Understanding the effects of solvents and vapours on interactions of asphaltene surfaces by surface forces apparatus (SFA)

Hongbo Zeng*, Jinggang Xie, Anand Natarajan, Jacob Masliyah, Zhenghe Xu*
Department of Chemical and Materials Engineering, University of Alberta, Edmonton, AB, T6G 2V4
*(*corresponding authors: hongbo.zeng@ualberta.ca and zhenghe.xu@ualberta.ca)*

Asphaltenes represent about 0-20% of crude oils and 10-20% of bitumen by weight. Asphaltenes are known to be composed of polyaromatic structures with aliphatic side chains, doped with some metals and polar heteroatoms (such as oxygen, nitrogen and sulphur) [1]. Asphaltenes play important roles in crude oil production, and bitumen extraction, processing and transportation due to its amphiphilic nature. A fundamental understanding of surface properties, intermolecular and surface interactions of asphaltenes is of great value in many engineering processes of crude oil and bitumen production [2-3]. Due to its unique ability to provide a simultaneous direct measurement of the force, F, as a function of the absolute surface separation, D, and the local geometry of two interacting surfaces (the local radius R or contact area A) with a force sensitivity of ~10 nN and a absolute distance resolution of 0.1 nm measured in situ and in real time [4-5], surface forces apparatus (SFA) has been extensively used in many biologically and non-biologically related research, and could be a unique and ideal technique for such research objectives.

In this study, an SFA was used to exploit the intermolecular and surface forces of asphaltene surfaces in organic solvents (toluene and heptane), organic vapours, and air of different relative humidity. The force against distance curves, or so-called force profiles, have provided valuable information on local material properties such as interaction energies, Hamaker constant, molecular conformation changes, phase transition, viscoelastic properties of the interacting asphaltene surfaces or films. Atomic force microscopy (AFM), and contact angle measurements were also employed to provide complementary information on the surface morphology and surface energy of asphaltene films studied.

The results show that the surface interactions and kinetics of asphaltenes strongly depends on types of surrounding solvents or vapours, contact time, load (pressure), adsorption time and supporting substrates. The adhesion energies of two asphaltene thin films were found to increase dramatically with contact time measured by contact mechanics tests using SFA, depending largely on the environmental vapour conditions. Bridging adhesion forces were measured between one asphaltene surface and one mica surface in both toluene and heptane, as well as between two asphaltene surfaces in heptane. While small bridging adhesion was observed for two asphaltene surfaces in toluene, pure repulsion was observed with increasing interaction time. The AFM experiments showed conformation and morphology changes with time of dip-coated asphaltene thin films in toluene, but showed no change in heptane, which is in line with the results from the SFA force measurements. Our results provide an insight into the basic interaction mechanisms and kinetics of asphaltenes in organic media and hence in crude oils and bitumen production.

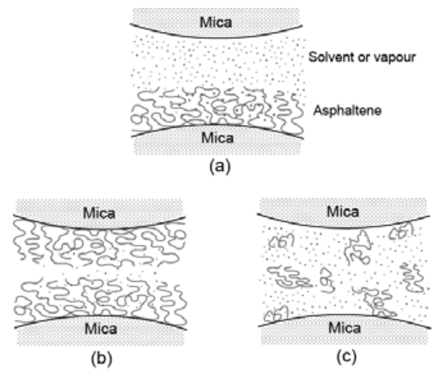

Fig. 1. Schematic of SFA experiments for studying the intermolecular and surface interactions of Asphaltenes in organic solvents or different vapours. (a) Asphaltene film *vs.* mica surface, (b) two asphaltene surfaces, (3) two mica surfaces across asphaltene solutions of different concentrations.

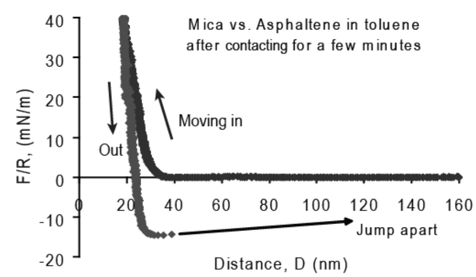

Fig. 2. Interactions between dip-coated asphaltene layer and mica surface in toluene (strong bridging adhesion was observed after compression, but only weak adhesion was measured following immediate contact, not shown here).

References

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