Characterization of Interfacial Interactions by Functionalized AFM Probes

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Abstract

Interfacial interactions play a crucial role in many complex materials systems, determining many of their properties. However, characterization of these interactions, especially at the micro- to nanometer length scales is experimentally challenging. Consequently, insufficient knowledge of these systems limits technological advances in important applications. In this work, custom functionalized atomic force microscopy (AFM) probes were developed to measure the interaction forces in two important systems: petroleum reservoirs and nanocomposites. Our work seeks a deeper understanding of the specific interactions that occur in these two systems so that modified approaches can be developed to improve them.

Petroleum recovery is concerned with maximizing the collection of crude oil, which adheres to rock surfaces underground and resists release when flushed with injection water. To promote more efficient oil extraction, the injection water can be tailored to decrease this oil–rock adhesion. In our study of petroleum recovery, we coated a probe in crude oil and dried the oil to create a robust layer. By performing force measurements with this probe on a mica substrate and varying the surrounding aqueous composition, we observed the effect of multiple variables on the relevant forces in a reservoir, ultimately providing enhanced predictive capabilities for increased oil extraction in injection wells. To achieve a graphene oxide (GO) nanocomposite with optimal properties requires a strong bond between the nanofiller particles and surrounding polymer matrix. To this end, we studied the interactions within a GO–polymer nanocomposite by coating a probe in GO flakes and performing force measurements on polymer substrates. The preferential attraction between GO and some polymers is consistent with the results of recent interfacial tests performed in our lab. Our research provides crucial information for the selection of novel GO–polymer combinations, which can be implemented in superior reinforced nanocomposite systems. Through development of these novel tools, we anticipate that our customized probes will enhance predictive capabilities in the study of colloidal and other interfacial systems.