

Electronic Supplementary Information

Contactless Sensing of Liquid Marbles for Detection and Characterisation

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S1 Particle size measurement

The polyethylene (PE) and polytetrafluoroethylene (PTFE) powder was visualised using a FEI Quanta FEG 650 scanning electron microscope (SEM). SEM images were gathered using the Everhart-Thornley detector (ETD). The working distance was approximately 9 mm (specifics visible in individual images). The accelerating voltage was either 500 V or 5 kV (specifics visible in individual images). Example images are shown in figure S1.

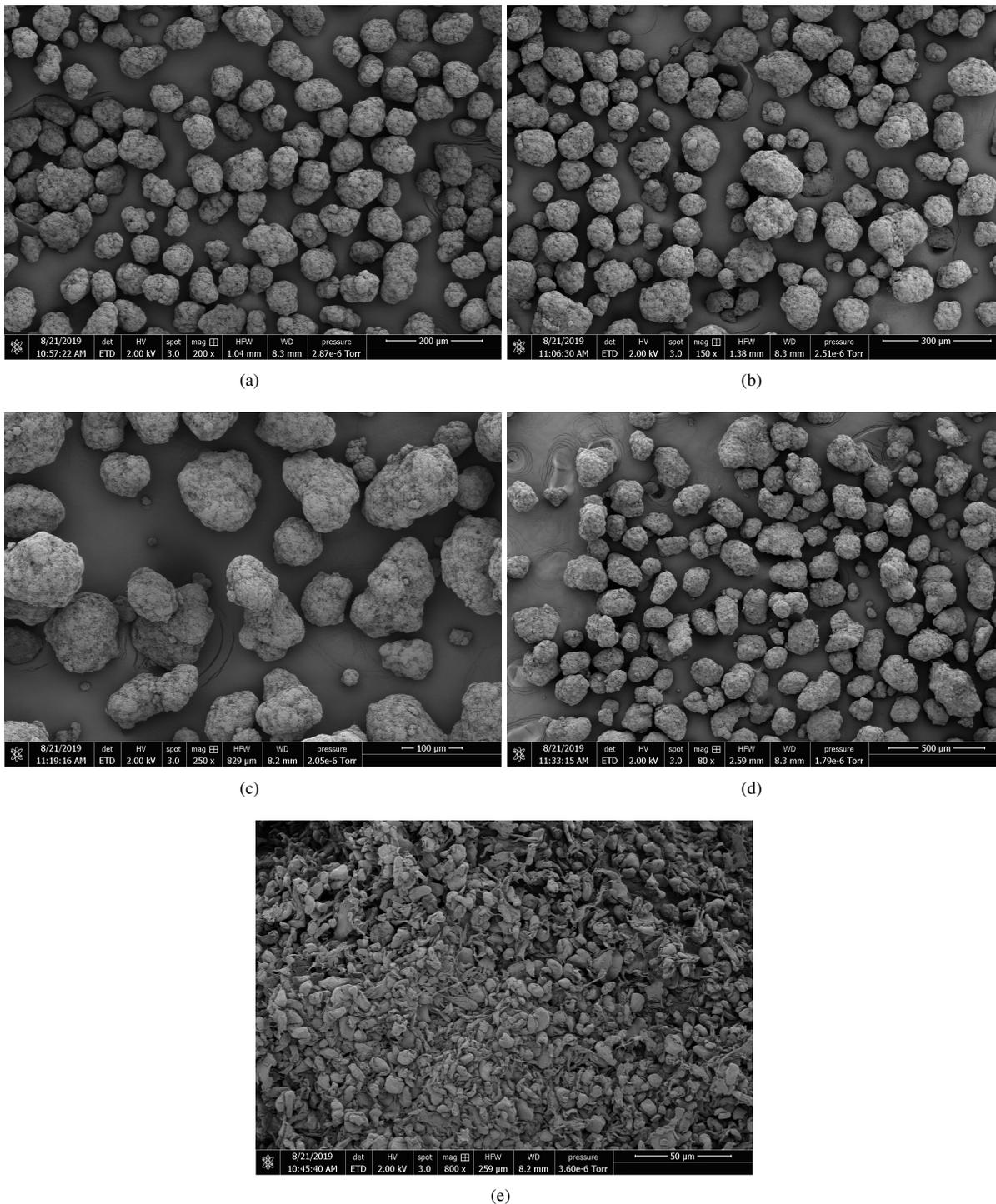


Figure S1: SEM images of the powders used to form liquid marbles. The powders are: (a) PE sieved as 63 μm to 90 μm , (b) PE sieved as 90 μm to 125 μm , (c) PE sieved as 125 μm to 180 μm , (d) PE sieved as 180 μm to 250 μm , and (e) PTFE powder. The scale bar is in the bottom right of each image. The accelerating voltage (HV), magnification (mag), and working distance (WD) can also be seen in each image.

