Stability and Viscoelasticity of Magneto-Pickering Foams

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SUPPLEMENTARY INFORMATION

Stress Sweep Data

Oscillatory stress sweeps were performed on foam samples of different ages to determine the range of stresses across which the linear viscoelastic region for the foam exists (Figure S1). These experiments were performed for foams containing 2.7 wt% Fe, using the TA Instruments AR2000 rheometer as described in the paper.

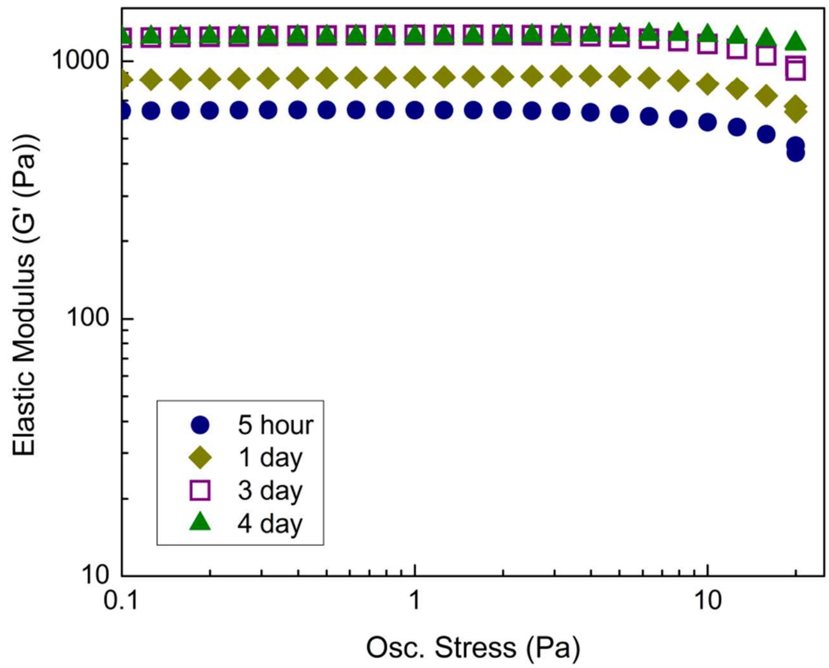

Figure S1. Elastic modulus, *G'*, as a function of applied stress.

Parameters Used in the Calculation of Wet and Dry Foam Models

The key values associated with the calculation of forces in the wet and dry foam collapse models are presented in Tables S1 and S2 below. The magnetic susceptibility used in the wet foam calculations, χ_{wet}, was determined using the Maxwell-Gannett equation for the magnetic susceptibility of a suspension of non-interacting spherical particles.[i] The magnetic susceptibility used in the dry foam calculations, χ_{dry}, was obtained from a literature value for carbonyl iron powder.[ii] The bubble radii as well as the surface tension values used in the calculations were obtained experimentally.

Table S1. Parameters associated with calculation of forces in wet foams.

Parameter	*Value*
χ_{wet}: (mass) magnetic susceptibility	6.28×10^{-4} m^3 kg^{-1}
F_{mag}: magnetic force	3.3×10^{-9} N
R_{bubble}: bubble radius	50 µm
ΔP: Laplace pressure	2000 N m^{-2}

Table S2. Parameters associated with calculation of forces in dry foams.

Parameter	*Value*
χ_{dry}: (mass) magnetic susceptibility	1.88 x 10^{-3} m^3 kg^{-1}
F_{mag}: magnetic force	9 x 10^{-9} N
γ: surface tension	0.05 N m^{-1}
$l_{stretch}$: film length	125 μm

Videos of Macroscopic and Microscopic Foam Collapse

Macroscopic Collapse Movies. Collapse videos of the bulk foam sample demonstrate how differences in foam age influence the rate of foam collapse. Foams reported in the paper were collapsed from the side using a NdFeB magnet of 0.5 T field strength. Movies S1 and S2 demonstrate bulk foam collapse in magnetic field for a 5 hour foam sample and a 3 day old foam sample. As seen in the movies, the 5 hour old foam sample deforms very slowly toward the source of the magnetic field, whereas the attraction between the 3 day old foam sample and the magnetic field is very violent. The aged foam sample collapsed immediately toward the source of the gradient field. Movie S1, which shows the collapse of the 5 hour old foam sample, is playing in real time for the first 15 seconds of the movie and then at 8x speed for the remainder of the video. Movie S2, which shows the collapse of a 3 day old foam sample, is playing in real time.

