Characterization of Acoustic Cavitation in Surfactant Containing Aqueous Solutions

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Megasonic irradiation – Commonly used for particle removal in integrated circuit industry

Use of surfactant assists in achieving higher cleaning efficiency

Limited literature available on characterization of acoustic cavitation in solutions containing surfactant

Proper understanding of the effect of surfactant on the bubble behavior will enable development of damage-free and efficient cleaning processes for the semiconductor industry
Key Objective and Approach

**Key Objective:**
- Characterize cavitation/bubble behavior for solutions containing different concentrations of surfactants (Triton® X-100 and NCW® - 1002) at two different sound field frequencies (~ 0.7 and 1 MHz) and varying power densities

**Approach:**
- Fluorometric technique based on complexation of OH• by terephthalic acid
- Pressure measurements using a hydrophone
- Microelectrode based chronoamperometric investigations
- Sonoluminescence study using Cavitation Threshold Cell®

**Surfactants:**
- Triton® X-100: polyoxyethylene alcohol based surfactant
- NCW® - 1002: polyoxyalkylene alkyl ether
Hydroxyl radical trapped using terephthalic acid to form 2-hydroxyterephthalic acid, measured using fluorescence spectroscopy.

- 2-hydroxyterephthalic acid is stable up to 6 hours at room temperature.

Excitation at 318 nm

Emission at 425 nm
Effect of Addition of Triton® X-100 on Rate of Generation of OH•

Decrease in generation rate of OH• with addition of Triton® X-100 at two different power densities.
Hydrophone Set-up

Processed data shows peaks at fundamental frequency of 1 MHz and also at harmonics, sub-harmonics and ultraharmonics.

Integral under the peaks used to characterize the intensity of stable cavitation.
Quantification of Transient Cavitation

Integral under the broadband signal used for calculation of pressure due to transient cavitation
Effect of Triton® X-100 on Transient Cavitation Pressure in Solutions Subjected to 1 MHz (8 W/cm²)

- Transient cavitation pressure suppressed in the presence of surfactant
- No effect of surfactant concentration on transient cavitation pressure

CMC: 12E-3 – 16E-3% at 25 °C
Effect of Triton® X-100 on Transient Cavitation Pressure in Solutions Subjected to 0.7 MHz (8 W/cm²)

- Transient cavitation pressure significantly reduced after adding Triton® X-100
- No effect of surfactant concentration on transient cavitation pressure

CMC: 12E-3 – 16E-3% at 25 °C
Electrochemical Sensor Set-up

Glass holder

To potentiostat (Gamry)

Glass enclosure for Pt electrodes

Electrodes immersed in Megasonic tank filled with solution

0.5 mm Pt wires as reference and counter electrodes (1 cm protruding out of the glass enclosure)

I\textsubscript{mon} and E\textsubscript{mon} of Potentiostat to Oscilloscope (sampling rate ~4 MS/sec)

To computer for measurements using Labview (NI)

25 μm diameter Pt working electrode (WE) (only flat surface exposed to solution) at an applied potential of -0.6 V (Vs Pt reference)

K\textsubscript{3}[Fe(CN)\textsubscript{6}] was used in solution as a chemical probe
Investigations of Transient Cavitation in Solutions Containing Triton® X-100

The magnitude of current peaks corresponding to transient cavitation intensity is lower in the presence of Triton® X-100.
CT-cell Set-up

Cavitation Threshold (CT) Cell (ProSys®)

CT Cell Details

- **Volume** = 163 cc, **Length** = 10.4 cm
- **Internal Diameter** = 4.8 cm
- **Sonic Frequency** = 0.925 MHz
- **PMT Wavelength Range** = 280 to 630 nm
- **Power Density Range** = 0.1 to 4 W/cm²
Sonoluminescence Studies on the Effect of Triton® X-100

- Increase in Triton® X-100 concentration decreases transient cavitation when below CMC
- No further decrease in transient cavitation achieved above CMC
Effect of NCW® - 1002 concentration similar to that of Triton® X-100.
We have successfully characterized transient cavitation in aqueous solutions with and without surfactants using Hydrophone, Microelectrode and CT Cell based techniques.

All studies indicated that transient cavitation decreased in the presence of surfactants (Triton® X-100 and NCW® - 1002).

Hydrophone studies showed that Triton® X-100 concentration did not affect transient cavitation pressure.

CT cell measurements revealed that Triton® X-100 and NCW® - 1002 concentration affected sonoluminescence intensity below CMC but did not have any effect above CMC.
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