Investigations of Acoustic Cavitation in Aqueous Surfactant Solutions for Cleaning Applications

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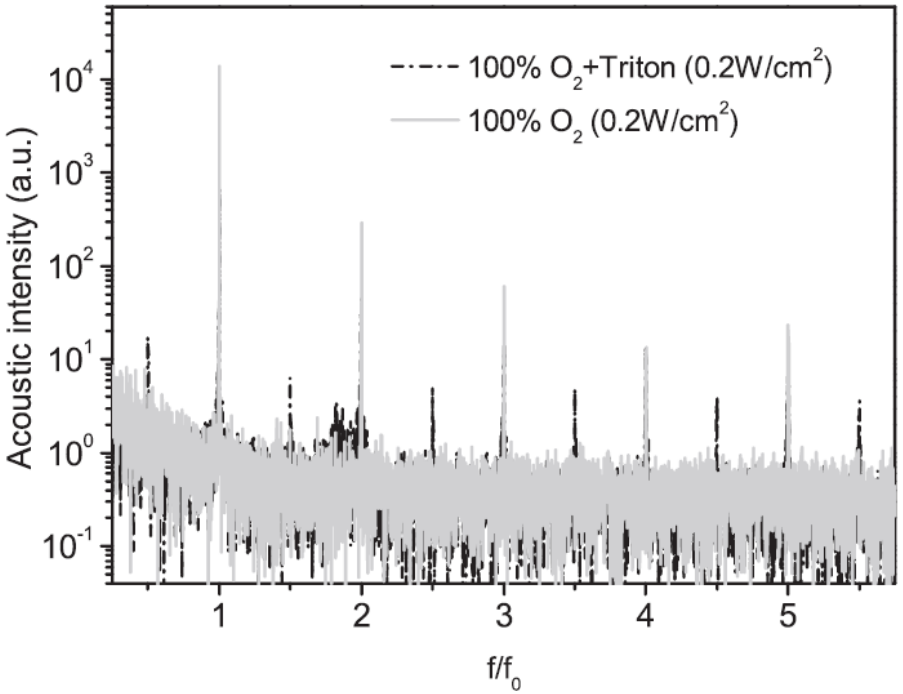
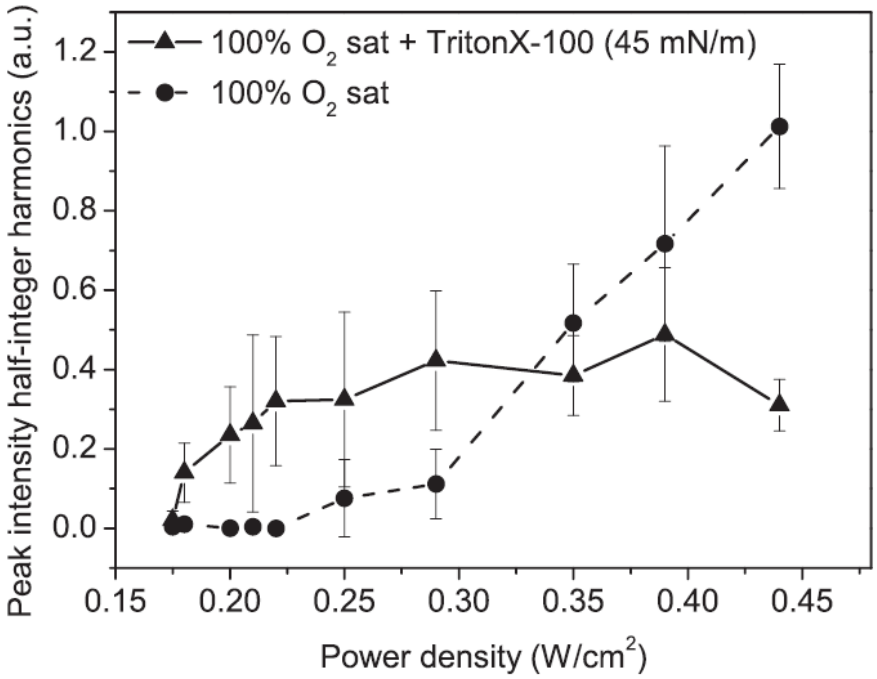
Introduction

