Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supplementary Information

Low Cost Sponge Based Piezocapacitive Sensors Using Single Step Leavening Agent Mediated Autolysis Process

*Chithra Parameswaran and Dipti Gupta**

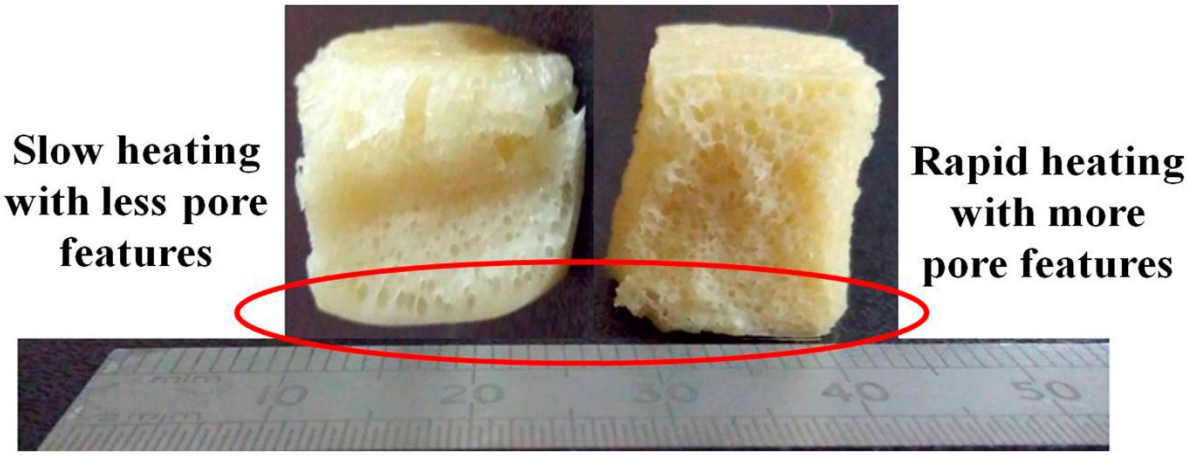
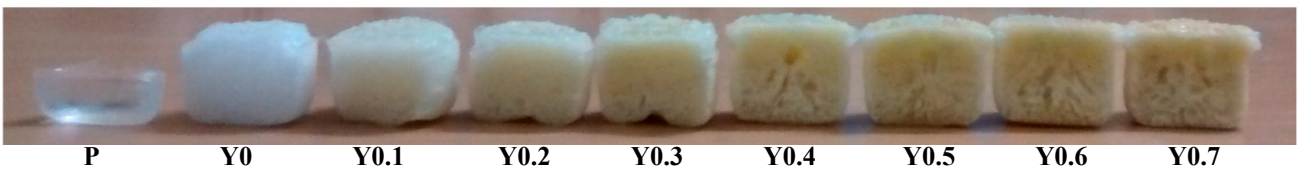


Fig. S1 Effect of heating on formation of pore features. The regions circled in red indicate formation of lumps rather pores upon slow heating.

Fig. S1 shows the photographs of sponges obtained at two heating conditions. When heated slowly, a lump of PDMS is formed at the bottom due to the collapsing of uncured PDMS from above into the pores forming due to effervescence during the heating time; under rapid heating fine pores are obtained throughout the sponge.

(i)



