Ice Fracturing by Means of Pulsed Power

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Abstract

Past research has been conducted to explore the feasibility of utilizing the exploding film phenomena to fracture ice in attempts to ease sea navigation in artic regions [1]. This study enhances those past works by conducting experiments under conditions that more closely model the real-world conditions of the process. The exploding film phenomena was induced across an aluminum metallized polypropylene film (MPPF) while frozen in freshwater, and measurements were taken of the voltage and current waveforms. The experiments were then repeated replacing the freshwater with water containing salt at 35 parts per thousand [2]. This work presents the setup and comparison of the two sets of experiments.

Introduction

When high voltage is applied across, and a current is induced through metalized nano-particles on a dielectric surface, heat transfer caused by the resistance of the metal can cause the particles to melt into a liquid state and then evaporate into a gaseous state. Given enough surplus energy, a spark will overcome the gap left in the solid still attached to the substrate. This forces the metalized particles even further away from the surface and breaks the circuit. This process is known as the exploding film phenomenon.

Methods

A high voltage power supply was used to charge a 2 μF capacitor at 7.5 kV. An oscilloscope was used to monitor the voltage on the capacitor by means of a voltage probe. Once the voltage reached 7.5 kV, a switch was opened to disconnect the power supply from the capacitor to prevent damage caused by a back-feed current. A second switch was then opened allowing the capacitor to discharge across the MPPF. The current and voltage waveforms at the film were captured via a current transformer and voltage probe.

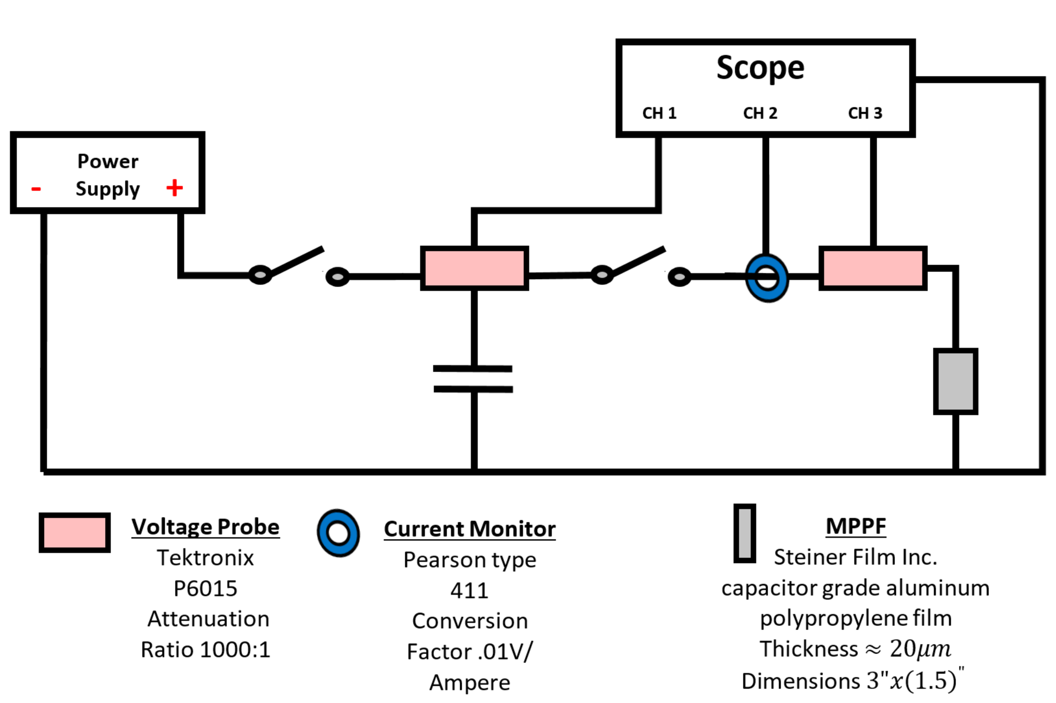

Fig. 1. Schematic of the circuit used to discharge the capacitor over the MPPF

Results

Fresh Water

Fig. 2. Fresh water ice before event.

Fig. 3. Fresh water ice during event.