- **Megasonic irradiation – Commonly used for particle removal in integrated circuit industry**
- **Use of surfactant assists in achieving higher cleaning efficiency and minimizing feature damage**
- **Limited literature available on characterization of acoustic cavitation in solutions containing surfactants**
- **Proper understanding of the effect of surfactant on the bubble behavior will enable development of damage-free and effective cleaning processes for the semiconductor industry**

Effect of Surface Tension on Cavitation Behavior in Ultrasound Fields



Sound emission spectra of Triton X-100 solution and ultrapure water (UPW) for 100% O_2 saturation and 0.2 W/cm^2 applied power density. Frequency = 928 kHz.

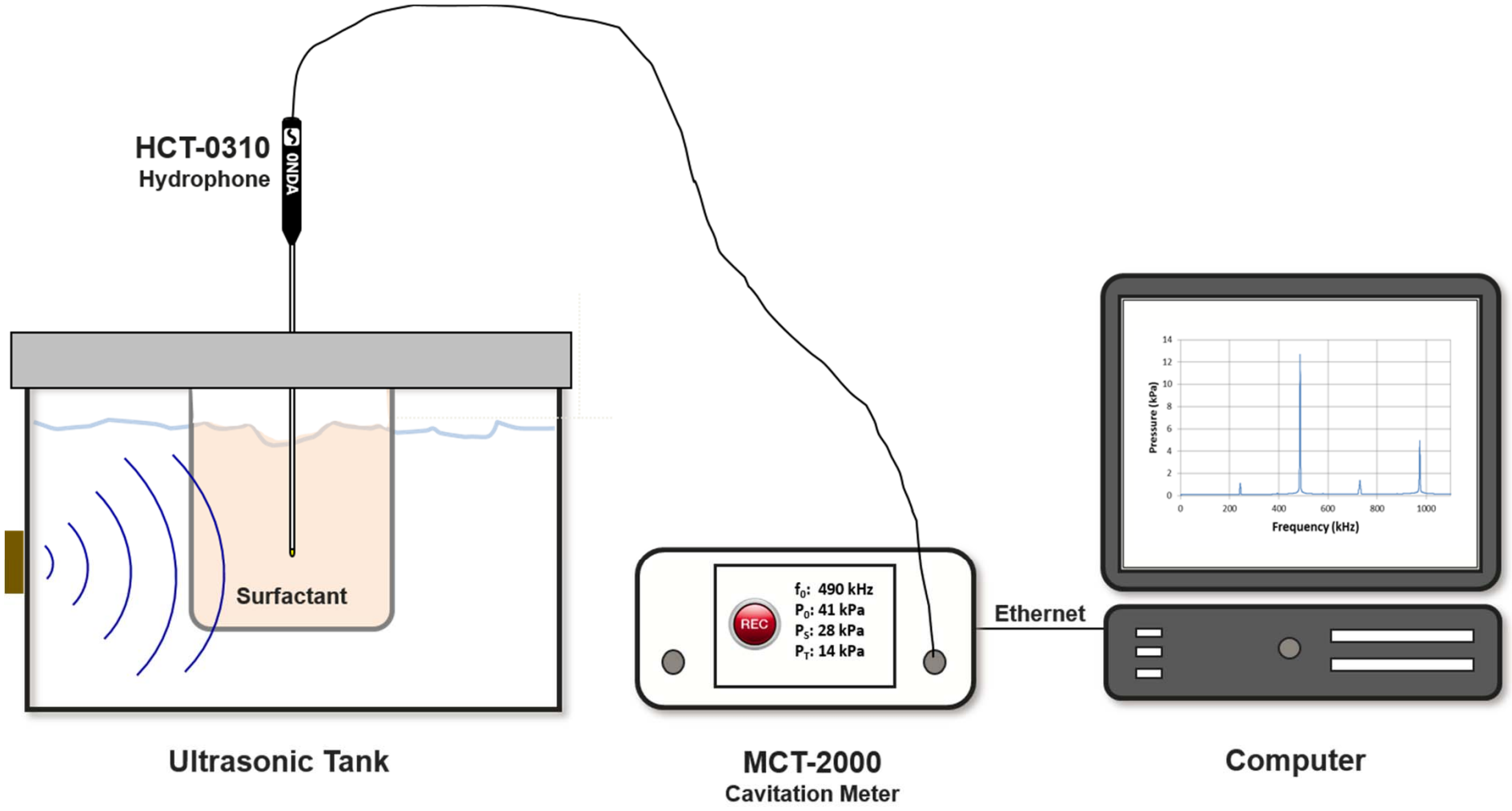


Integrated ultra-harmonics of a Triton X-100 solution (3.2E-3%) and UPW for 100% O_2 saturation and different applied power densities.

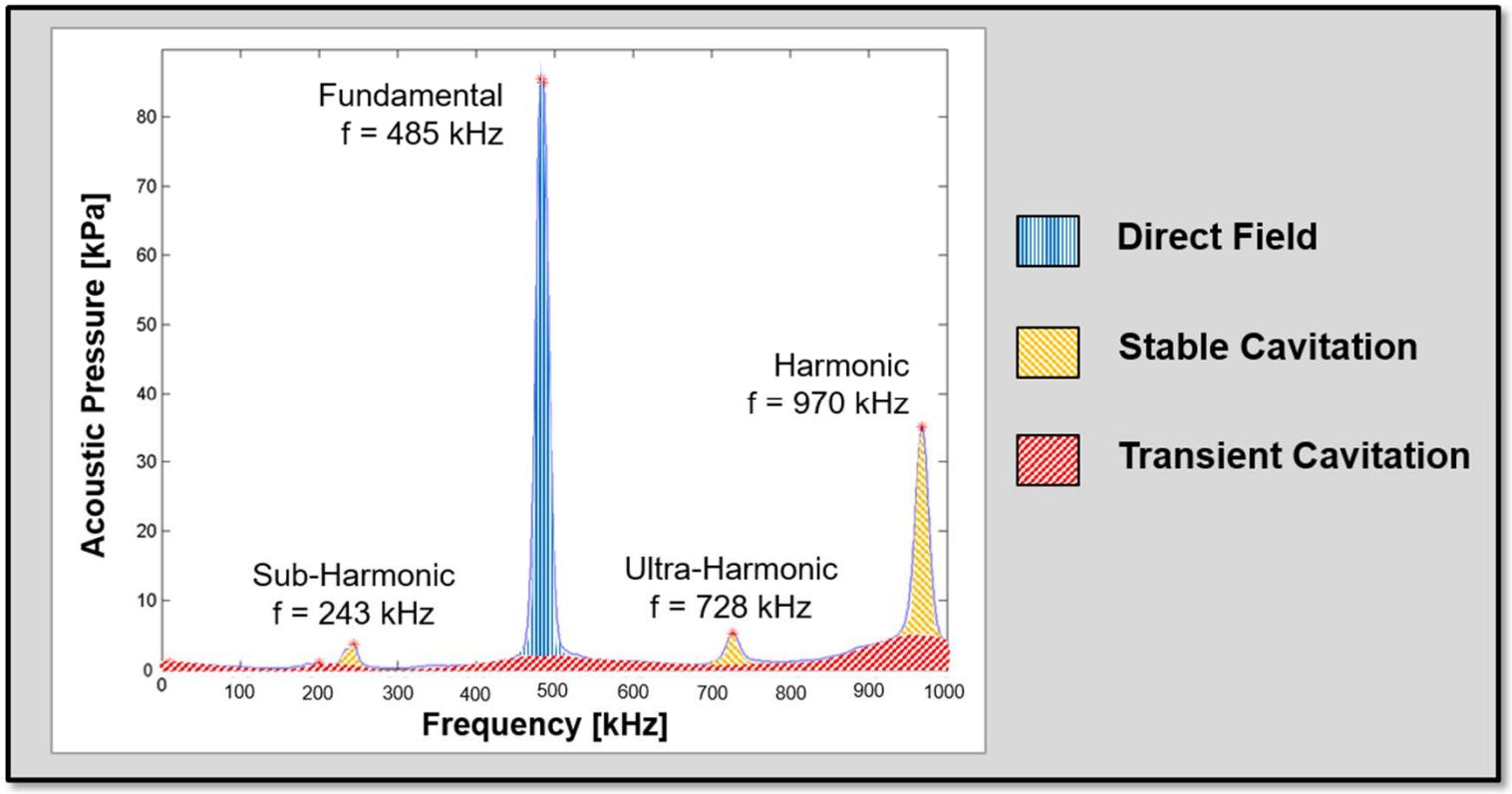
- ***Sound emission spectra was obtained from hydrophone measurements***
- ***Ultraharmonics (1.5, 2.5, 3.5…) are present in the Triton solution while completely missing in UPW***
- ***Bubble activity is highly enhanced at a lower acoustic power for a lower surface tension***

