# Impact of Coating Particles on Liquid Marble Lifetime: Reactor Engineering Approach to Evaporation

**Joshua Saczek,[1] Koren Murphy,[1] Vladimir Zivkovic,[1] Aditya Putranto,[2] Stevin S. Pramana[1]***

1. School of Engineering, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK
2. School of Chemistry and Chemical Engineering, University of Surrey, Guildford GU2 7XH, UK

***Correspondence:**
stevin.pramana@newcastle.ac.uk

## Supplementary Material

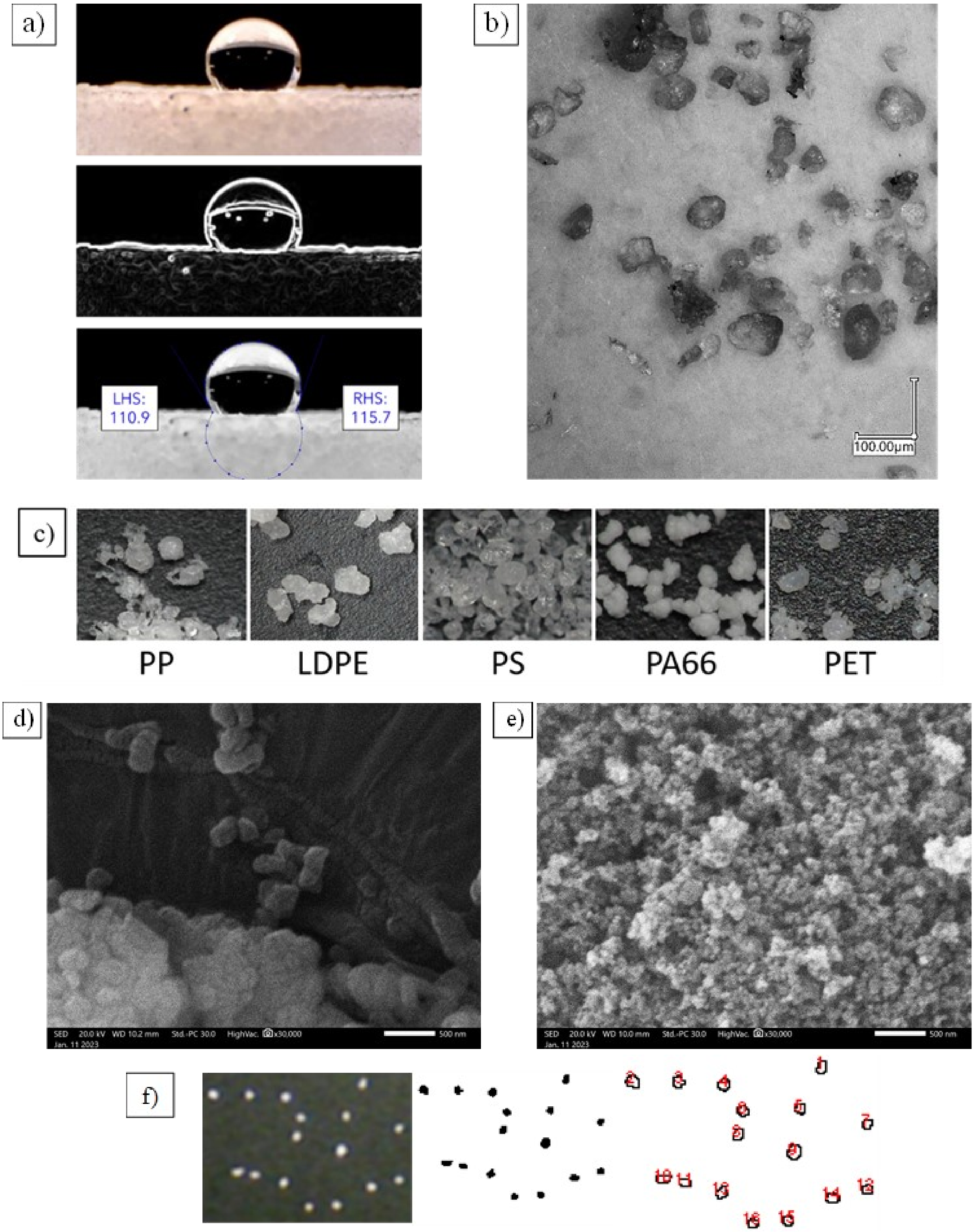



Figure S1: Examples of powder a) contact angle (LDPE), obtained via capturing an image of a sessile drop on a compressed tablet of MPs and applying “Find Edges” process through ImageJ allowing for a clear outline of the droplet to be observed with the DropSnake plugin measuring the contact angles. b) image of PVC MPs using a light microscope with scale bar. c) remaining images of the other MPs using a light microscope. Scanning electron microscope images of d)

PTFE 250 nm powder and e) untreated $Fe_2O_3$ 50 nm powder. f) Example of ImageJ's particle counter feature to allow for the determination of particle diameter.

