Lanthanide Doped Silica Nanospheres: Surface Sampling in Deposition Studies

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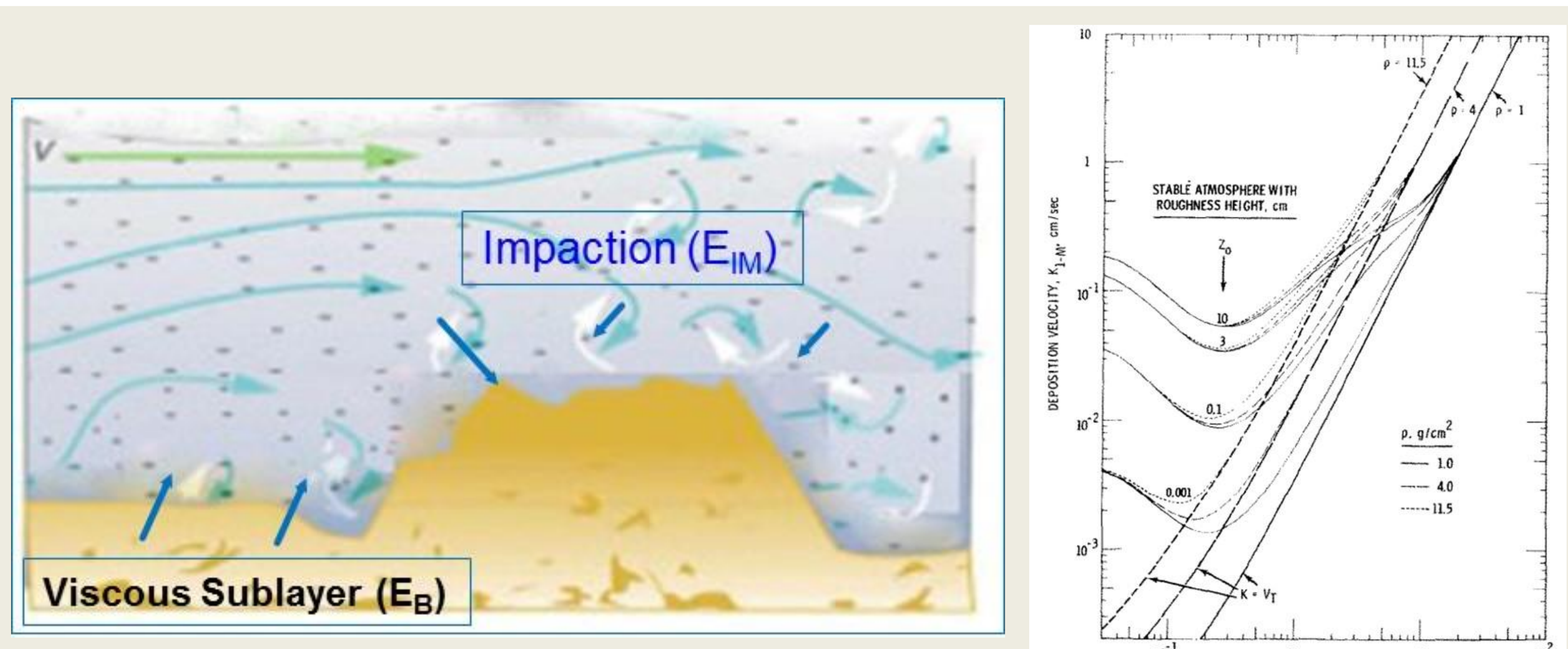
Abstract

The dissemination of a chemical agent in aerosol form will expose personnel, equipment, and buildings to both vapor and particulates. To assess and respond to such an exposure one must have fundamental knowledge of the chemical and physical properties of the aerosol colloid (vapor and particulates), as well as understand the mechanisms of interaction with various surfaces, over a range of environmental conditions. For example, a chemical aerosol release in the desert would most likely create a contaminated area which varies significantly from that resulting from a release of chemical aerosols in the jungle. Not only do the terrains possess extreme differences in relative humidity and temperature, but the surfaces which aerosols will encounter are completely dissimilar (e.g., sand vs. vegetation). Determination of the deposition velocities as a function of aerosol concentration, material type, and various environmental conditions will provide an improved understanding of how emerging threat aerosols collect on solid surfaces; an important factor to consider when conducting an assessment of potential hazards, optimal protection, and adequate decontamination.