T. Leong, S. Wu, S. Kentish and M. Ashokkumar, *J. Phys. Chem. C* 114, 20141-20145 (2010).

Hydrophone Set-up



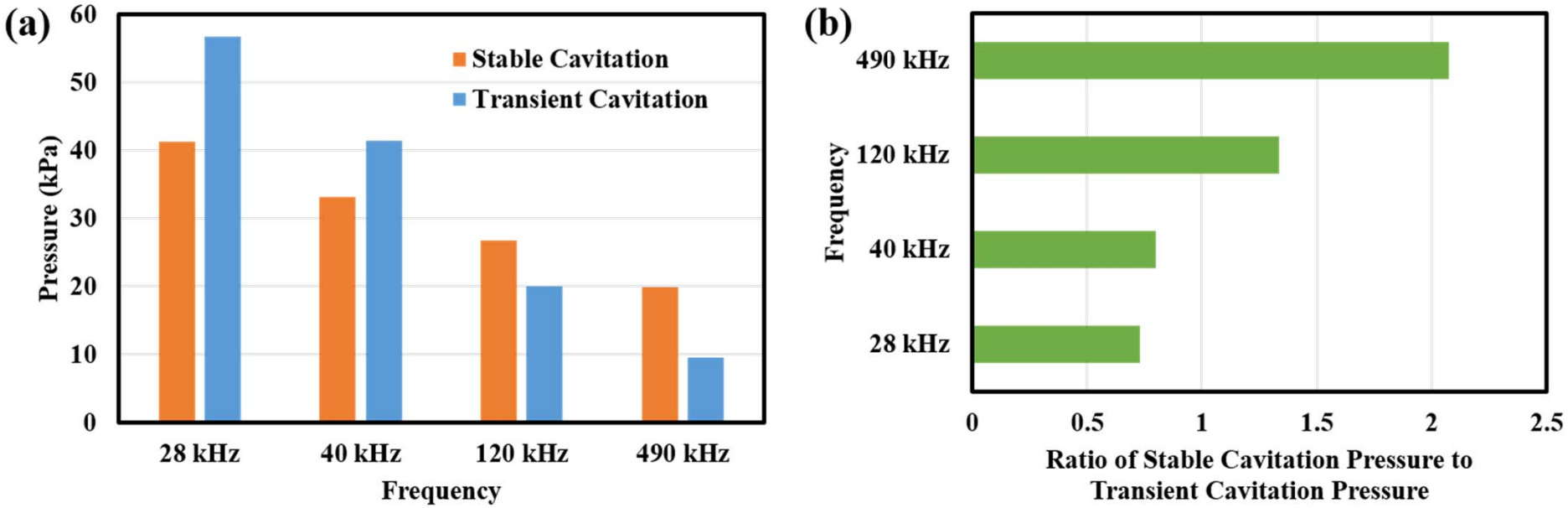
Quantification of Stable and Transient Cavitation Pressure



