Liquid water confined between hydrophobic objects of sufficient size becomes metastable with respect to its vapor at separations smaller than a given separation called the critical drying distance. Drying or cavitation to a vapor phase results in a strong attractive force that can promote the aggregation of the confining objects. A number of simulation studies have observed and characterized drying between idealized hydrophobic solutes, and drying has been implicated in playing a fundamental role in biological functions such as membrane channel gating and protein-ligand binding. A model system often invoked in interpreting these findings is that of two perfectly rigid parallel plate-like solutes immersed in water at a fixed temperature and chemical potential. Macroscopic thermodynamics arguments applied to this system predict a drying distance that either behaves like a constant or scales with solute size, depending on the behavior of a governing dimensionless group. However, no material is perfectly rigid, and it may be necessary to account for this fact in the thermodynamic analysis.

Here, we present a theory that blends the current macroscopic theory with the thermodynamics of elasticity to derive the critical drying distance for water confined between flexible materials. The general expression for the critical drying distance is a sum of the expression for perfectly rigid solutes and a term associated with the elastic response of the material. Thermodynamic arguments suggest that this elastic term is exclusively positive, meaning that flexibility augments the critical drying distance. We then consider a specific example of drying between simply supported plates with two free edges and show that the scaling behavior of the elastic response term is the opposite of the rigid term. We also show that the elastic term can be the same order of magnitude or greater than the rigid term for Young's moduli as large as 10 Gpa. These findings suggest that flexibility can be important in the function of biological systems and may be a necessary feature to incorporate into the engineering design rules of hydrophobic assemblies.