulation Results

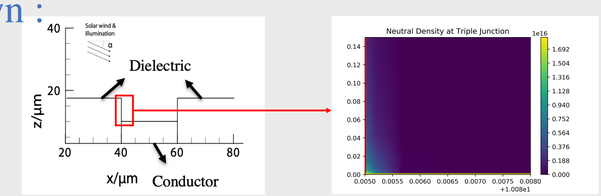
Charging:



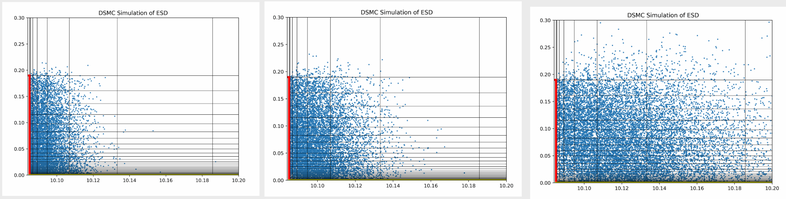


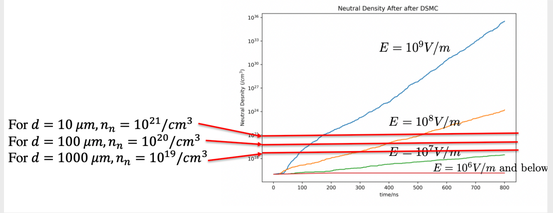
Simulation Results

Breakdown :

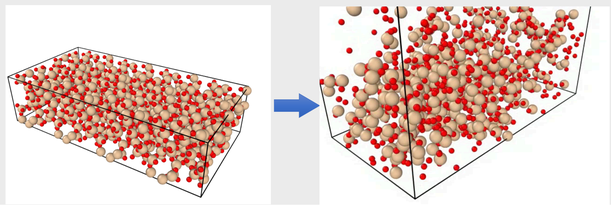


DSMC simulation of Neutral Emission





MD :



Conclusion

- Dust-spacesuit charging simulation was conducted by IFE-PIC, high electric field is observed to trigger enhanced electron field emission (EFEE)
- Neutral Desorption and Discharge process is modeled by DSMC and PIC-MCC, a relation between ambient neutral density and arcing possibility is built.
- High electric field induced material meltdown is modeled by molecular dynamics (MD) simulation.

Reference

Chou, K., Wang, A., Yu, W., and Wang, J., 2019. *IEEE Trans Plasma Science*, *47*(8), pp.3898-3904.

Han, D., Wang, J.. and He, X., 2018. *Journal of Spacecraft and Rockets*, *55*(6), pp.1490-1497.

Nomura, K.I., Kalia, R.K., Nakano, A., Rajak, P. and Vashishta, P., 2020. *SoftwareX*, *11*, p.100389.