S2 MatLab script for static data collection of liquid marbles

```
%Need to define and open serial connection on initial program run:
%s = serial('COM4'); fopen(s);

%%
clear plot;

total_its = 10; % How many measurements to make
avg_its = 20; %How many 'sub-measurements' each measurement is comprised of
A=zeros(avg_its,1); %Increase efficacy by predefining
plot=zeros(total_its,2); %Increase efficacy by predefining
total = 1;
tic;
while total <= total_its
    count = 1;
    while count <= avg_its
        fprintf(s,'meas:vamp?');
        out = fscanf(s);
        out = str2double(out);
        A(count,:) = out;
        count = count +1;
    end
    plot(total,1) = toc;
    m=mean(A);
    plot(total,2) = m;
    total = total + 1
end
csvwrite(sprintf('data/filename_%s.csv', datestr(now,'yyyy-mm-dd_HH-MM-SS')),plot)
clear total_its avg_its A total count out m;

%%
%When finished, close serial connection:
fclose(s); delete(s); clear s;
```

S3 MatLab script for dynamic measurements of mobile liquid marbles

```
z=100; %Number of splits/columns to make
csvfiles = dir('*.csv'); %Read in the files to be processed
for file = csvfiles'
    fprintf(1,'Now processing %s\n',file.name)
    filename = file.name; %Make a string of the full filename
    filename=erase(filename, '.csv'); %Make that said string loose the file extension
    waveform = csvread(file.name,1,0); %Load waveform
    s=waveform(:,1); %Signal only.

    while rem((length(s)/z),1)~=0 %Make s divisible by z
        s=[s;0];
    end

    VampFinal=zeros((round(length(waveform)/10)),1); %Predefine for speed
    VampRT = 0;
    s=reshape(s,[],z); %Split 1D array, s, into 2D array with z columns

    for i=[1:z]
        [pospkgs,postime] = findpeaks(s(:,i),'MinPeakProminence',0.01);
        [Tnegpkgs,negtime] = findpeaks(-s(:,i),'MinPeakProminence',0.01);
        negpkgs = -Tnegpkgs; %converts -ve peaks into actual -ve numbers
        postime=postime*10; %turn indicy number into timestamp, in ns.
        negtime=negtime*10; %turn indicy number into timestamp, in ns.
        while length(pospkgs) > length(negpkgs) %make arrays the same size
            pospkgs(1) = [];
            postime(1) = [];
        end
        while length(pospkgs) < length(negpkgs)
            negpkgs(1) = [];
            negtime(1) = [];
        end
        Vamp=pospkgs-negpkgs; %calculate difference in peaks, the signal amplitude
        VampFinal((VampRT+1):(VampRT+length(Vamp)),:)=Vamp;
        VampRT=VampRT+length(Vamp);
    end

    VampAv = movmean(VampFinal,25000,'Endpoints','discard'); %Moving average for smoothing
    postimems=[0:0.00001:(length(VampAv)-1)*0.00001]'; %times in ms

    figure,plot(postimems,VampAv,'k'), set(gcf, 'Color', 'w', 'Position', [150 150 750 600]),
    set(gca,'box','off', 'YMinorTick','on', 'xlim',[0 100], 'fontsize',12),
    xlabel('Time / ms', 'fontsize',15), ylabel('Signal amplitude / V', 'fontsize',15),
    ytickformat('%.3f')

    export_fig(filename, '-jpg', '-q95', '-r500') %export the figure as jpg

    fprintf(1,'%s finished.\n',file.name)
end
```

S4 Calculated values of impedance

Table S1: The impedance of the combined sensor and LM (Z_m) and of the LM in isolation (Z_{LM}), calculated from the voltage measured across the resistor (V_{ext}) and its standard deviation ($SD_{V_{ext}}$). Values are for varying thicknesses of powder coating, which have been plotted in the main paper. All tests used 30 μ L LMs with a saturated NaCl aqueous core. PE: polyethylene; PTFE: polytetrafluoroethylene.

Material	Thickness / μ m	V_{ext} / mV	$SD_{V_{ext}}$ / mV	Z_m / $k\Omega$	Z_{LM} / $M\Omega$
PE	250	307	1.3	641	29
PE	180	314	0.8	626	14
PE	125	316	0.8	623	13
PE	90	318	0.9	620	11
PTFE	10	321	1.0	612	9.3

Table S2: The impedance of the combined sensor and LM (Z_m) and of the LM in isolation (Z_{LM}), calculated from the voltage measured across the resistor (V_{ext}) and its standard deviation ($SD_{V_{ext}}$). Values are for a 30 μ L PTFE LM, with a core comprised of varying concentration of NaCl, which have been plotted in the main paper.

[NaCl] / wt%	V_{ext} / mV	$SD_{V_{ext}}$ / mV	Z_m / $k\Omega$	Z_{LM} / $M\Omega$
0	322	0.4	611	8.9
5	325	0.9	605	7.9
10	327	0.8	602	7.3
15	329	0.7	597	6.7
20	332	1.0	592	6.2
25	335	0.8	587	5.6

Table S3: The impedance of the combined sensor and LM (Z_m) and of the LM in isolation (Z_{LM}), calculated from the voltage measured across the resistor (V_{ext}) and its standard deviation ($SD_{V_{ext}}$). Values are for a PTFE LM with a saturated NaCl aqueous core, of varying volumes, which have been plotted in the main paper.

Volume / μL	V_{ext} / mV	$SD_{V_{ext}}$ / mV	Z_m / $k\Omega$	$Z_{LM}/M\Omega$
2.5	313	1.0	629	16
5	315	0.7	625	14
10	317	0.6	621	12
15	319	0.4	617	11
20	320	0.5	616	10
25	324	0.7	607	8.3
30	325	0.6	605	7.8
35	328	0.7	600	7.2
40	330	1.2	596	6.6
45	336	0.9	585	5.5
50	340	1.3	578	4.9
60	345	0.8	569	4.3
70	351	0.6	559	3.8
80	354	0.5	555	3.6
90	361	0.7	545	3.2
100	367	1.3	535	2.9

S5 Other supporting files

Included in the electronic supplementary information (ESI) are the CAD files for the 3D printed PCB holder (PCB_holder.stl) and the custom PCB (Sensor_grid_CAD.dxf).