Different pressure components contribute to cleaning and damage

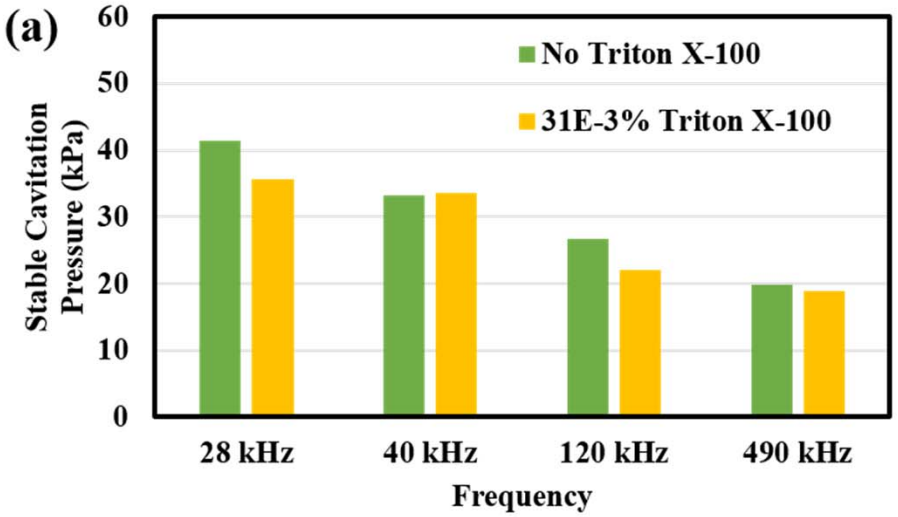
Stable and Transient Cavitation Pressure as a Function of Acoustic Frequency at Power Density of 4 W/cm^2

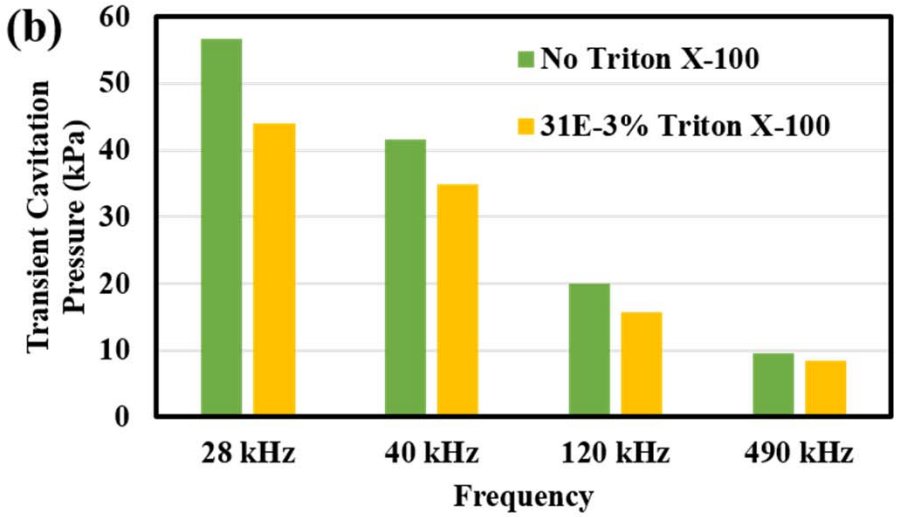
Air sat. deionized water

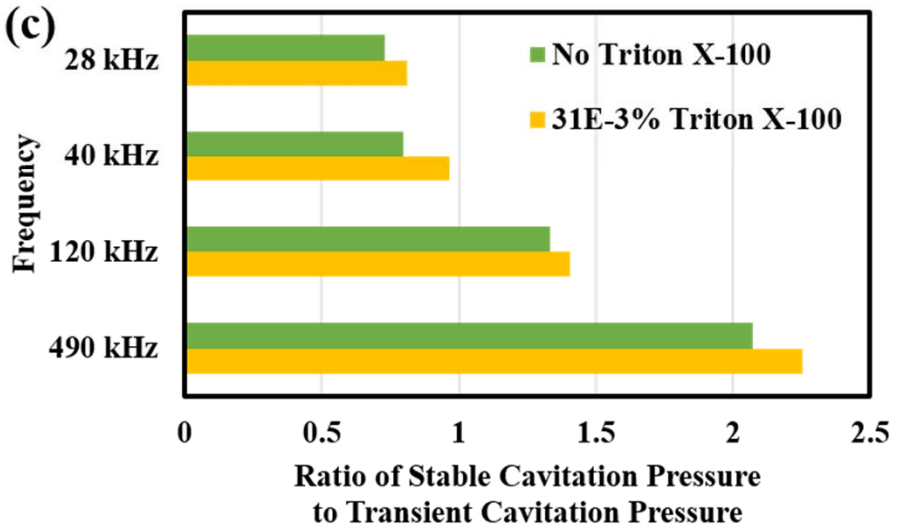


- ***Both stable and transient cavitation pressure generally decreased as frequency increased from 28 to 490 kHz***
- ***Ratio of stable cavitation pressure to transient cavitation pressure increased from 0.7 to 2.1 in the frequency range observed***

