Supporting Information for: Towards Precisely Controllable Acoustic Response of Shell-Stabilized Nanobubbles: High-Yield and Narrow-Dispersity

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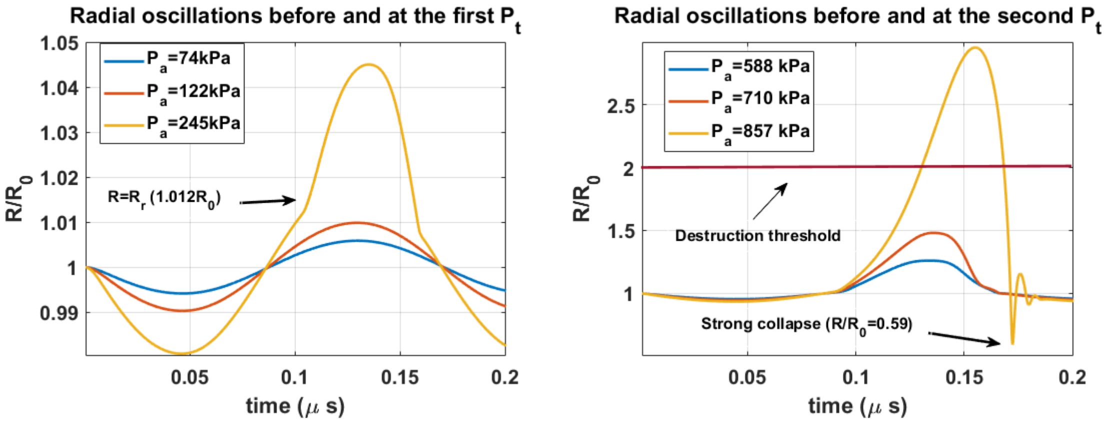
Examination of the radial oscillations before and at the pressure threshold of signal enhancement

Figure 1 shows the radial oscillations as a function of time for the Flexible NB in Fig. 11a. For pressure amplitudes below the first P_t, the radial oscillation amplitudes are small. The maximum oscillation amplitude is below $R_r = 1.012R_0$. When $P_a = P_t$, radial oscillations grow above R_r and as soon as the shell ruptures (marked in Fig. 1a), the rate of the growth of radial oscillations increases and the bubble expands very fast. This is the point where the first signal enhancement shown in Figs.

5a, 6a and 11a occur. In the collapse phase the bubble collapses rapidly but the speed of collapse decreases significantly after the radial oscillation is less than R_r; this is due the fact that the shell reseals and resists the fast collapse. At the higher pressure of $P_a = 857kPa$ a second enhancement occurs (Figs. 5a, 6a and 11a). In Fig. 5a, a loss of echogenicity takes place for $P_a \geq 857kPa$. The radial oscillations in Fig. 1b show that the maximum oscillation amplitude increases beyond the minimum reported threshold of bubble destruction ($R/R_0 = 2^{1,2}$). This threshold is marked in Fig. 1b. In the collapse phase, due to the higher wall velocities (compared to the first P_t) the shell resistance after reseal is not strong enough to withstand the fast wall velocity, thus the NB collapses to a size close to half of its initial size and thus it is likely to undergo fragmentation. This can be one possible reason for the loss of echogenicty seen in Fig. 5a for pressures more than 857kPa. Moreover, since NB destruction is not modeled in the simulations, this can be a possible reason for the discrepancy between the simulations and measurements above the second P_t (Fig. 11c). One discrepancy is seen in the peak of the slope graph at the 2nd P_t in Fig. 11e. The next discrepancy occurs in the amplitude graph (Fig. 13a) above the second P_t. When the experimental amplitude graphs (Figs. 6a-c) are examined, the maximum enhancements are 36, 37.5 and 34.5 dB for flexible, intermediate and stiff NBs respectively. In the case of the flexible NBs, the maximum enhancement takes place at $P_t = 857kPa$, beyond which the enhancement decreases slightly with increasing pressure. In the case of intermediate and stiff NBs the maximum occurs at the highest examined pressure of 1249 kPa. Examining the 2nd harmonic amplitude in Figs. 11a-c, shows that this trend does not hold above the second pressure threshold of 857 kPa in the case of the flexible NBs. The maximum 2nd harmonic amplitude for intermediate and stiff NBs are -30 and -41 dB respectively. The maximum 2nd harmonic amplitude for the flexible NB is -32 dB right after the 2nd P_t which shows a good agreement between trend observed in experiments and numerical simulations. However, beyond this point the trend does not hold and numerical simulations predict a constant growth in the 2nd SuH amplitude which at $P_a = 1249kPa$ reaches to -7 dB. This discrepancy beyond the second P_t may be another indicator that the NBs undergo destruction which was not taken into account in the simulations.



(a) (b)

Figure 1: simulated radius *versus* time for the case of the flexible NB for: (a) radial oscillations before and at the first $P_t = 245kPa$ and (b) radial oscillations before and at the second $P_t = 857kPa$.

References

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