Objective

The goal of this proposed effort is to characterize the aerosol properties of emerging solid chemical threats. Characterization of the solid aerosols will help identify the physical properties which impact particle deposition on materials and surfaces of interest.

Deposition Modeling in SCIPUFF



Nicholson, K. W. "The Dry Deposition of Small Particles: A Review of Experimental Measurements," Atmos. Env., 22, 12, pp 2653-2666, 1988

Figure 1. Various factors impact dry deposition of particles onto a surface. Current hazard prediction models do not account for all processes and slight changes in conditions can have a dramatic effect on predicted results.

Sampling Requirements

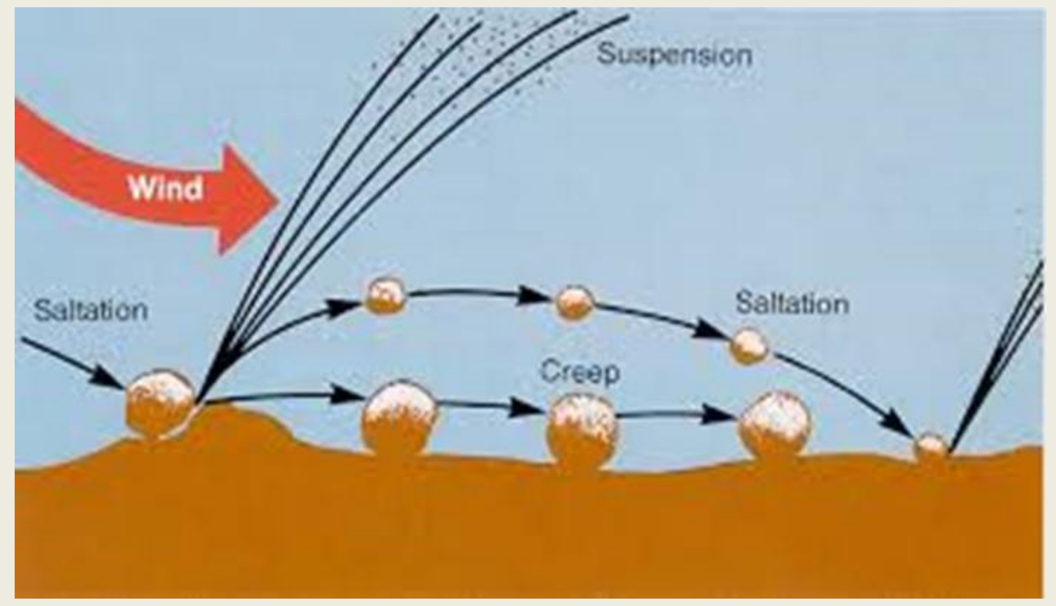


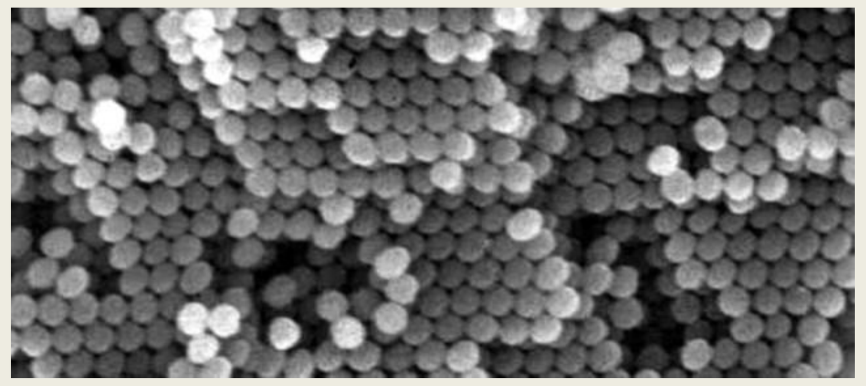
Figure 2. Quantitative sampling requires overcoming challenges such as resuspension.

In order to make quantitative determinations of the amount of material deposited onto a surface, one must be able to sample the surface in place, without disturbance. Aerosols, especially dry particulates, are subject to resuspension, as a function of wind, physical displacement, and other processes that may dislodge the material.

