Generation of Ultra-stable Microbubbles for Industrial Applications

Papoole. VALADBAIGI*, Rammile. ETTELAIE & Brent. S. MURRAY

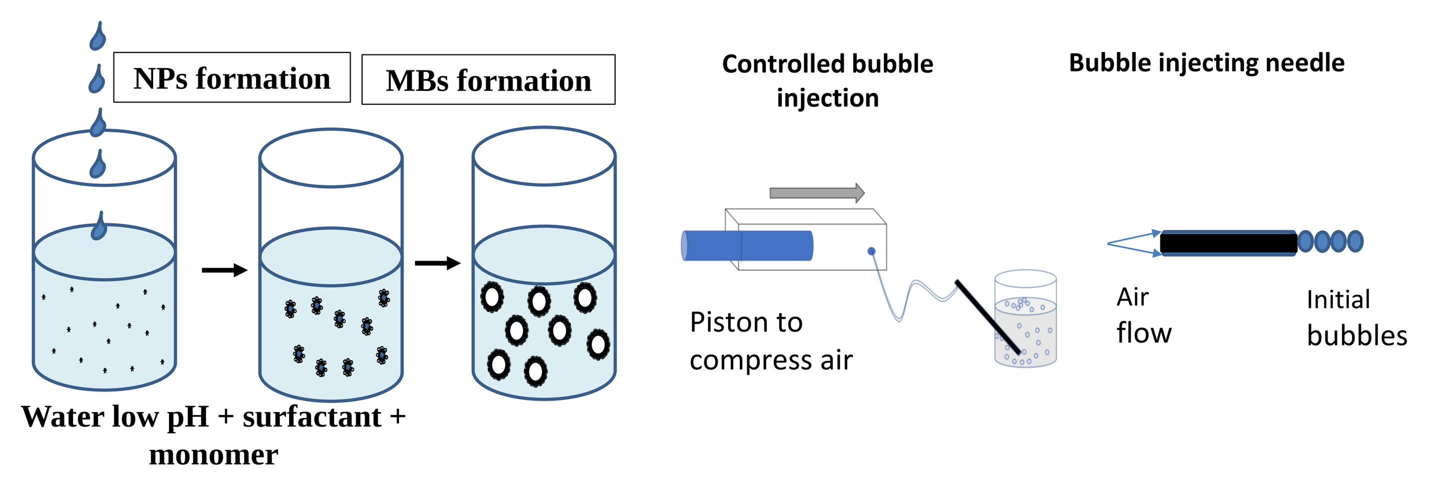
Introduction

Aqueous foams are widely used by variety of different industries: from foods to cosmetics, fire extinguishing, oil recovery and blast mitigation. However, the thermodynamically unstable nature of liquid foams raises critical issues in all of these applications.

Foam instability arises from the high interfacial energy (tension) of the gas–liquid interface, and constitutes a driving force for decreasing the total interfacial area of the foam through coalescence and disproportionation (dissolution and shrinkage).[1] The best route to prevent disproportionation is to stabilise small gas bubbles by adsorption of nanoparticles to their surface, analogous to Pickering stabilisation of emulsion droplets.[2]

Butyl cyanoacrylate (BCA) is a wound tissue glue. PBCA nanoparticles can be made via polymerisation of butyl cyanoacrylate monomer and are effective MB stabilizers. These MBs and nanoparticles are biodegradable and have many applications e.g. in medical science, including as an ultrasound contrast agent.

