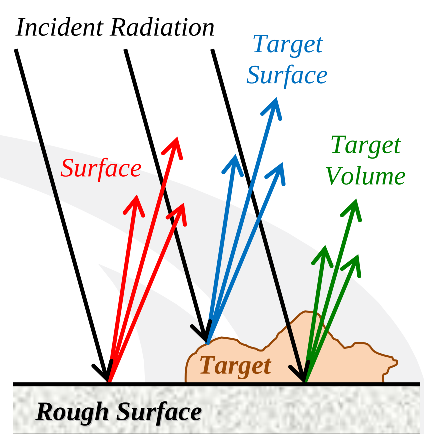
Radiative Transfer Model for Contaminated Rough Surfaces

The subject of scattering and reflectivity of rough surfaces appears in diverse applications such as radar measurements (e.g., reflectivity of sea surfaces) and quality control of manufacturing optical surfaces used in different instruments. In this effort, the primary interest is scattering off rough surfaces in the presence and absence of chemical contamination—a subject that is of fundamental importance for developing a technology capable of detecting the presence of residues of explosive material on various surfaces. In practical applications the contamination may also contain morphology (e.g., spots, irregularities) that makes it a “rough surface”, even if the underlying substrate is perfectly smooth. In this work, the reflectance of potassium chlorate and ammonium nitrate contaminated surfaces was studied and a simple radiative transfer model for lab and field applications was developed. The model was able to fit both lab and field data. Good specificity was demonstrated against lab data (low probability to misidentify potassium chlorate as ammonium nitrate and vice versa). A schematic showing relevant spectral radiance terms for contaminated rough surfaces is shown below.

Key findings: rough surfaces are relatively specular, without strong diffuse components; rough surface reflectance may be accurately modeled by modifying Fresnel reflectance (theoretical specular reflectance for a smooth surface) with an exponential decay term; absorption coefficients derived from standard techniques (KBr pellet method) that do not reflect the contaminant morphology can model observed radiance relatively well; improved performance can be realized with a simple experimental procedure to produce “effective” absorption coefficients that do reflect target morphology. These observations suggest that a simple signature library of absorption coefficients derived from the KBr pellet method may have utility. An expanded signature library that included effective absorption coefficients could improve performance but would require multiple measured signatures per material.



Schematic of radiance components from a contaminated surface.

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