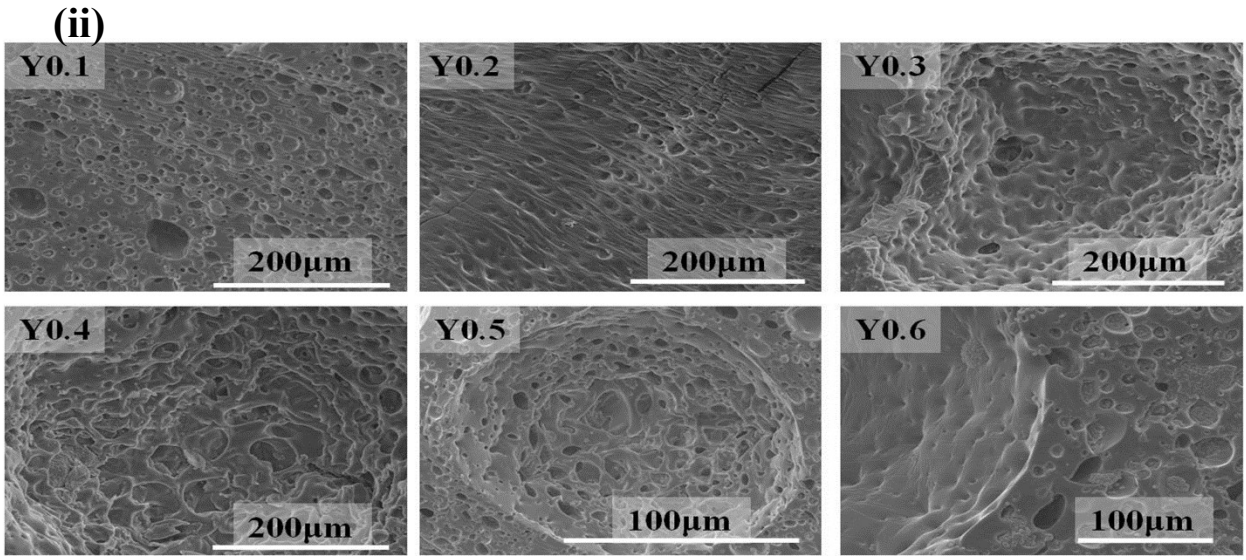


Fig. S2 (i) Optical photograph of obtained sponge. P refers to pure PDMS. Y samples refer to samples with yeast and the numerical value indicates its concentration in 3 mL DI water. (ii) SEM images of PDMS sponges with yeast concentration varied from (a) 0.1 g to (f) 0.6 g yeast in 3 mL DI water in steps of 0.1 g.

The effect of yeast concentration was studied using bare PDMS, without yeast and with increasing the concentration from 0.1 g to 0.7 g in 3 mL DI water. From Fig. S2(ii) it is observed that as the yeast concentration increases, small continuous porous structures are formed. This chain pore structure is possible only in the presence of yeast alone which facilitates the effervescence that is otherwise impossible. The dimensions of the sponges were measured using a digital vernier caliper and are tabulated in table ST1 below. It shows an increase in the height of the sponge with an increase in yeast concentration.

Sample name	Diameter (mm)	Height (mm)
PDMS	23.12	7.71
Y0	23.18	16.54
Y0.1	22.54	16.55
Y0.2	22.25	16.96
Y0.3	22.51	17.34
Y0.4	22.65	18.49
Y0.5	22.72	19.05