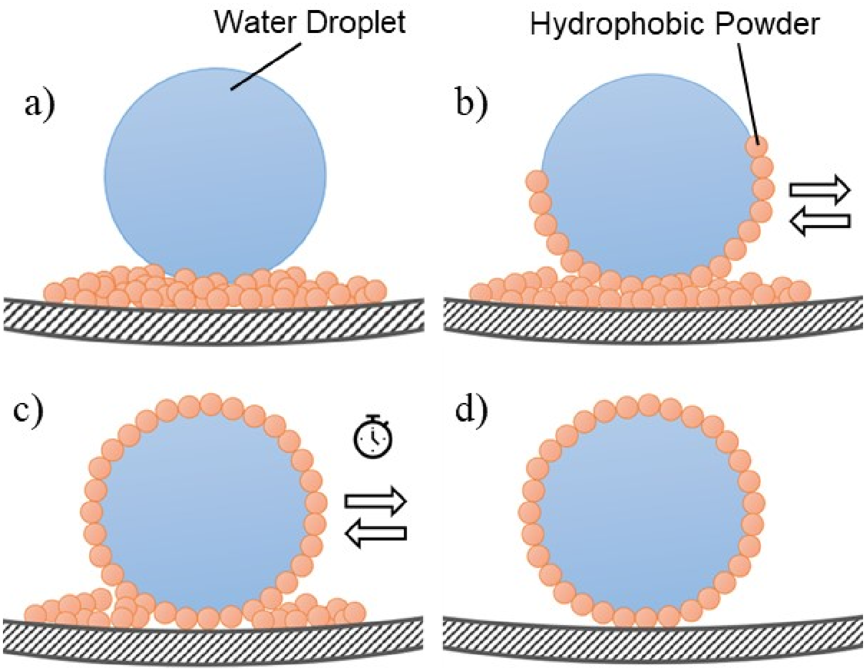



Figure S2: The standard process for the formation of liquid marbles within this thesis, via the simple method of agitating a liquid droplet on a powder bed.

Table S1: The overall lifetimes and buckling times for the different coatings used within this study.

| Material | Particle Diameter / µm | Overall Lifetime / minutes | Buckle Time / minutes |
|---|---|---|---|
| PTFE | 0.25 | 124.3 ± 4.1 | 40.0 |
| PTFE | 1 | 111.0 ± 2.1 | 36.8 |
| PTFE | 20 | 106.3 ± 3.9 | 36.1 |
| PTFE | 200 | 82.0 ± 2.5 | 33.3 |
| PVC | 50 | 90.5 ± 2.9 | 35.3 |
| PS | 50 | 102.7 ± 2.1 | 32.0 |
| LDPE | 50 | 105.8 ± 1.8 | 33.6 |
| PP | 50 | 104.2 ± 3.2 | 36.9 |
| Fumed-$SiO_2$ | 0.25 | 139.8 ± 2.1 | 50.0 |
| Fe/HDTMS | 0.25 | 126.7 ± 3.7 | 40.2 |
| Fe/PFDTMS | 0.25 | 131.7 ± 3.3 | 41.2 |