Effect of Triton® X-100 on Transient and Stable Cavitation Pressure in Solutions Subjected to Single Frequency (4 W/cm^2)



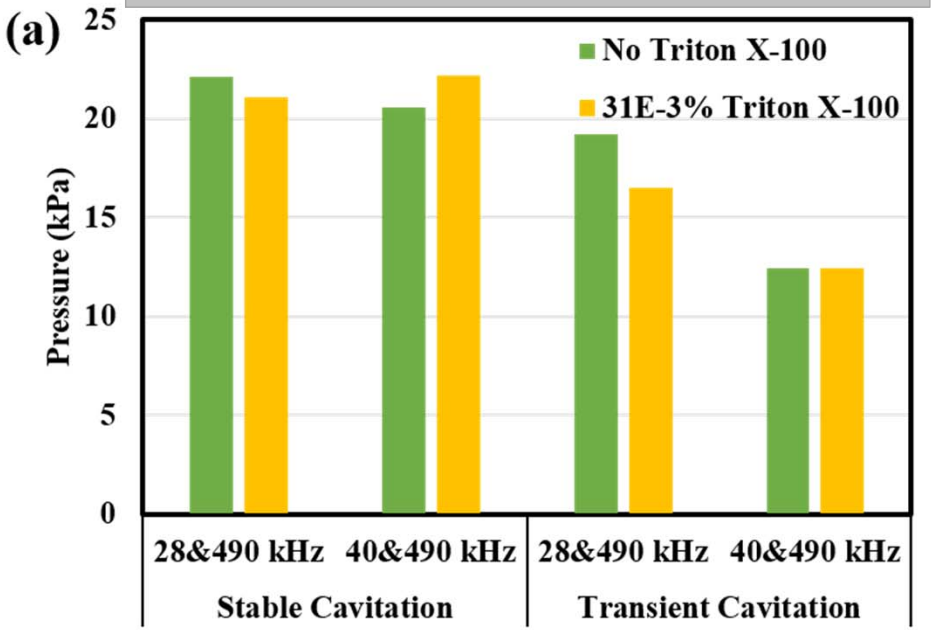


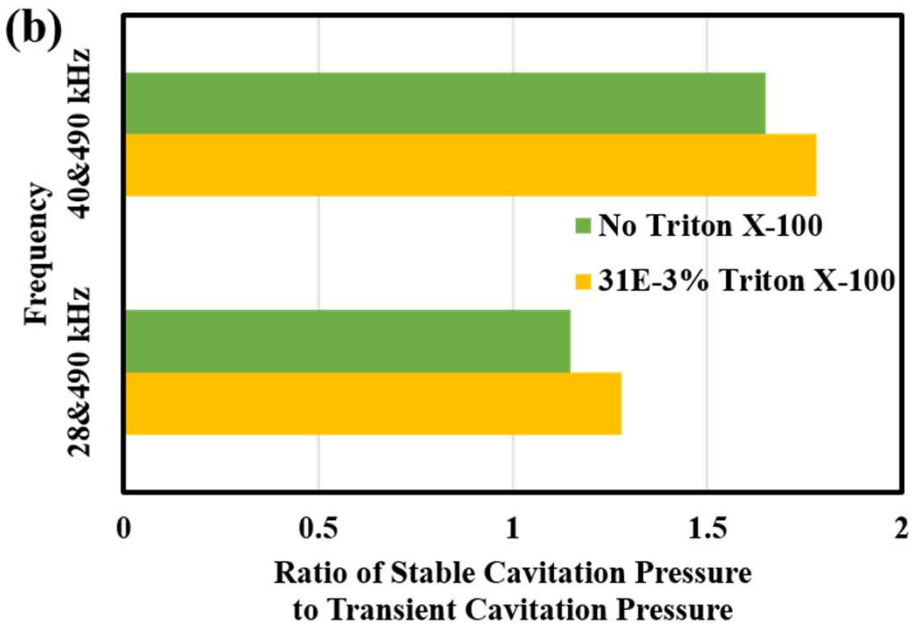


- ***CMC: 15E-3%; Surface tension: 35 mN/m***
- ***Stable cavitation pressure decreased slightly or remained unchanged at all frequencies when Triton® X-100 was employed***
- ***Transient cavitation pressure decreased with addition of surfactant***
- ***Ratio of stable cavitation pressure to transient cavitation pressure increased in the presence of Triton® X-100***

Effect of Triton® X-100 on Stable and Transient Cavitation Pressure in Solutions Subjected Dual-Frequency