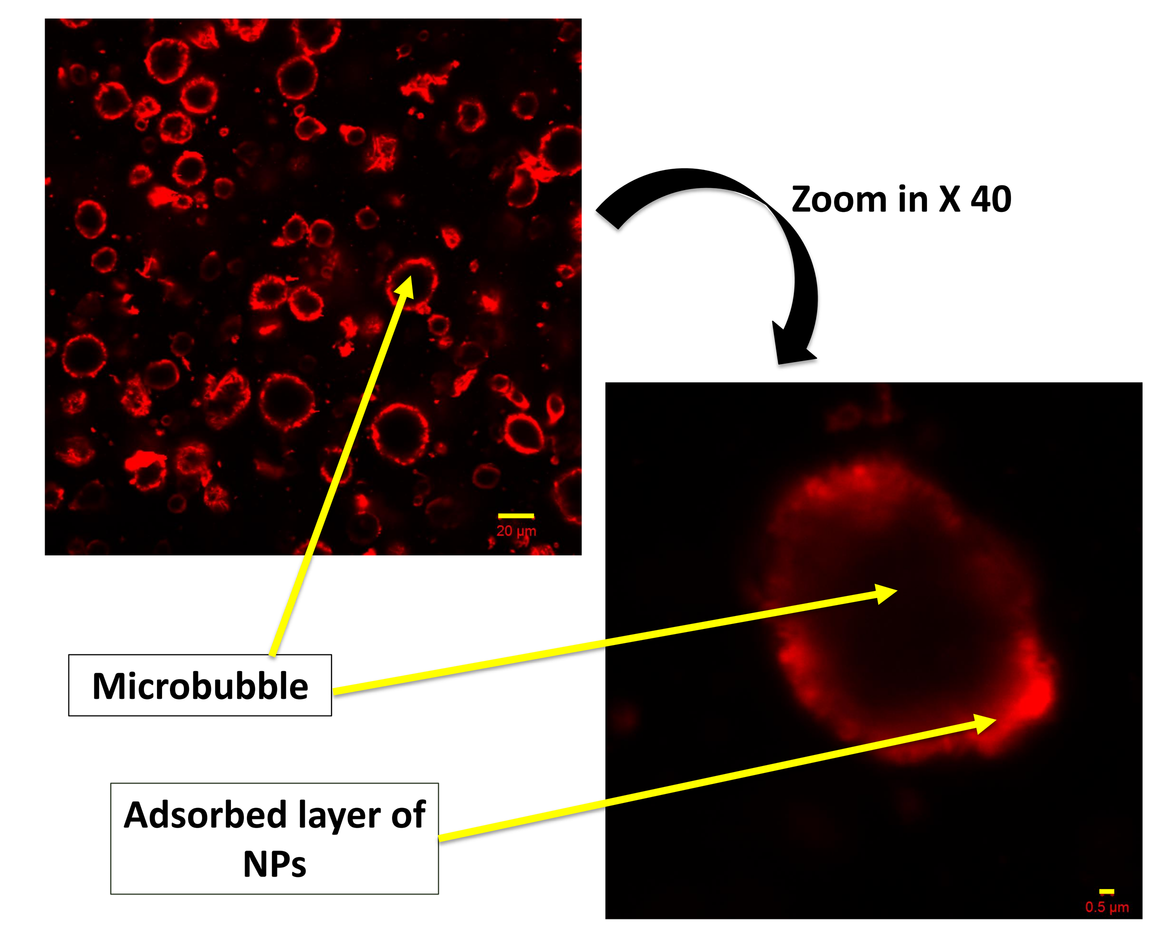
Materials & Methods

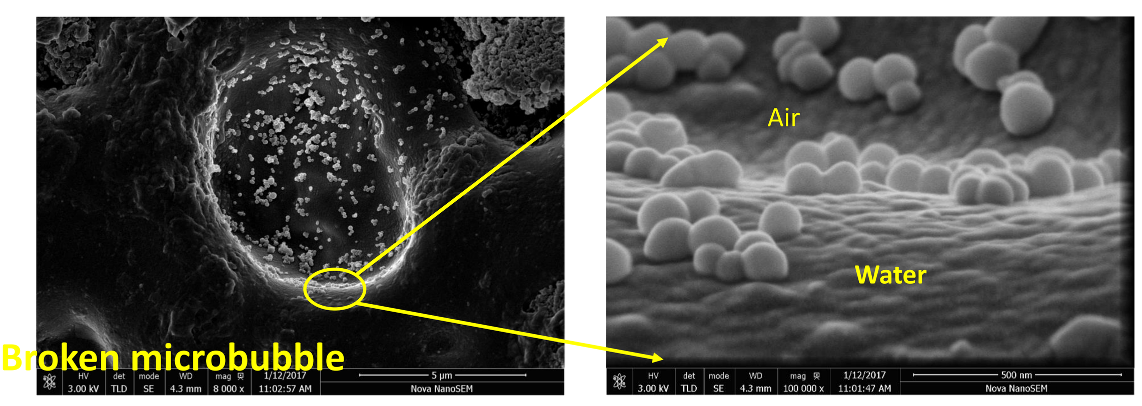


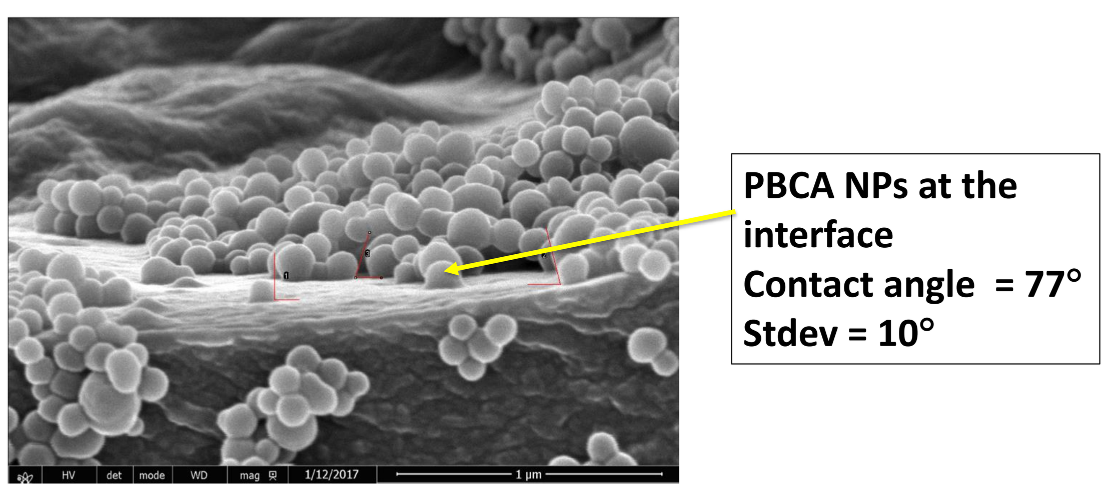
MBs produced by controlled bubble injecting, where a piston compressed air. The air then passed through a needle of known size to produce