Foam Collapse on the Bubble Scale. Videos showing the reaction of foam bubbles to an applied magnetic field are shown in Movies S3 and S4. In Movie S3, one can see how a sample of fresh foam bubbles deforms slowly toward the source of the magnetic field. The bubbles, liquid and magnetic particles move together toward the center of the field gradient. On the contrary, when a magnetic field is applied to an aged foam sample, the attraction of the iron particles toward the field source results in the stretching of foam films and deformation of bubbles (Movie S4); these actions result in film rupture and bubble coalescence, which will ultimately lead to foam destruction. The difference in the response of these different foam samples on the microscopic level can be attributed to a lower water fraction in aged foam samples, which results in higher level of structural order (i.e. bubble packing and particle packing) in the foam. This can be observed in the videos. Both Movies S3 and S4 are playing in real time.

Microscope Photos of Foam Bubbles for Bubble Size Determination

Figures S2 and S3 show microscope images of foam bubbles at 0 days old. Images such as these are used for determination of average bubble size in the foam.

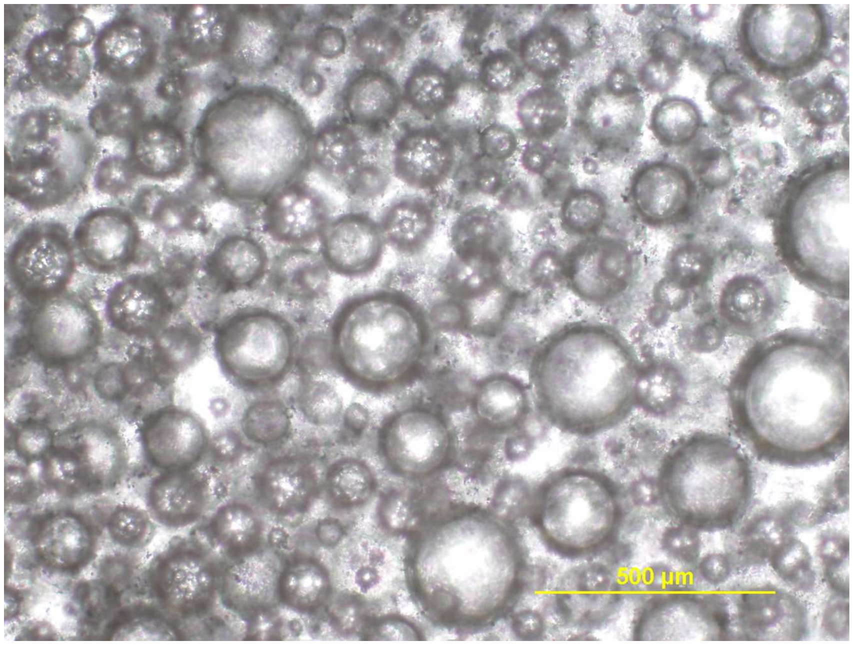

Figure S2. Micrograph of foam bubbles from a fresh foam sample (2.7 wt% Fe).