Material Selection

With the intent to study the deposition of dry particles in real world environments, a material must be selected that is able to mimic the physical aerosol properties that dictate deposition, as well as possess properties that allow for direct surface sampling. Important aerosol properties for the simulant are spherical shape, significant size range, narrow size distribution, and a density similar to that of the agent under study. The simulant material selected for these studies is silica spheres, shown in Figure 3. These spheres are commercially available, perfectly spherical and come in a wide range of sizes (0.01 to 2 µm) with a very narrow size distribution (< 10%). Most importantly, this material can be custom synthesized. In order to modify the spheres to permit direct surface sampling, we incorporated lanthanides into the spheres (e.g., Eu, Tb, Sm).

Figure 3. The simulant chosen for these studies is silica spheres. The material is perfectly spherical in shape, comes in a variety of different sizes, is produced with a very narrow size distribution, and the custom synthesis of the material allows us to incorporate lanthanides into the bulk.



Eu-doped Silica Spheres

Using fluorescence, the lanthanide doped spheres are easily distinguishable from the undoped. A calibration curve was made for the europium doped spheres deposited onto a surface. The fluorescence detection is sensitive down to µg, and potentially ng, quantities of Eu on the surface.

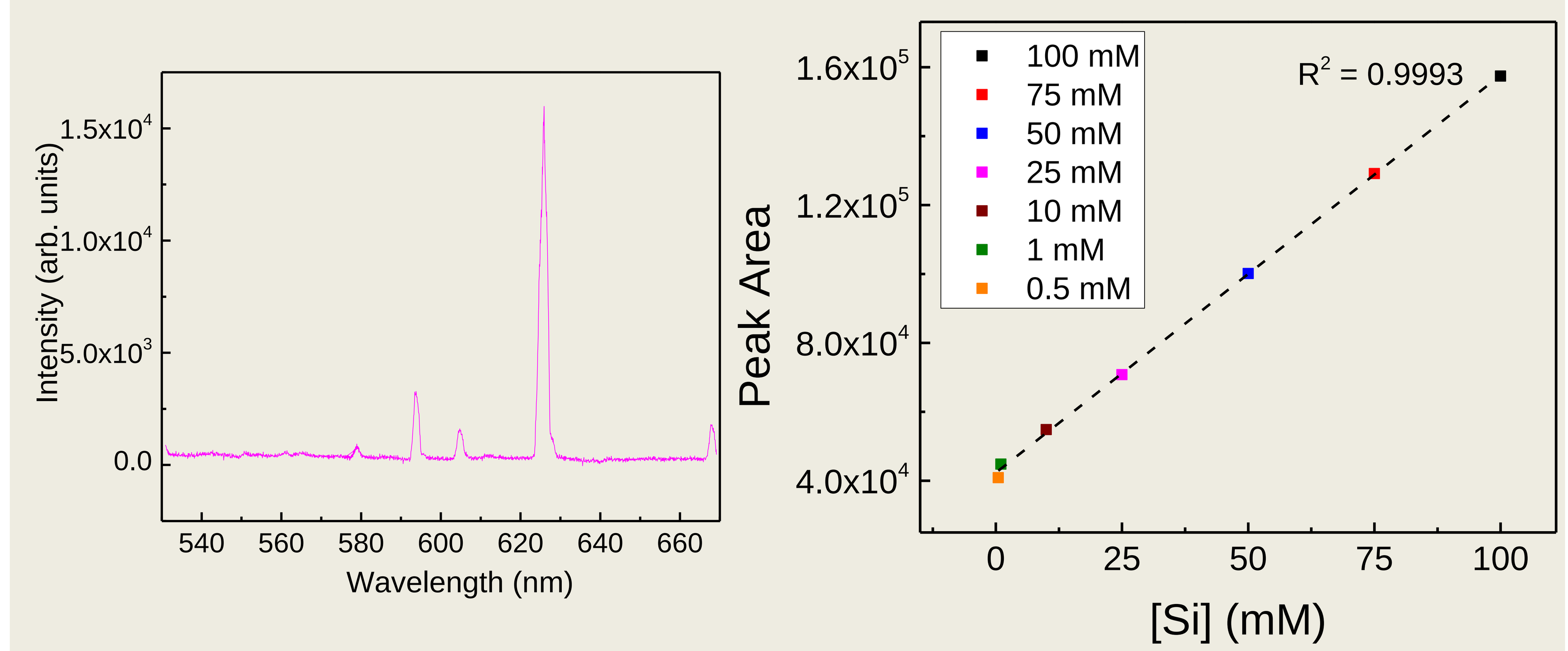


Figure 4. The Eu-doped spheres were excited with short-wavelength UV (254 nm). The excitation resulted in several peaks (580, 590, 610, and 625 nm) indicative of the Eu 4f electron transition from the $^5D_0$ level to the $^7F_2$ level. The graph on the left shows the calibration curve created for Eu-doped spheres deposited onto a surface.

