Electrode-Mineral Interfaces for the Evaluation of Prebiotically Relevant Electrochemistry

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The field of Astrobiology studies life's origin and mechanisms for survival in extreme environments, which is relevant to the search for life elsewhere. One particularly interesting geological environment for habitability and prebiotic chemistry is hydrothermal vents and chimneys, which occur at water-rock interfaces such as those on Europa and Enceladus. These hydrothermal chimneys represent "far-from-equilibrium" natural systems that have been shown to generate electrochemical energy [1] which life can harness directly from conductive mineral surfaces [2] and which may also have driven organic synthesis at the emergence of life [3]. The minerals present in these systems serve as both heterogenous catalysts as well as electron conduits to enable these chemical reactions. To evaluate the electrochemical behavior of these complex and stochastic systems, a variety of electrochemical methods have been employed. These include direct electrode contact to active hydrothermal vents [4], flow-through chemical reactors [5], and half cell electrochemical techniques [5]. In these systems, the structure of the mineral may play a pivitol role in the electrochemical performance [6]. However, this role is particularly challenging to evaluate. We have recently developed new strategies to begin investigating this role. In particular, the use of 3D printed electrodes and electrochemical deposition processes provide a new means for evaluating how the mineral structure and environment may influence the electrochemical properties. These techniques may provide insights regarding the chemical-structure relationship in these active geochemical environments. By understanding these relationships we can better understand the role of water-rock chemistry on Early Earth as well as ocean worlds.

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