monodisperse initial bubbles. The diameters of initial bubbles were 550 and 380 μm for large and small diameter needles respectively. Top foam was removed and each dispersion aerated again.

Results

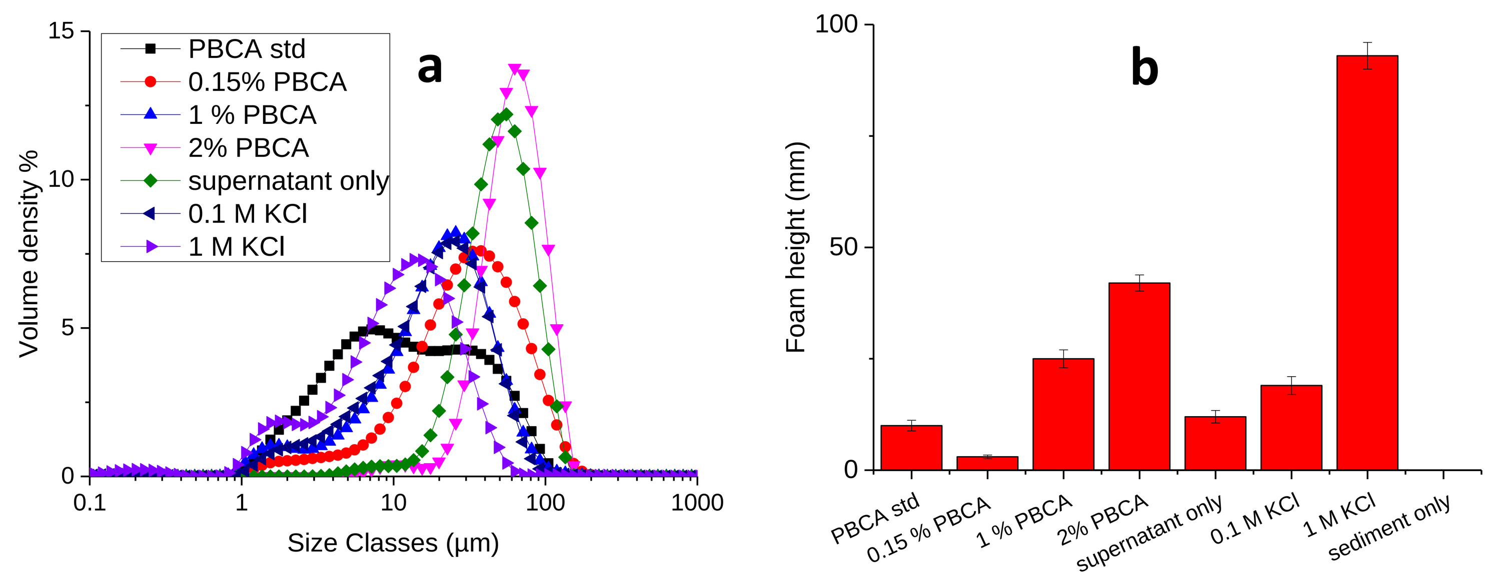
Shape and structure of NPs at the interface