Deposition Studies with Doped Spheres

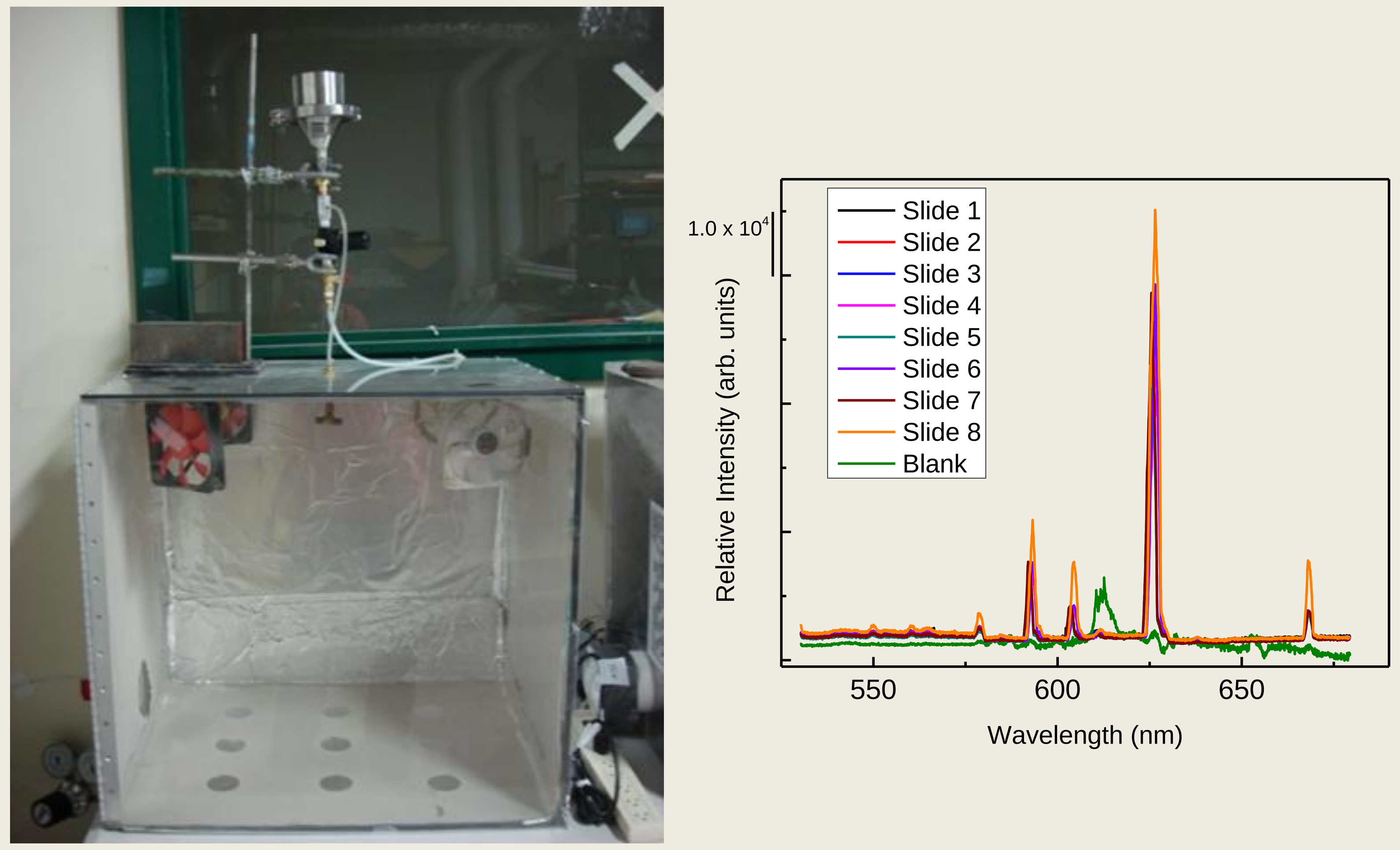


Figure 5. Deposition studies are necessary, not only for basic research, but also for developing technologies during test and evaluation. In this study, the Eu-doped spheres were used to evaluation the deposition on a military coating.

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