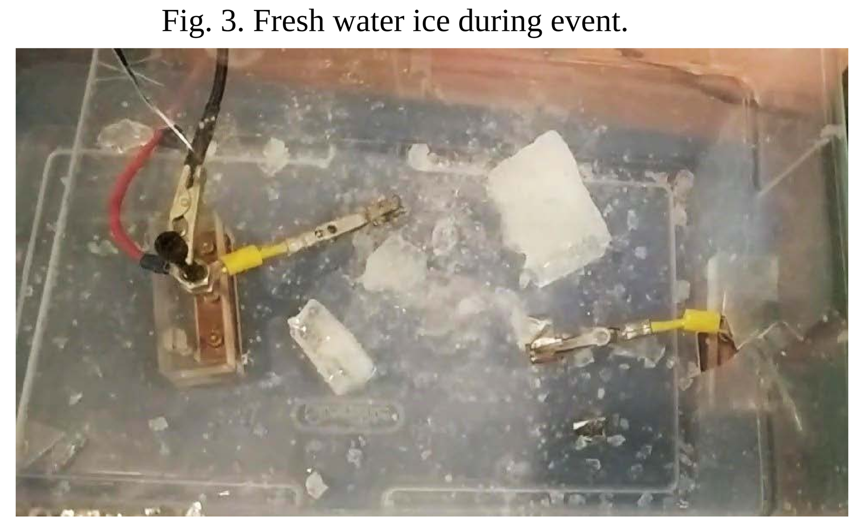

Fig. 4. Fresh water ice after event.

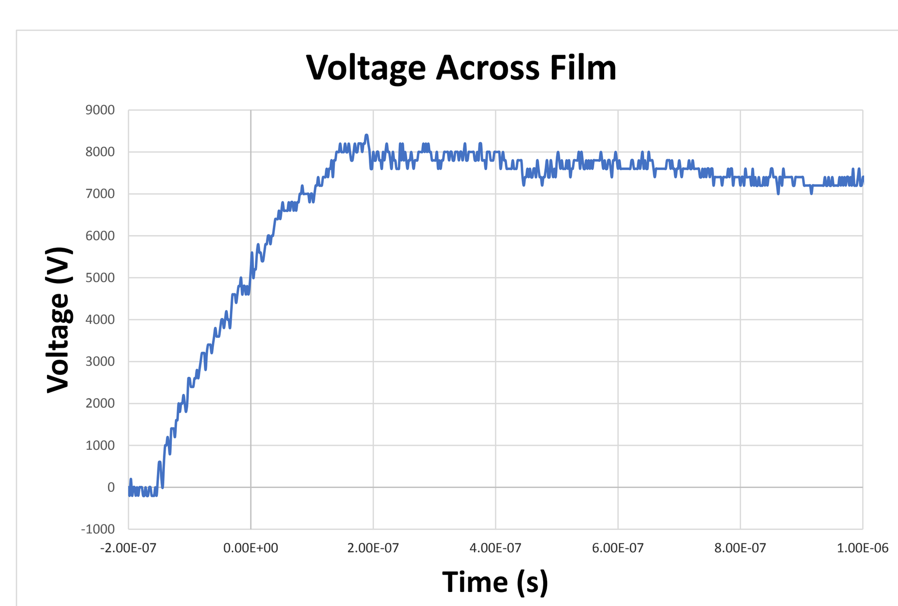

Fig. 5. Typical voltage waveform across the film for a fresh water sample.

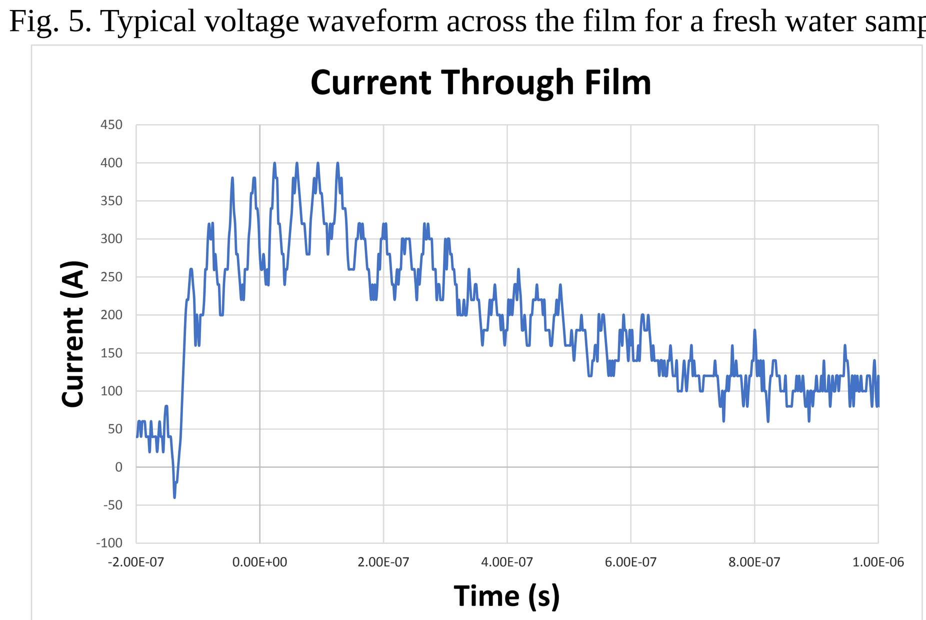

Fig. 6. Typical current waveform across the film for a fresh water sample.