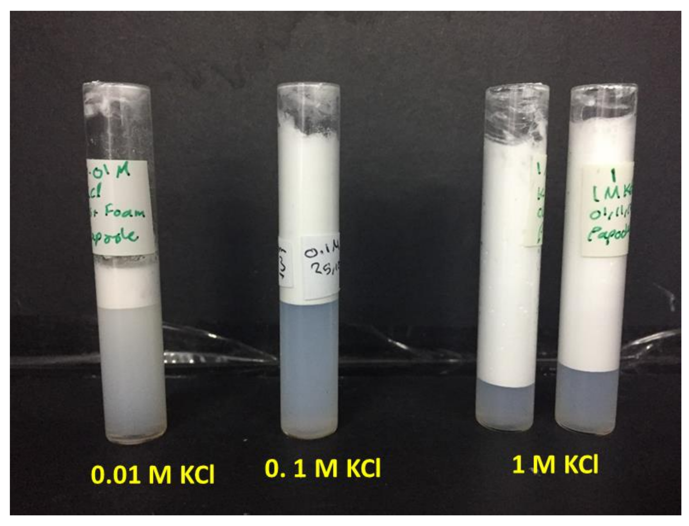


Measurement of size distribution and foam height of different aerated systems



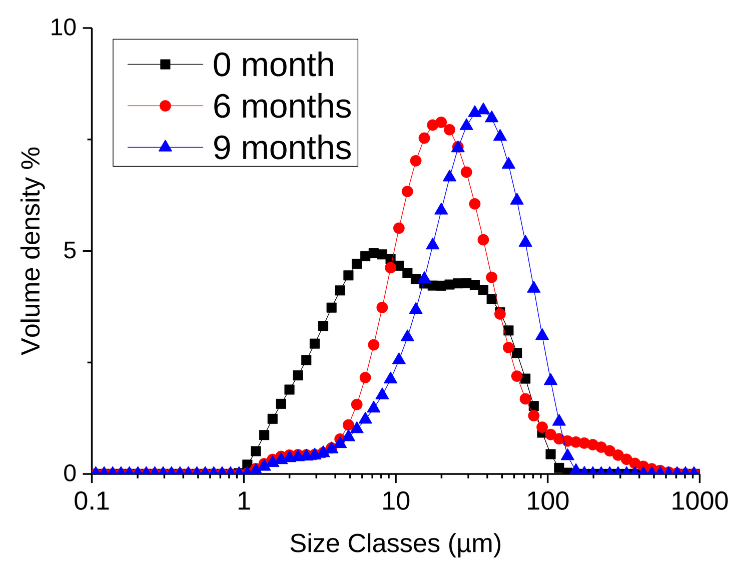
Comparison of 1st foam produced at different concentration of PBCA. a : size distribution PBCA standard (■), 0.15 % PBCA (●), 1 % PBCA (▲), 2% PBCA (▼), supernatant only (♦), PBCA + 0.1 M KCl (◄), PBCA + 1 M KCl (►), b: foam height

