COMBINATIVE EFFECTS OF SOLAR WIND IMPLANTATION AND MICROMETEOROID IMPACT ON LUNAR VOLATILE FORMATION Z.Huang[1], K.Nomura[2], J.Wang[1] 1 Department of Astronautical Engineering (University of Southern California, Los Angeles, CA, 90089), 2 Department of Chemical Engineering and Materials Science (University of Southern California, Los Angeles, CA, 90089)

Introduction: Water on the moon is generated by both endogenous and exogenous mechanisms. Endogenous sources include volcanism and outgassing events from the lunar interior. Exogenous sources include solar wind, micrometeoroid impact, or water-rich comet impact. The physical form and the evolution of the water generated by each mechanism have shaped the observed water features on the lunar surface.

Chrbolková et al.[1] pointed out that there have been some extensive studies investigating the space weathering effects by solar wind implantation and micrometeoroid impact individually. However, very few of them combined these two mechanisms. However, the combinative effect could differ significantly from individual cases. Gillis-Davis et al. [2] tested the space weathering effect of the combination of micrometeoroid impact and electron bombardment. The results of the combination case are much more significant than only conducting a single space weathering process.

For the investigation of lunar water formation, the combinative effects could be more important and complicated. Implantation of protons from solar wind depends both on latitude and longitude since the vertical component of the implantation velocity is $V_n = 400 \times \cos(\varphi) \times \cos(\theta)$ where φ is the latitude and θ is the solar zenith angle. The vertical component of the velocity defines the implantation depth. As micrometeoroid impact converts the hydroxyl formed from the implantation step, the implantation depth further determines the effects of micrometeoroid impact.

Timescales of solar wind implantation and micrometeoroid impact should also be considered. As reported in previous ion irradiation experiments[3] and simulations [4], the implantation of protons will be saturated. In the real lunar environment, the upper layer of the regolith is not always saturated when the micrometeoroid impact occurs. If the timescale of solar wind implantation and the time scale of micrometeoroid impact are not synchronized, the efficiency of converting protons from solar wind to water molecules would not be ideal.

Method: In this study, we implemented reactive molecular dynamics(RMD) simulation to study the combination of solar wind implantation and micrometeoroid impact. RMD simulation can capture the molecular structure of the regolith after implantation and impact and provide information of chemical reactions directly through modelling bond breaking and bond formation.

Parameters for solar wind implantation include implantation angle and surface temperature, representing different latitudes and diurnal variation. For micrometeoroid impact, we include different impact angles, impact speeds and take the results of solar wind implantation as an input.

The overall parameter space consists of 4 dimensions. Other parameters will be discussed in a future study, such as surface porosity, size of the impactor and water content in the impactor. Based on the results obtained from the four-dimensional model, we measure the saturation status and the saturation timescale. Combined with micrometeoroid flux on the moon (Cintala[5]), we estimate whether the surface can be saturated by solar wind implantation between two micrometeoroid impact events given the location and the local time.

Results and Discussions: Simulation results give a general trend of water retention rate on the lunar surface. With latitude larger than 80 degree, water molecules accumulate. When the latitude is lower than 30 degree, the surface loses water. However, for high latitude regions, a large number of solar wind protons are reflected, and the surface almost always reaches saturation before impact/ This makes the efficiency of converting H from the solar wind to water molecules lower than low latitude regions. As a prior step in the simulation, solar wind implantation contributes more significantly to the overall results.

For all the cases studied, micrometeoroid impact always generates more water molecules than the original water amount. However, not all of the water molecules are retained locally. A large fraction of water molecules will be in the ejecta, and they are either lost to space or re-distributed to other locations through ballistic trajectories. The dynamics of the water molecules in the ejecta change significantly with the impact angle.

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References:

[1] Chrbolkova K (2021) A&A [2] Gillis J. J. (2018) LPSC [3] Ichiruma A. (2012) EPSL [4] Huang Z. (2020) LPSC [5] Cintala (1992) JGR