Results cont.

Salt Water

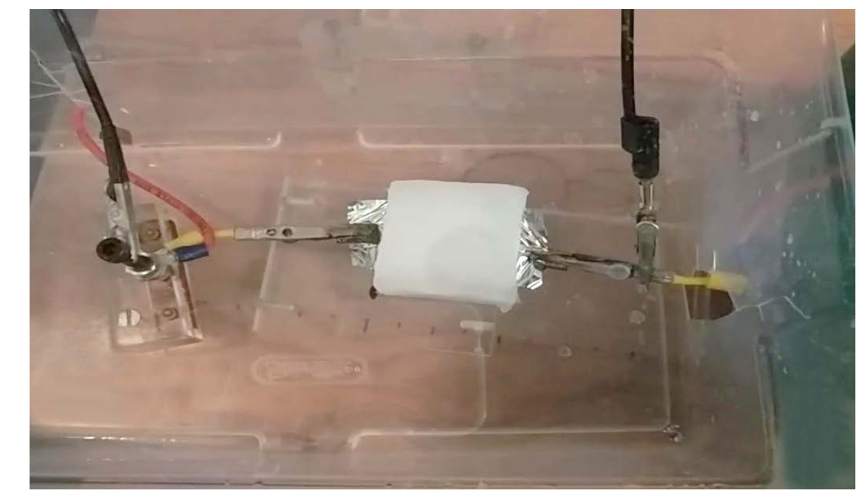

Fig. 7. Salt water ice before event.

Fig. 8. Salt water ice during event.

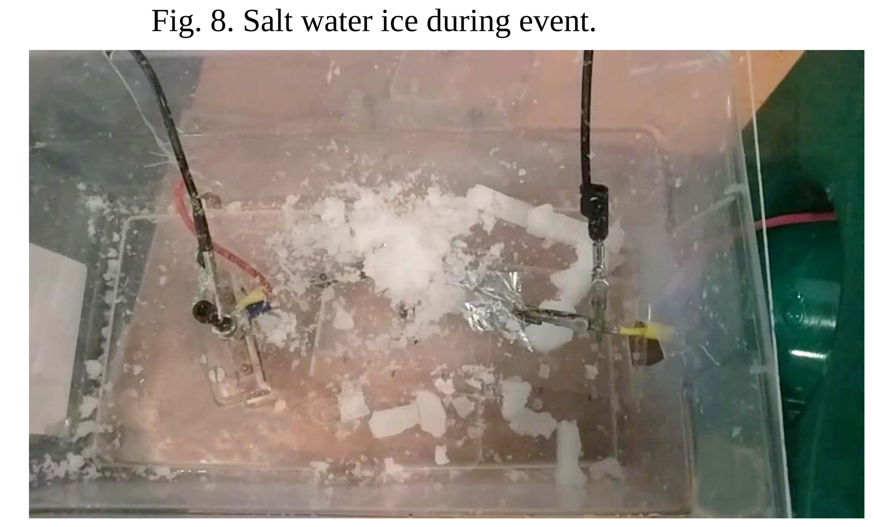

Fig. 9. Salt water ice after event.

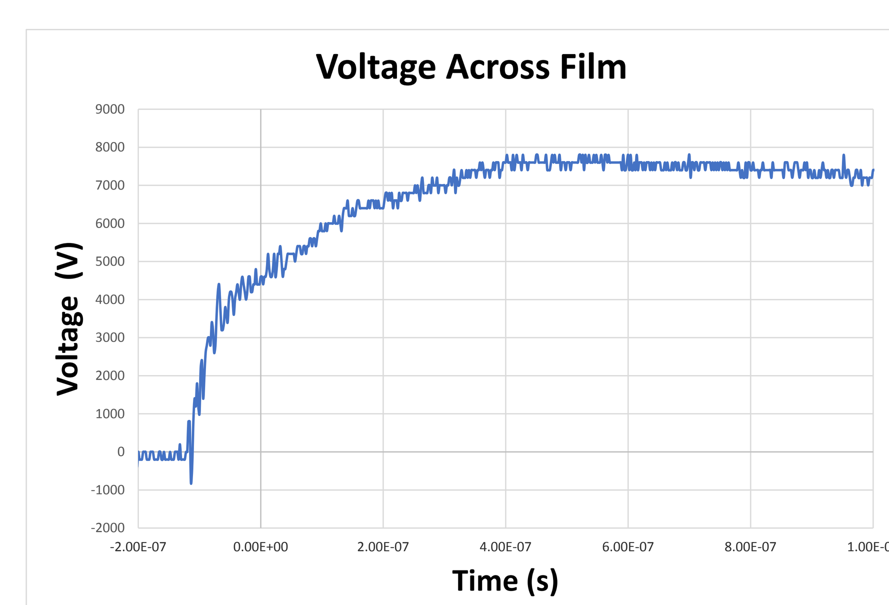

Fig. 10. Typical voltage waveform across the film for a salt water sample.

