Electronic Supplementary Information:
Thermally driven bubble evolution at a heater wire in water characterized by high-speed transmission electron microscopy

John R. Vance†, Shen J. Dillon†

† Department of Materials Science and Engineering, University of Illinois at Urbana-Champaign, 1304 W. Green St., Urbana, IL 61801, USA.

Thermodynamic modeling:
The vapor pressures of 1 mM dissolved O₂, N₂, and H₂ as functions of temperature are shown in Fig. S5. These were calculated using a Henry’s law treatment. Temperature dependent Henry’s law coefficients were calculated from data in [¹] with the van ‘t Hoff equation:

\[
\frac{d \ln H}{d (1/T)} = \frac{-\Delta H_{sol}}{R},
\]

where \( H \) is the Henry solubility (dissolved concentration/vapor pressure), \( T \) is temperature, \( R \) is the gas constant, and \(-\Delta H_{sol}\) is the enthalpy of dissolution. The vapor pressure of water as a function of temperature was calculated using the Antoine equation:

\[
\log(p) = a - \left(\frac{b}{T - c}\right),
\]

where \( a, b, \) and \( c \) are parameters extracted from [²].

References:

Supplementary Video:
Video S1 shows the first 125 ms of bubble evolution in experiments A-E, at heater wire voltages of 0.10, 0.50, and 1.00 V (speed = 1/80 * real time).
Supplementary Figures:

(a) Low magnification scanning electron micrograph of SiN$_x$ window chip prior to heater wire deposition, (b) scanning electron micrograph of SiN$_x$ window with heater wire and electrical traces. The heater wire is powered by applying a voltage across the two outer traces; the middle trace is not biased. The sample is tilted at 45° to show the relative topography.
Fig. S2: Schematic of the employed experimental setup and electron beam path. The liquid layer thickness is ~500-1000 nm.
Fig. S3: (a) Transmission electron micrograph showing defects in the middle Pt trace, (b) image sequence, 2.5 ms apart, showing heater wire destruction and subsequent bubble nucleation at large heater power.
Fig. S4: Steady state temperature profile of the window (bottom view) with heater wire (modeled in COMSOL), voltage = 0.10 V, and liquid layer thickness of 750 nm, assuming thermal conductivities in water and SiN$_x$ of 0.6 and 2.0 W m$^{-1}$ K$^{-1}$ [3], and no electrical resistance in the middle Pt trace. Inset shows a merged transmission electron micrograph of the experimental system with overlaid temperature profile.
Fig. S5: Partial pressure of dissolved 1 mM H$_2$, O$_2$, and N$_2$ using a Henry’s Law treatment and saturated water vapor vs. temperature.
Fig. S6: (a) Image series showing Ostwald ripening and subsequent bubble collapse in experiment C, (b) the diameters of the two bubbles with time.