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Electro-porosity of media depends on external electric fields

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From nanomaterials to living tissues, the electro-porosity and thus electrodiffusion of media have been attributed entirely to their structure. However, brain tissue suggests prominent non-ohmic properties, the origins of which continue to be poorly understood.

To address the question [1], we explore Monte Carlo simulations and the Nernst-Planck mathematical formalism of ion electrodiffusion in a space filled with overlapping spheres. The stochastic computations indicate that the permeability of such media is saturated non-ohmically with stronger external electric fields, with this dependence growing stronger with lower medium porosity.

We tested the simulation results empirically using voltammetry measurements in electrolytes filled with non-polarizing dielectric (glass) microscopic spheres and found good correspondence with our predictions.

A first-approximation theoretical insight relates this non-ohmic conductance to a disproportionately increased dwell time of diffusing ions at potential barriers (or traps), represented by geometric obstacles when the field strength increases.

These discoveries have some potentially fundamental implications for understanding electricity in porous media. For instance, it suggests that routinely recorded brain field potentials may not necessarily scale linearly with the strength of current sources inside the brain tissue. At the microscopic scale, this predicts retarded diffusion of charged molecules, heterogeneous charge accumulation, and possibly supra-linear heat dissipation - with increased electrical activity. The dependence of medium permeability on the electric field could help accurately interpret electric activity recordings in brain tissue.

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Reference

[1] L.P. Savtchenko, K. Zheng, D.A. Rusakov: *Conductance of porous media depends on external electric fields*. Biophysical Journal **120 (8)**, 1431-1442 (2021).