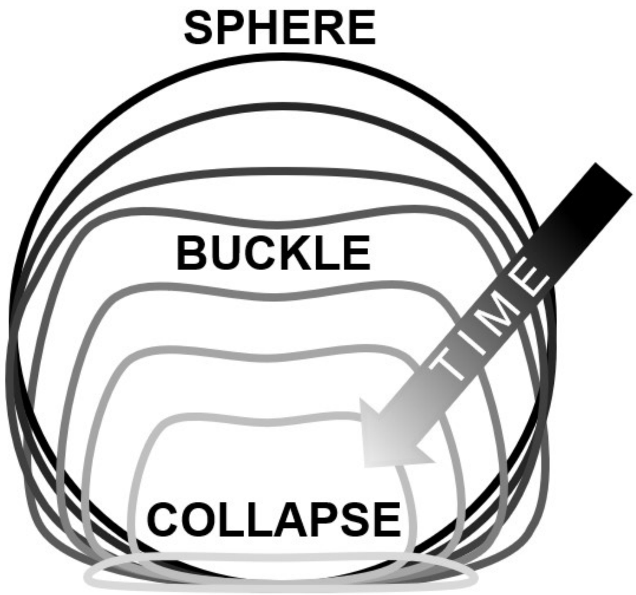



Figure S3: Schematic demonstrating the change in profile of the LM over time. Initially starting with a spherical structure, over time compression of the surface of the LM begins to occur due to liquid evaporation, eventually leading to surface buckling (~30-40% of overall lifetime). The volume of the internal liquid continues to reduce, reaching a critical point where collapse of the structure occurs (~>90 % of overall lifetime).

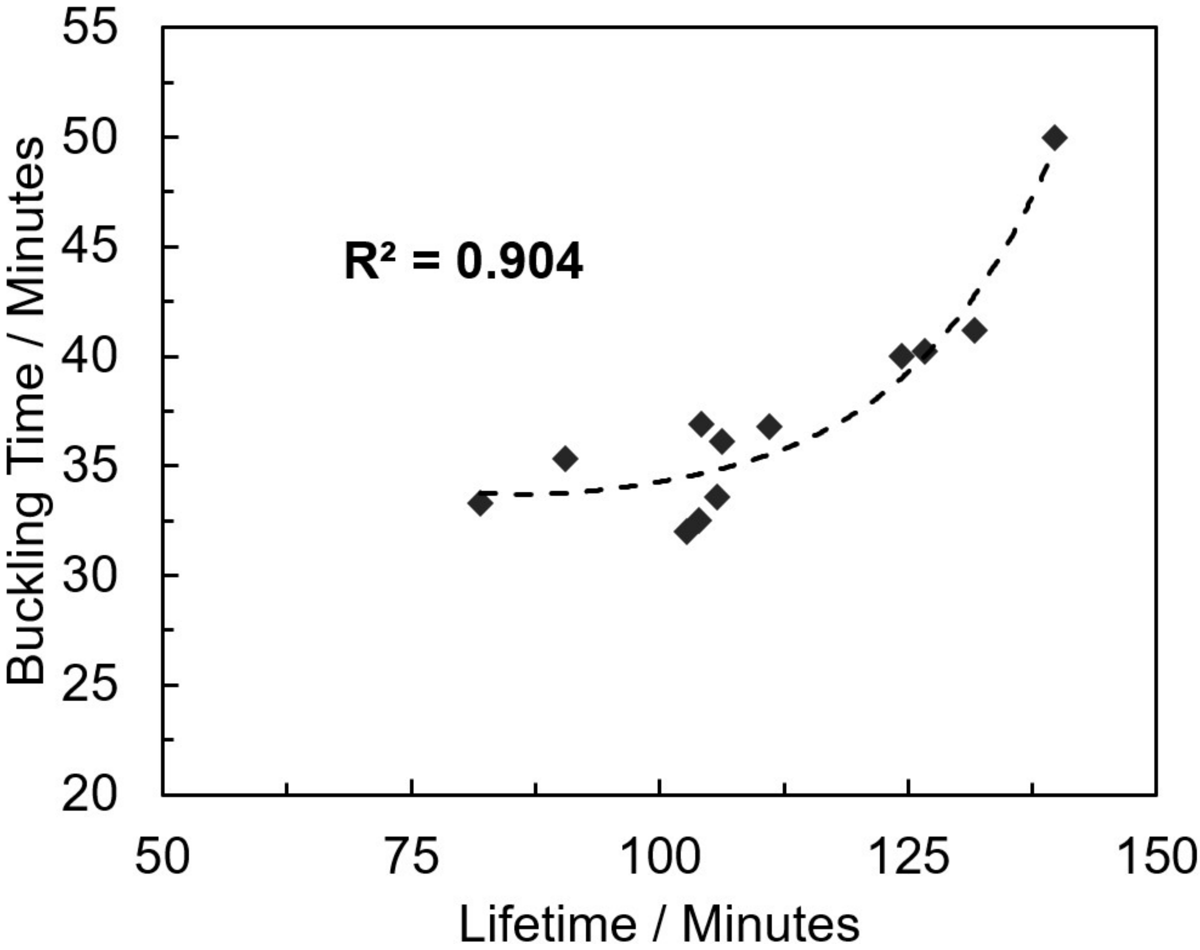
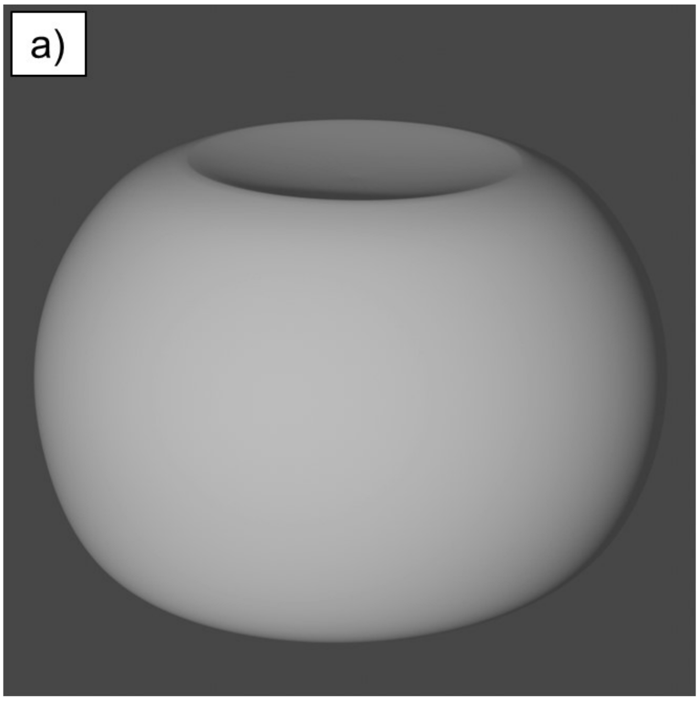
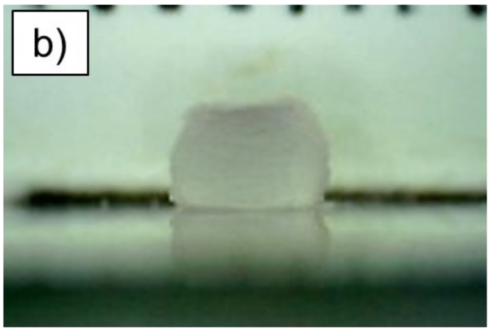