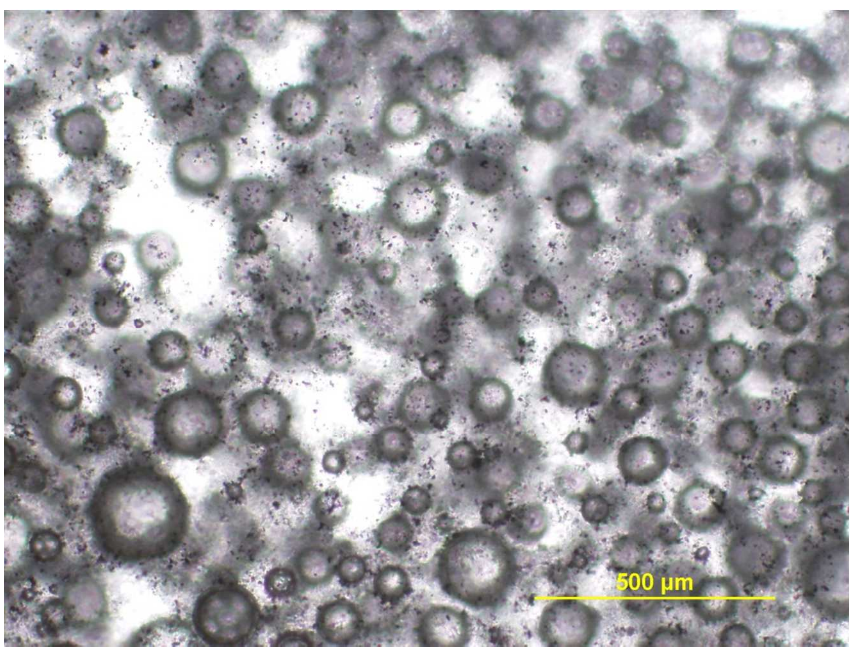

Figure S3. Micrograph of foam bubbles from a fresh foam sample (2.7 wt% Fe).

Error for Power-Law Scaling of Bubble Size Growth

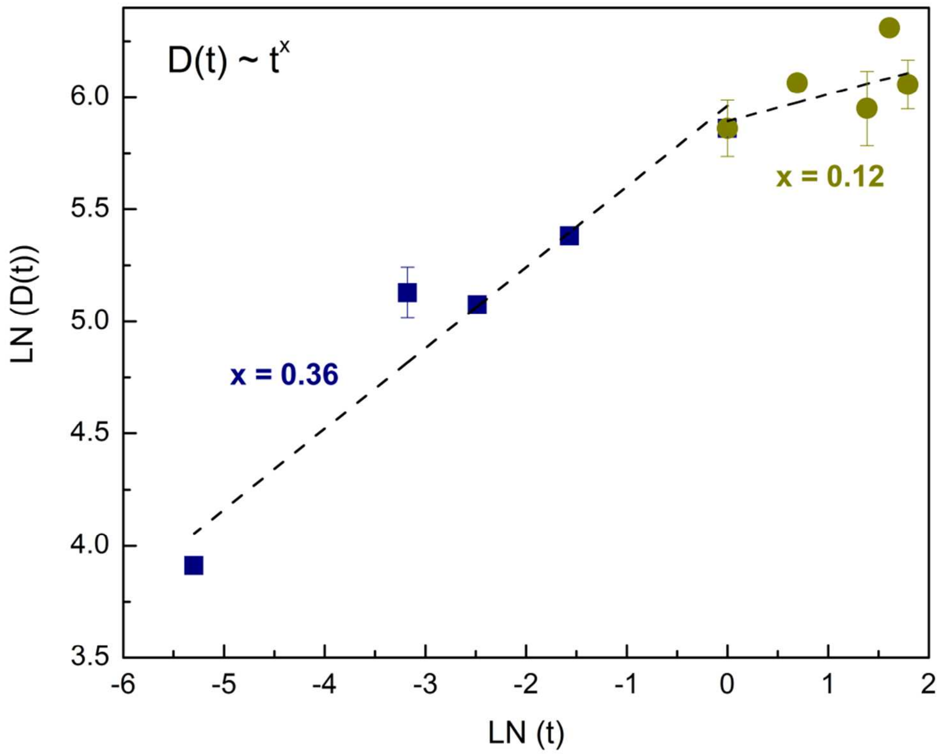

Figure S4. Log-log plot of data for bubble growth over time in the foam showing power law fits to the data. The square points represent data for foams ≤ 1 day old. The circular points represent data for foams ≥ 1 day old. The dotted lines are the fits for the data based on bubble size growth scaling to a power of 0.36 for foams less than one day old, and 0.12 for foams greater than one day old. The R^2 value for the x = 0.36 fit for foams ≤ 1 day old is 0.98 and the R^2 value for the x = 0.12 fit for foams ≥ 1 day old is 0.84.

REFERENCES

[i] Bombard, A.J.F.; Knobel, M.; Alcantara, M. R.; Joekes, I. Evaluation of magnetorheological suspensions based on carbonyl iron powders. *J. Intell. Mater. Syst. Struct.* **2002**, 13, 471-478.

[ii] Gorodkin, S. R.; James, R. O.; Kordonski, W. I. Magnetic properties of carbonyl iron particles in magnetorheological fluids. *J. Phys. Conf. Ser.* **2009**, 149, 012051(1)-(4).