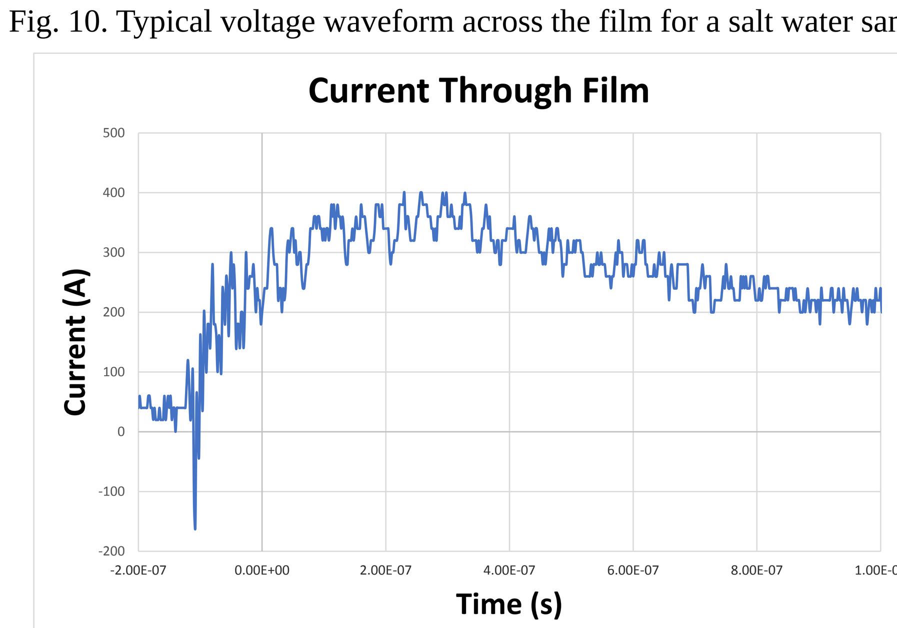

Fig. 11. Typical current waveform across the film for a fresh water sample.

Conclusion

Fresh Water

	Voltage (V)	Current (A)	Power (MW)
Trial 1	8400	480	3.744
Trial 2	8000	400	2.800
Trial 3	10200	480	3.936
Trial 4	7600	260	1.584
Trial 5	8400	400	2.964
AVERAGE	8520	404	3.0056

Salt Water

	Voltage (V)	Current (A)	Power (MW)
Trial 1	7800	400	2.960
Trial 2	7800	400	2.960
Trial 3	7800	340	2.304
Trial 4	8600	700	4.760
Trial 5	8600	480	3.444
AVERAGE	8120	464	3.286

Early experiments conducted were unsuccessful in fracturing ice. To achieve ice fracturing the volume of ice used was lowered by a factor of 2, at which time both the fresh and saltwater samples experienced fracturing. However, during the experiments not all samples that were tested appeared to fracture. In some cases it wasn't until viewing slow-motion playback of the individual event that fracturing was realized. This is believed to be due to having some variation in volume of each sample. Upon analysis the waveforms of the each experiment set showed no distinguishable differences. The peak voltage, current, and power was then tabulated and the average was taken. However, this also revealed negligible differences. The results indicate that inducing the exploding film phenomenon across an MPPF, while frozen in either fresh or salt water, is an equally effective method of ice fracturing.

Future Work

Although ice fracturing was observed in both fresh and salt water, moving forward more data from each test set will be taken to further solidify the findings. Afterwards, the volume of ice will be measured more precisely in attempts to define a clear cutoff as to what limitations the exploding film phenomenon has as a means to fracture ice formations, as a function of volume.

References

[1] S. Satoshi, and C. Yamabe, "Breaking of Ice Sheets Using Shock Waves Produced by Pulsed Power," 2003 Jpn. J. Appl. Phys. Vol.42

[2] "Why is The Ocean Salty?" . Oceanservice.noaa.gov.N.p., 2017. Web. 14 Apr. 2017.

[3] O. Olabisi, "Determination of Fracturing Mechanisms in Ice Using Pulsed Power," M. S. thesis, E.E., U.B., Buffalo, NY, 2007.

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