Y0.6	23.5	19.35
Y0.7	26.01	19.40

Table ST1: Quantitative description of effect of concentration of yeast

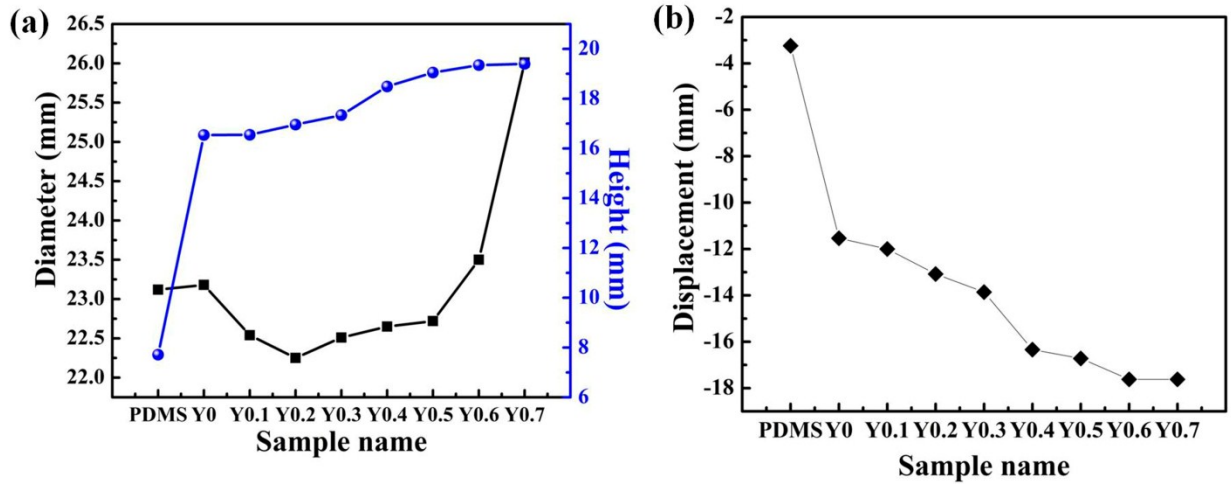


Fig. S3 Effect of yeast concentration on the sponge dimension. The diameter and height of the sponge show an increase with an increase in yeast concentration.

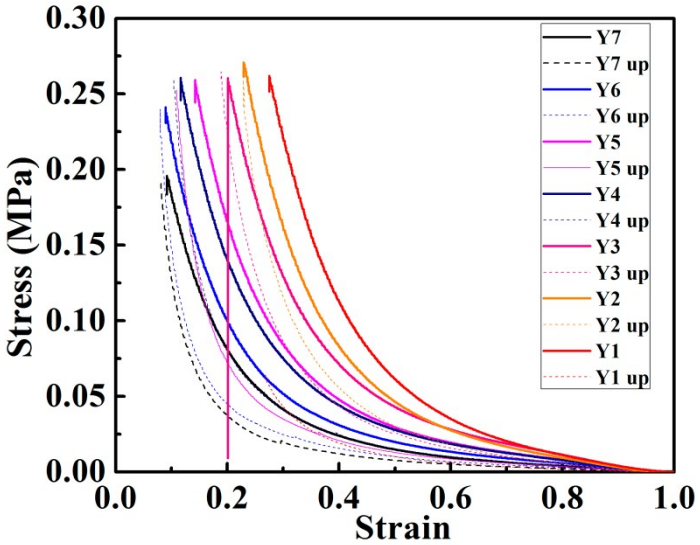


Fig. S4 (a) Force *vs* displacement curve for varied yeast loading. Y1 refers to 0.1 g yeast in 3 mL DI water, Y2 refers to 0.2 g yeast in 3 mL DI water and so on. (b) Displacement with applied pressure shows increase in stress that sponge can withstand. This increase in negative displacement by the sponge for increasing porosity facilitates equipping the increased load.

The sponges were studied for their compressibility using the MARK 10 tensile instrument with an upper limit of 210 N. The pores facilitate larger displacements possible referring to higher porosity upon load application. Fig. S4 shows the explicit saturation in force at 0.7 g/3 mL of yeast. The optimum yeast concentration of 0.7 g/3 mL is found to yield maximum compression. We further study the feasibility of the proposed approach in terms of its ability to scale up to large area and shape which is discussed in the section below.

