Thermal effects in the collapse of a cavitation bubble

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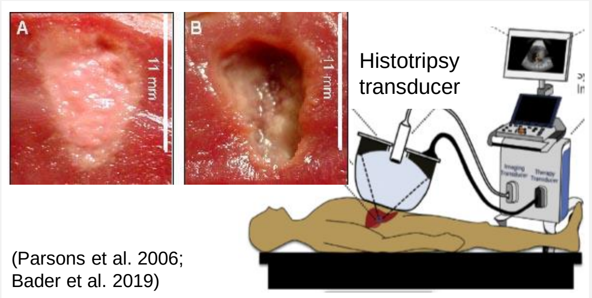
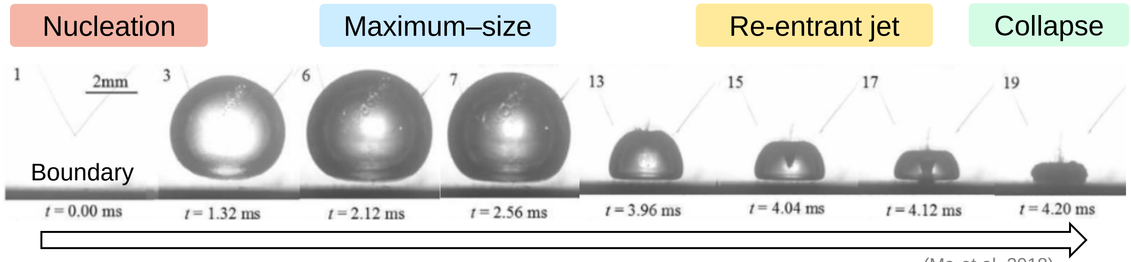
Ablate the cancer cells in tissue



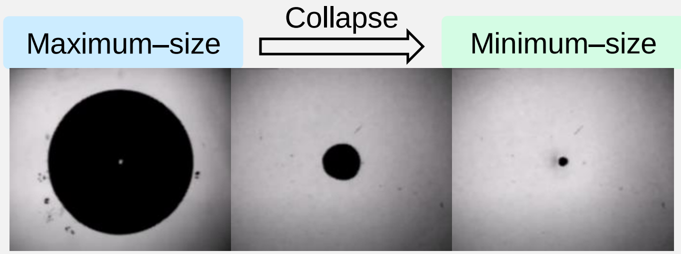
(Parsons et al. 2006; Bader et al. 2019)

Life of a cavitation bubble



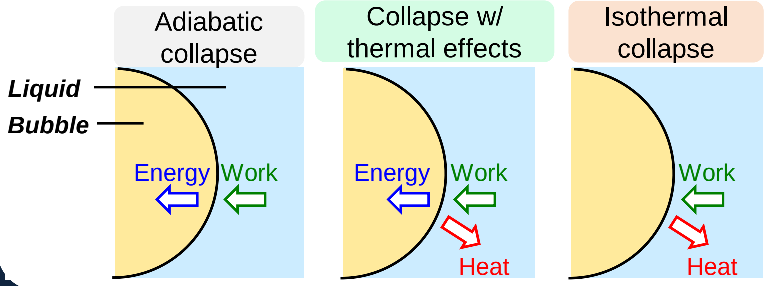
(Ma et al. 2018)

Implosion process



(Supponen et al. 2016)

Thermal effects in the collapse of a spherical gas bubble



Gas bubble Fourier number

Thermal penetration length

$$Fo_h = \left[\frac{(\alpha_{th} t_c)^{1/2}}{R_o}\right]^2$$

Initial bubble radius

Adiabatic: $(\alpha_{th} t_c)^{1/2} \ll R_o$

Isothermal: $(\alpha_{th} t_c)^{1/2} \gg R_o$

Methods: Equations of motion

Bubble–wall motion: Keller–Miksis equation

$$R\ddot{R}\left(1-\frac{\dot{R}}{a_l}\right)+\frac{3}{2}\dot{R}^2\left(1-\frac{\dot{R}}{3a_l}\right)=\left[\frac{p_b(R)-p_l}{\rho_l}\right]\left(1+\frac{\dot{R}}{a_l}\right)+\frac{R}{a_l}\frac{d}{dt}\left[\frac{p_b(R)-p_l}{\rho_l}\right]$$

Thermal E equation for liquid

$$\frac{\partial T_l}{\partial t}+\left(\frac{R^2\dot{R}}{r^2}\right)\frac{\partial T_l}{\partial r}=\frac{K_l}{\rho_l c_{p,l}}\nabla^2 T_l$$

Gas pressure inside the bubble

$$\dot{p}_b=-3kp\frac{\dot{R}}{R}+\frac{3(k-1)}{R}K_b\left.\frac{\partial T}{\partial r}\right|_w$$

Polytropic — Heat conduction

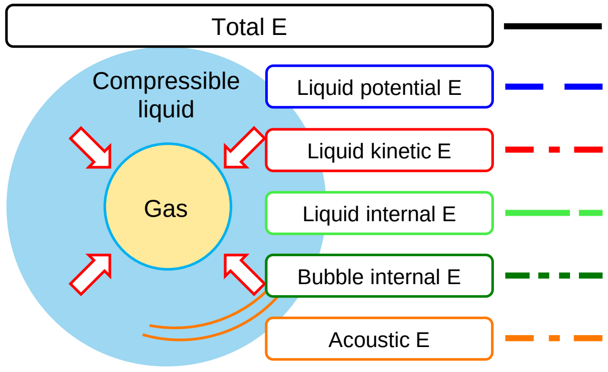
Thermal E equation for gas

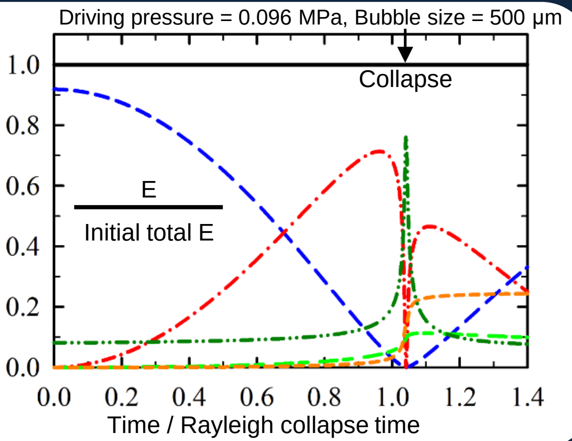
$$\frac{dT_b}{dt}=\frac{\dot{p}_b}{\rho_b c_{p,b}}+\frac{K_b}{\rho_b c_{p,b}}\nabla\cdot(\nabla T_b)$$

Assumptions

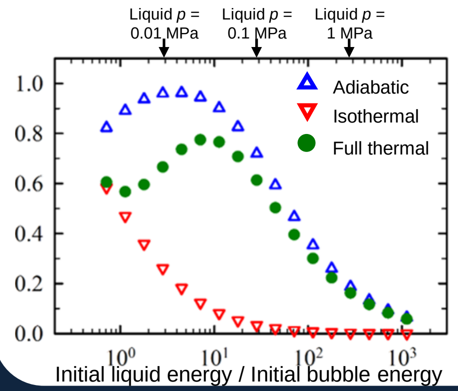
- Homogeneous gas pressure inside a bubble
- Thermodynamic properties of liquid is constant

Time evolution of energy modes





Bubble internal E at collapse



Gas bubble Fourier
Bubble – wall Mach

Bubble–wall Mach number — Reference velocity

$$Ma_b=\frac{(p_{l,o}/\rho_l)^{1/2}}{a_l}$$

Speed of sound