Increasing the ionic strengths



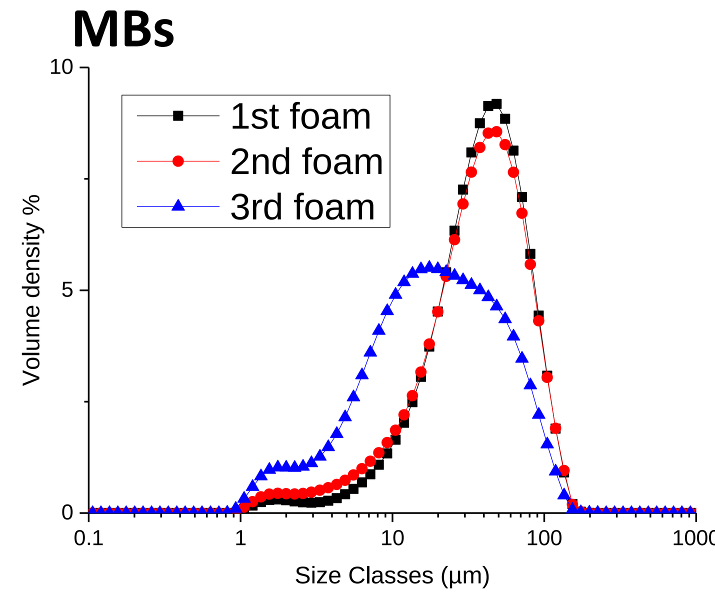
Shows the impact of increasing the KCl concentration on foam height of PBCA stabilized MBs

Long term stability of MBs



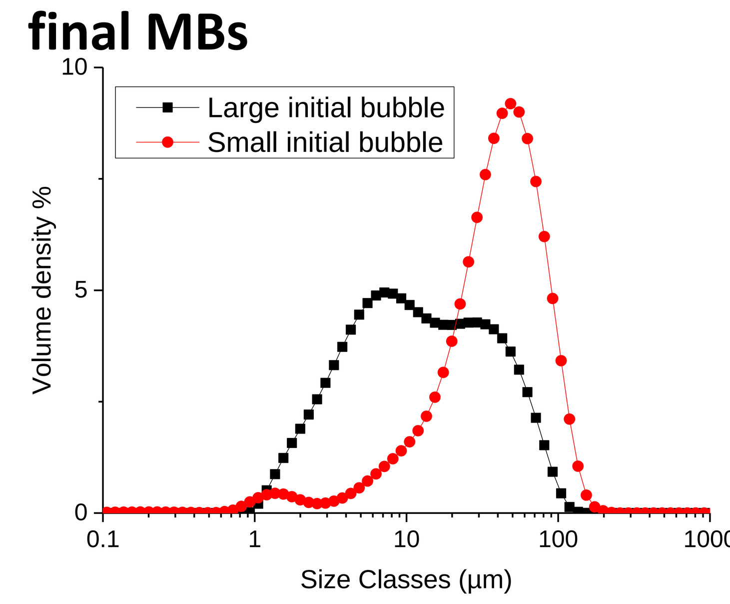
Size distribution and bubble stability of standard PBCA stabilized MBs, over 9 months

NPs concentration impact on MBs



Shows the impact of particle concentration on size distribution

Impact of initial bubble size on final MBs



Represents the effect of initial bubble size on final size of MBs

Density and air volume fraction of PBCA stabilized MBs:

Density of foam = 275-320 kg/m^3

i.e., air volume fraction, $\phi \approx 70$ %

Discussion

- Butyl cyanoacrylate (BCA) forms spherical NPs during polymerisation. The contact angle of PBCA NPs at the air water interface is 77°.
- This PBCA NPs stabilize MBs for a long period of time (>9 months).
- Controlled bubble injection when using the above PBCA NPs produced foam with high $\phi \approx 70$ % .
- Increasing the ionic strengths of PBCA NPs dispersion led to significant increase of foam height.
- Higher concentration of PBCA NPs produced MBs with narrow size distribution.
- Controlled bubble injection produces bubble size distributions that change in ways that will allow future comparison of experimental data with a mathematical model [3] of how the dynamics of particle adsorption versus bubble shrinkage affects the final stable bubble size distribution.

References:

[1] A. J. Wilson (1989) in Springer Series in Applied Biology (Ed.: A.W. Robards), Springer, Berlin, pp. 233.

[2] B.P. Binks, T.S. Horozov (2005) Aqueous foams stabilized solely by silica nanoparticles, *Angew. Chem. Int. Ed.*, **44**, 3722–3725

[3] Ettelaie, R. & Murray, B. S. (2015). Evolution of bubble size distribution in particle stabilised bubble dispersions: Competition between particle adsorption and dissolution kinetics. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, **475**, 27-36.