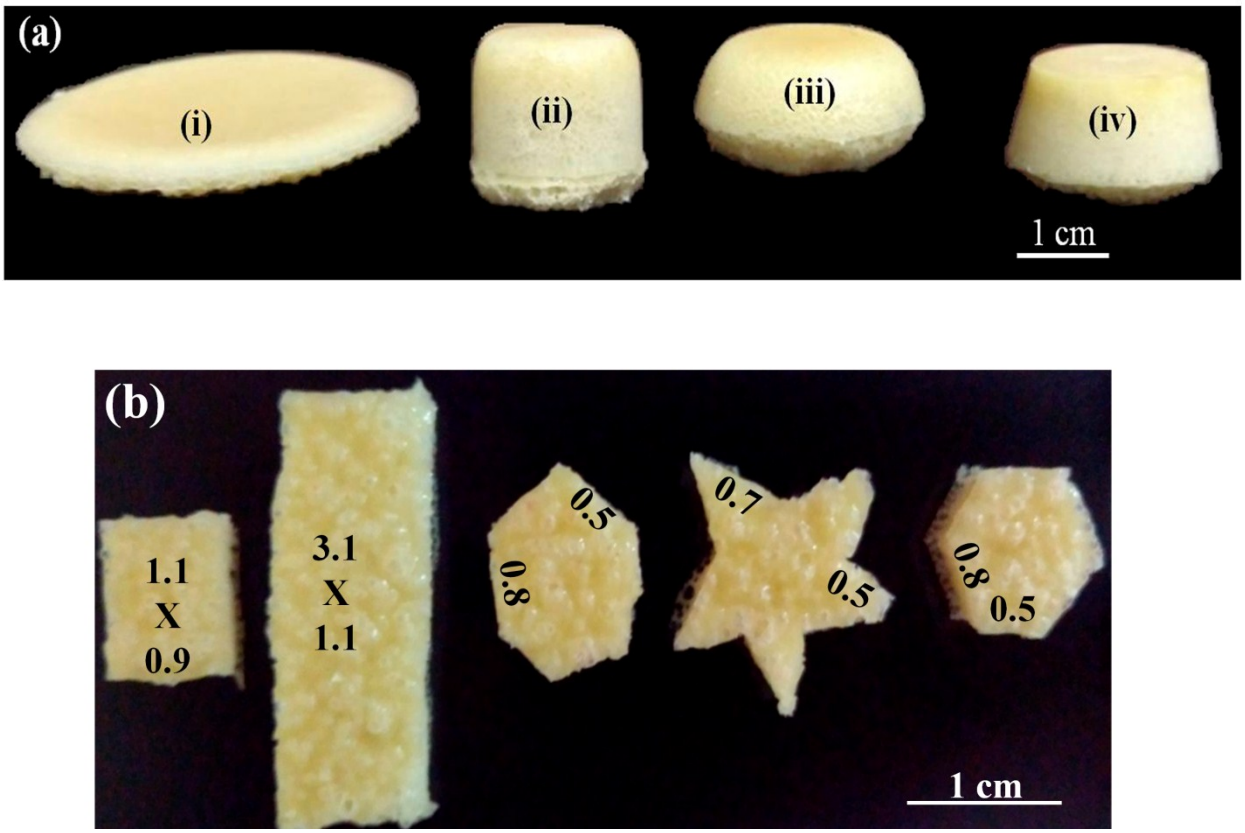


Fig. S5 (a) Sponges of different shapes and area. (b) Smaller shapes cut out from item (i) in (a).

To understand the effect of the substrate used for curing the PDMS mixture on the pore formation, we have used substrates of different dimensions such as base area and height. For this the amount of the PDMS mixture was kept constant. Fig. S5(a) shows sponges of PDMS

fabricated in varied shapes and heights. For all items (i) to (iv) 3 g of elastomer was taken in the desired container. Item (i) has dimensions of base diameter 60 mm and was obtained in an open flat vessel with depth ~ 3 mm. Item (ii) has a cylindrical structure with height of 18 mm and base diameter 20 mm. Item (iii) was synthesized in a vessel of base diameter 25 mm and height 15 mm with a widened neck. This shape of the vessel leaves its replica on the obtained sponge. Item (iv) had a tapered bottom of diameter 25 mm. The vessel had an actual height of 35 mm. However, the elastomer leavened to the height of 15 mm only as the volume of the mixture was kept constant for all shapes shown in Fig. S5(a) and was less as compared to volume of the vessel. The side view of the sponges as seen in Fig. S5(a) of varied heights and shapes further emphasize the possibilities that can be achieved from this method. Fig. S5(b) shows sponges which were cut out from the circular flat sponge (Item (i) in Fig. S5(a)), whose dimensions are mentioned there in. It is also seen that sponges of any size and shape can be obtained from the method outlined above, making the method to stand out amongst the existing approaches; without requiring customized molds. Features of any complicacy can also be obtained and the scalability is huge for the proposed approach.

