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Stochastic Modeling of Sulphation-Induced Marble Degradation: A Strongly Repulsive Particle System Chemically Interacting with its Environment

Abstract

This is a joint work with D. Morale and S. Ugolini (University of Milan, Italy), and with N. Jävergård and A. Muntean (Karlstad University, Sweden).

We present a hybrid stochastic model to study at the microscale the sulphation of calcium carbonate, a key phenomenon driving the formation of gypsum and marble deterioration.

The dynamics of sulfuric acid particles are governed by Itô-type stochastic differential equations (SDEs), incorporating strong particle repulsion via the Lennard-Jones potential and nonlocal interactions with the surrounding environment; while calcium carbonate and gypsum are described as random fields, evolving according to random ordinary differential equations (rODEs). Chemical reactions are modeled through a marked Poisson measure, coupling particle dynamics with the evolving environment.

We prove the well-posedness of the system for a broad class of singular potentials, including Lennard-Jones, ensuring that particle collisions almost surely do not occur in finite time. This model sheds light on the microscale mechanisms underlying marble degradation, offering insights relevant to Cultural Heritage conservation.