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Coupled Brownian motion at liquid-air surfaces

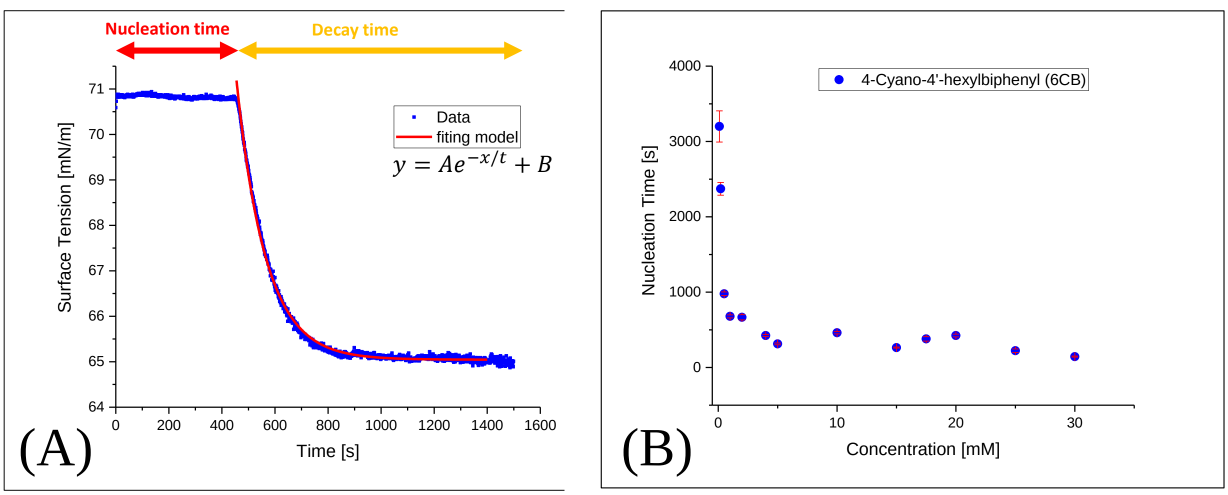
Bruce M Law (PI), Kansas State University

This research is a collaboration between the PI at Kansas State University and Professor H. K. Pak's group at UNIST (Ulsan National Institute of Standards and Technology) in Ulsan, South Korea. Unfortunately, a number of set backs occurred at the beginning of this research project.

(i) Despite the PI's efforts to recruit a student to this project in the summer and fall of 2017, from the graduate student pool at Kansas State University, it was not possible to attract a student until August of 2018 when Mr Shital Rijal joined the PI's research group.

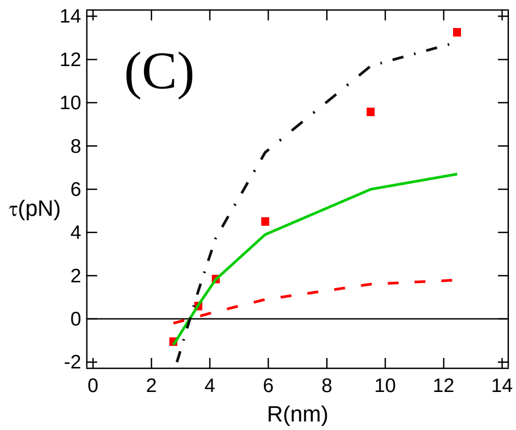
(ii) In November 2017 the PI suffered a medical injury, which took more than 6 months to recover from. The medical injury incapacitated the PI and (a) prevented him from conducting any experimental work in the lab (as he was on crutches) and (b) prevented him from traveling to South Korea as part of this collaboration.

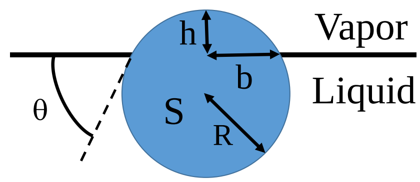
Despite these set backs everything is getting back on track now. However, due in part to this change in circumstance, the original emphasis of the research has had to be altered. In order to keep this collaboration going the PI has had a weekly video conference meeting with his Korean collaborators, specifically with Mr Jintae Park (a PhD graduate student) and Dr Govind Paneru (a postdoc) in Professor Pak's research group. Professor Pak's group have completed a novel set of dynamic surface tension measurements using the pendant drop technique for an emulsion of 6CB (4-cyano-4'-pentylbiphenyl) liquid crystal droplets of diameter ~ 800 nm suspended in water. 6CB and water possess low miscibility and almost identical densities where the surface tension of 6CB is lower than that of water. Rather unusual behavior is observed as a function of time, as depicted in figure (A).



The initial surface tension, at time t = 0, is approximately the value for pure water. After a surface nucleation time of hundreds of seconds the surface tension starts to decrease where this decrease in surface tension can be fitted by an exponential with a decay time of hundreds of seconds. The nucleation time is found to be a strong function of the 6CB concentration in water (figure (B)). As far as we are aware, this dependence of the surface nucleation time on bulk concentration is novel and has never been reported in the literature before. A theory has been develped to explain this phenomenon. This work is currently being written up for publication.

In other work, also using the pendant droplet technique to measure the (air/liquid) surface tension, the variation in surface tension for dodecane thiol coated gold nanoparticles (NP) has been measured as a function of NP concentration in the solvent n-octadecane at a temperature of 30ºC. From this NP concentration dependence of the surface tension one can extract the line tension at the three phase solid-liquid-vapor boundary of the NP. This line tension is found to exhibit a novel finite-size effect where the line tension τ depends upon the NP particle radius R, as shown in figure (C). The curved lines in the figure are an approximate theory (at various cut-off parameter values) to explain the experimental data (red solid squares). As far as we are aware this is the first report of a finite-size line tension effect. This work, which is now published [1], was conducted in collaboration with Professor Matsubara's research group at Kyushu University in Japan.





<u>Research Impact:</u>

This research has assisted in developing stronger ties between the PI's research group at Kansas State University and Professor Pak's research group at UNIST and Professor Matsubara's research group at Kyushu University. The work done by Jintae Park at UNIST is part of his PhD research while the work done in collaboration with Professor Matsubaru's group at Kyushu University was part of the BS research of Mr Otsuka. Mr Rijal, who joined the PI's research group at Kansas State University (and is funded by this ACS PRF grant), is likely to continue research examining novel soft matter aspects for particles at liquid surfaces, as part of his PhD research.

[1] H. Matsubara, J. Otsuka, B.M. Law, Finite-Size and Solvent Dependent Line Tension Effects for Nanoparticles at the Air−Liquid Surface, Langmuir, 34 (2018) 331-340.