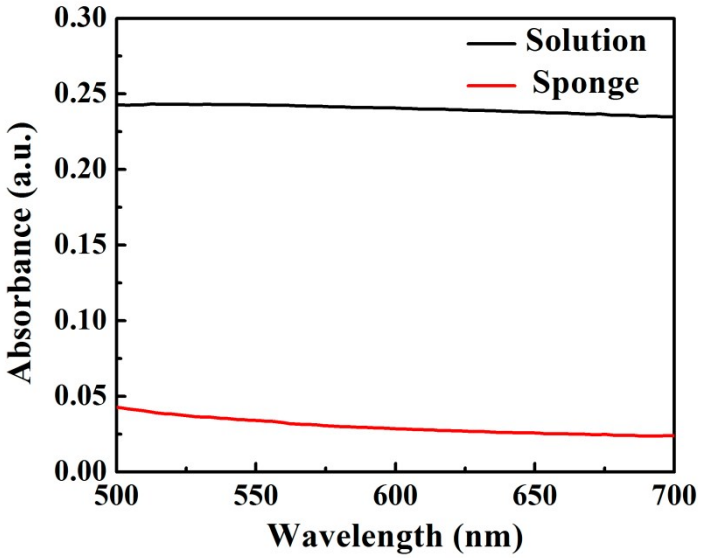


Fig. S6 Absorbance spectra of yeast solution and sponge showing autolysis with little absorbance at 660 nm for the sponge.

Fig. S6 shows the absorbance spectra of alive and dead yeast cells. The solution has alive cells showing good absorbance at 660 nm. The sponge when formed via the rapid heating process causes autolysis of the cell leading to cell death which gets reflected in the absorbance spectrum as a decline in absorbance. This decline in absorbance also advocates the FTIR response which leads us to the proposed mechanism of the single step approach.

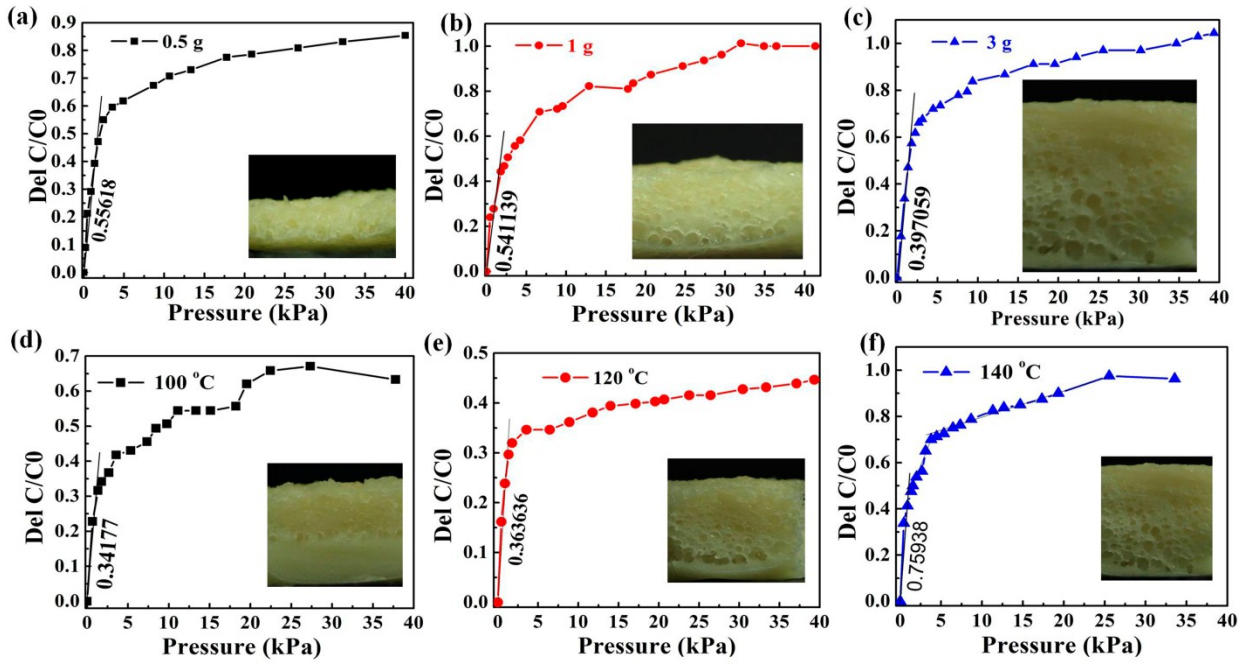


Fig. S7 (a) – (c) Sensitivity calculation for different quantities of PDMS with inset showing the photographs of the corresponding sponges obtained. (d)-(f) Sensitivity calculation for different curing temperatures with inset showing the photographs of corresponding sponges.