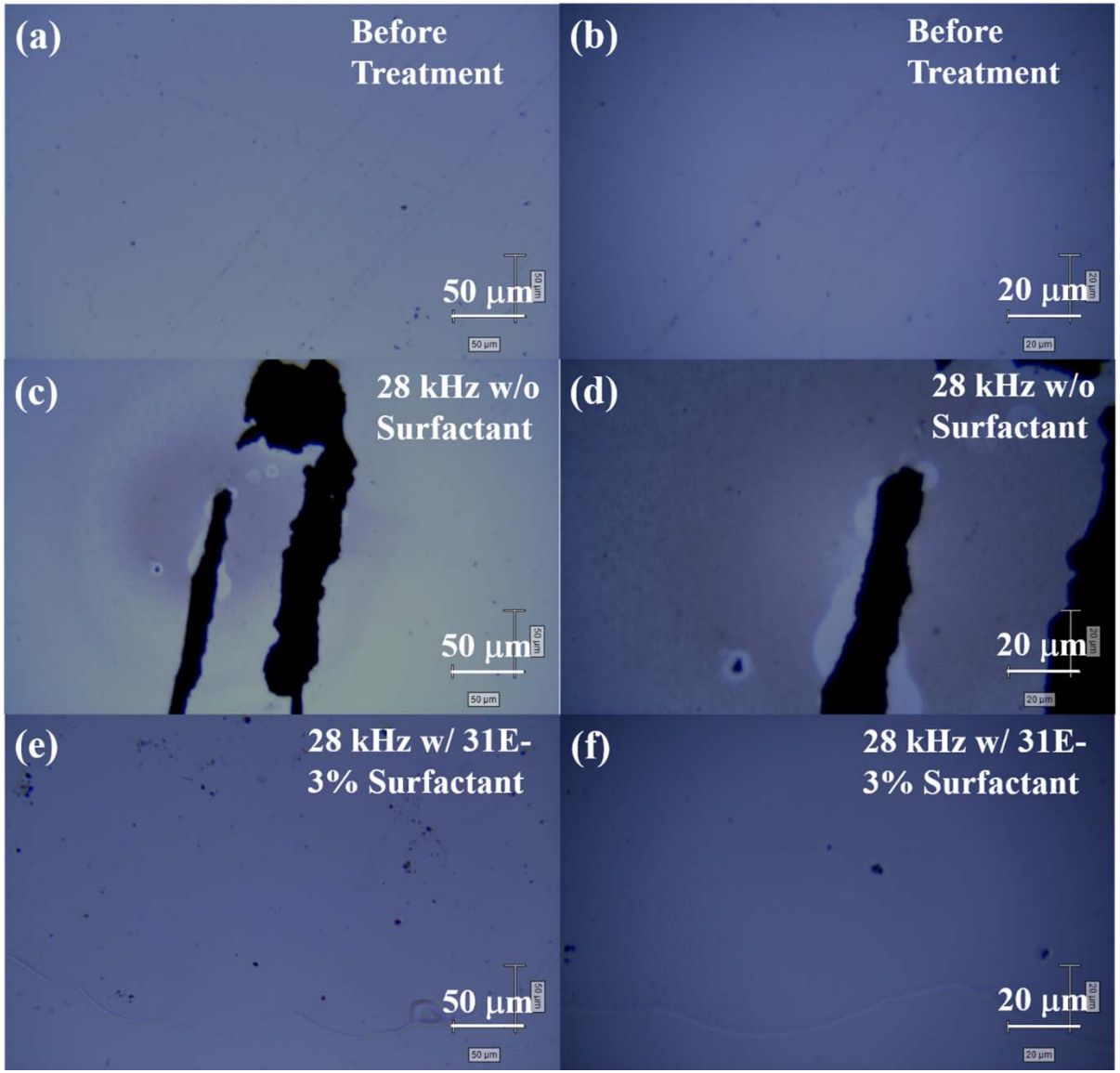
CMC: 15E-3%; Surface tension: 35 mN/m





- ***Stable cavitation pressure was maintained and transient cavitation pressure was suppressed with the addition of Triton***
- ***Ratio of stable cavitation pressure to transient cavitation pressure increased in the presence of Triton***

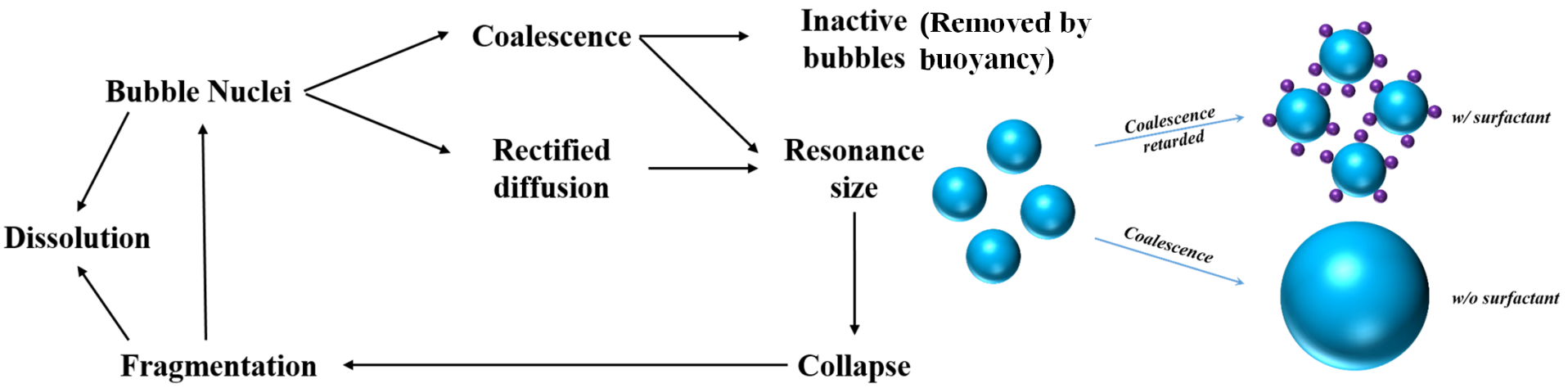
Damage Study



- Aluminum coated glass samples
- 200 and 500X magnifications
- Acoustic power: 4 W/cm^2
- Duration: 1 hour

- ***Severe damage was observed on the surface when using UPW***
- ***Surface damage greatly reduced by adding Triton® X-100***

Discussion



- ***In a multi-bubble field, cavitation bubble growth can occur by either rectified diffusion or bubble coalescence***
- ***Surfactants can adsorb at bubble-liquid interface and reduce the coalescence between bubbles and negatively affect rectified diffusion***
- ***Transient cavitation is suppressed due to inhibition of bubble growth (preventing the bubbles from reaching pressure threshold for cavitation)***
- ***Retardation of diffusion also reduces the bubble growth and may affect the stable cavitation activity***

Summary

- ***Hydrophone measurements allowed quantitative characterization of stable and transient cavitation pressure in sound field***
- ***In single and dual-frequency systems, the ratio of stable cavitation pressure to transient cavitation pressure increased with addition of Triton® X-100***
- ***Surface damage significantly reduced in surfactant containing solutions compared to de-ionized water***