Figure S4: Relationship between the overall lifetime and the buckling time from Table S1, suggesting a quadratic relationship between the variables.




$$SD = \frac{d_v^3}{d_s^2}$$

$$d_s = \left(\frac{A_p}{\pi}\right)^{\frac{1}{2}} \quad d_v = \left(\frac{6V_p}{\pi}\right)^{\frac{1}{3}}$$

| LM Shape | Volume ($V_p$) / uL | Surface Area ($A_p$) / mm$^2$ | $A_p$:$V_p$ Ratio | Height / mm | Width / mm | Surface Diameter ($d_s$) / mm | Volume Diameter ($d_v$) / mm | Sauter Diameter (SD) / mm |
|---|---|---|---|---|---|---|---|---|
| Sphere | 10 | 22.4 | 2.24 | 1.34 | 1.34 | 2.67 | 2.67 | 2.67 |
| Buckle (Inset a and b) | 10 | 23.0 | 2.30 | 1.41 | 1.10 | 2.71 | 2.67 | 2.59 |
| Collapse (Ellipsoidal Puddle) | 10 | 35.9 | 3.59 | 2.25 | 0.38 | 3.38 | 2.67 | 1.66 |

Figure S5: Comparison of the surface areas (Ap) and volumes (Vp) of the LMs following shape change during evaporation. a) A typical example of the shape of a multilayer LM following buckling, this model allowed for the surface area of the buckles structure to be obtained and was formed using ImageJ's Surface Plotter, Blender and the side profile from b). The table then compares the 3 structures commonly seen during multilayer LM evaporation at the same volume to understand how variations in shape can impact the surface area available to evaporation. As can be seen, comparison in terms of the sphere and buckled LM show very similar surface areas, Ap:Vp ratios and Sauter Diameter. Suggesting that it can be assumed that the shape change from sphere to buckled sphere will have little impact on the rate of evaporation.