Researchers to develop new methods to passively mitigate lunar dust for space exploration

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A team of UCF researchers is pioneering a new nanocoating to passively mitigate the effects of lunar dust, protect equipment and ultimately extend future lunar missions. Credit: University of Central Florida, Antoine Hart.

Lunar dust is more than a mild irritant or hallmark of an untidy room like dust found on Earth.

Lunar dust particles are sharp and abrasive due to the lack of atmosphere gradually dulling their surfaces, leading them to potentially damaging critical lunar equipment or causing respiratory issues for astronauts.

Managing lunar dust (also known as regolith) and safeguarding astronauts or sensitive equipment on the moon isn't as simple as sweeping it up with a broom and pan.

That's why a team of UCF researchers is pioneering a new nanocoating to passively mitigate the effects of lunar dust, protect equipment and ultimately extend future lunar missions.

"The dust particles on the moon are very sharp, very sticky and very toxic," says Lei Zhai, director of the NanoScience Technology Center and project lead.

"Right now, the efforts we have seen are based on studies here on Earth, and so we want to have a more complete picture of the interactions and guide the design on how to mitigate dust using a simulated lunar environment."

UCF's research team aims to conduct testing as true to the lunar environment as possible through modeling and the use of a simulated regolith in a vacuum chamber to mimic lunar conditions and exclude the effects of Earth's atmosphere.

The goal is to understand how lunar dust interacts with surfaces and which surface properties, such as surface structures, polarity and electrical conductivity, are key to repelling the dust, even in complex lunar charged particle and light radiation environments.

"It's a really new, novel way to approach this. Lunar dust is one of the most significant problems that we have for going to the moon, especially for long duration stays," says Dove.

"We'll put our engineered coatings or surfaces into the vacuum chamber with lunar simulants and study how the dust interacts with the surfaces in the simulated lunar surface environment," Zhai says.

"There is also strong irradiation on the moon, so we will also introduce irradiation sources in the setup. We also will use a specific instrument called an atomic force microscope to study these specific interactions at the dust particle level."

Repeated experimentation will allow Zhai and his team to adjust surface structure, hardness, conductivity and other properties to further fine tune the surface coatings.

"With that data, we can design specific surface structures for effective dust mitigation," he says. "My role is to provide the surface. Then I'll give this surface to Dr. [Laurene] Tetard, who will carry out the atomic force microscope studies, and also Dr. [Adrienne] Dove, who has a vacuum chamber and irradiation sources."

Dove, who is a professor of physics and the department chair, says she's excited to work on this project.

"It's a really new, novel way to approach this," she says. "Lunar dust is one of the most significant problems that we have for going to the moon, especially for long duration stays. So, it's really exciting to be working on this, and to be doing this as an applied way to look at lunar dust problems."

Dove has been studying lunar dust physics for many years, and this project extends her existing knowledge and outcomes to how they may directly affect exploration. For this project, she studies how the dust particles interact with the new coatings during the experiments in the vacuum chamber to better inform the prototype coatings Zhai will develop.

"A lot of the work I do is to implement different ways to measure the sticking forces of dust grains and other materials," Dove says. "So, one way to do that is to put a lot of dust on a surface and then to spin the surface really fast with a centrifuge and see at what speed the grains come off—we use that to measure the force."

The research team hopes that their new understandings of lunar dust can inform more efficient ways to reduce the dust's harmful interactions with surfaces by minimizing efforts to physically remove the dust and instead use passive methods such as relying on solar wind or radiation .

"When astronauts are hopping around the surface or rovers are driving around, they're going to stir up dust, and that dust naturally gets all over the place," she says.

"We think of it like when we get sand on us at the beach, you can mostly just wipe it off. Sometimes you get a little scratched, though. That same thing can happen with lunar dust, but it's much worse than beach sand—much harder to get clean and it's scratchier."

The researchers are opting to explore passive methods to mitigate the dust to avoid potentially scratching technologies such as sensors or cameras by wiping away dust. Passive dust mitigation may rely on solar wind, radiation or other passive forces distinct from an active approach such as applying an electric field to remove the dust.

"This project is really focusing on passive ways to change the surface so that dust just doesn't stick as well in the first place," Dove says. "So, if we do things like shake it off or blow some air on it, the dust comes off more easily."

The idea for the project progressed as the team continually discussed dust and surface interactions over the years.

Laurene Tetard, a professor of physics, specializes in atomic force microscopy. Atomic force microscopes (AFM) are powerful enough to examine challenges at the nanoscale, and they are critical to further understanding the dust experiments in the vacuum chamber and how successful the surfaces engineered by Zhai are.

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"We are hoping to develop a new platform that links nanoscience and space research in a new way," Tetard says. "We will design a platform that can perform these measurements under conditions that mimic space conditions. The information obtained from these measurements will provide important feedback to optimize the engineered surface."

She says expanding the frontiers of AFM to space research is particularly unique, and that the future opportunities to build on this research are equally gratifying.

"It will be great to train students in this new direction for future applications of interest of NASA and other space-related industries," Tetard says. "And it's especially exciting to do that with experts in these fields who know a lot about the complementary aspects of this work."

Tarek Elgohary, associate professor of mechanical and aerospace engineering, is collaborating with other team members to create simulations that will help them understand how the particles interact with each other and with different surfaces.

"We've got particle-to-particle and particle-to-surface interactions," he says. "We want to simulate those on the computers and then match what we know from the experiments, such as the physical properties, with what we get from the simulation. So, essentially, we're trying to close the loop between simulations and experiments to better understand the physical phenomena."

Understanding how electrical charges may move among dust particles and how the dust maintains charges or discharges through simulated environments is an important aspect of the research component that Elgohary is studying.

"That will essentially help us with the design process of the passive mitigation techniques that Lei, Addie and Laurene are looking into," he says.

The interdisciplinary nature of the project and the longstanding desire to tackle the elusive challenge of lunar dust are some of what Elgohary says are the most rewarding aspects of the research process.

"I started talking to Addie many years ago, and we have had several efforts to try to understand how the dust moves and interacts," he says.

"It's a fascinating problem, and it requires understanding the physics and connecting that to an engineering application to allow us to have a greater presence on the lunar surface. The fact that there are four of us covering each piece of this problem is one of the most exciting things about this project."

Provided by University of Central Florida