Fig. S7 shows the sensitivity calculation and photographs of sponges thus obtained for the precursor quantity varied and temperature varied study. As seen in Fig. S7(a)-(c), as the quantity of precursor increases the sponge height increases. The pore profile as seen in the inset has more uniformity in the 0.5 g sponge and less in the 3 g sponge. In 3 g sponge, as the heating proceeds, PDMS gets cured; however at the top, lesser pores are formed due to less heat available for rapid heating which causes uncured elastomer to collapse and form lumps rather than pores. As the quantity increases, the effervescence formed can be accommodated in the PDMS which leads to bigger pores in it, where as for lesser elastomer quantity, it pops out in air and so small pores alone are accommodated. For change in temperature, at 100 °C it took 40 min for complete curing of the mixture. Also as seen from inset in Fig. S7(d) the lower portion has little pores compared to the upper part. This can be attributed to the slow curing due to less temperature,

resulting in the collapse of uncured PDMS from above into the pore formed at the bottom hence covering it up. At both 120 °C and 140 °C, the mixture got cured in 20 min each. However, the sponge formed at 140 °C leavened higher compared to that at 120 °C. This can be due to the faster curing of the elastomer that can trap bigger pores as the effervescence escapes through the uncured mixture which otherwise forms a lump when the heat is insufficient for rapid curing.

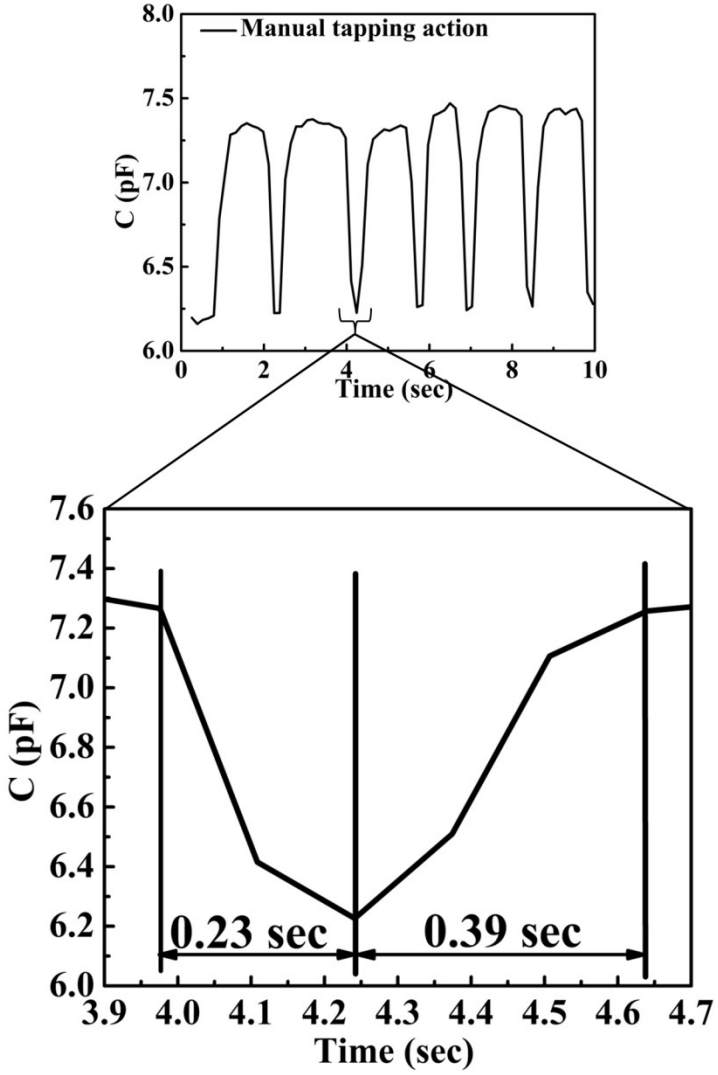


Fig. S8 Response time for rise and fall in tapping on the pressure sensor

The time response of pressure application and release is measured and found to be precise for each tap.