Enhancement of solar stills through corrosion prevention and improved hydrophobic glass coatings

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1. Introduction

The U.S. Federal Highway Administration found that every year the direct cost related to metallic corrosion was $276 billion[1]. Systems exposed to high sodium levels, like those found in brackish water and seawater are at the highest risk for corrosion and scaling. These lead to increased maintenance costs. Solar stills are no exception. Solar stills provide a low-cost method for desalination by harnessing the energy of the sun to create a distillate free from contaminates. Corrosion from exposure to the saline water reduces the efficiency of a solar still, as well as increases maintenance cost. This project focuses on using a newly developed (yet to be published) aluminum etching process that allows the metal's surface to have corrosion resistant properties. The goal of etched aluminum is to create a barrier between the aluminum surface and the brackish water, which will reduce corrosion. The purpose of these experiments is to test the integrity of the etching. These experiments combined with an innovative design from the lab of Dr. Sarada Kuravi (also at NMSU) will result in a solar still with long-term corrosion resistance and improved efficiency. In conjunction with determining the anti-corrosion effectiveness of the etched aluminum, a different aspect of the solar still is also studied. In solar desalination via solar still, the glass that collects the evaporated water and recondenses it into distillate must have a hydrophobic coating to increase the efficiency. While hydrophobic coatings are becoming more commercially available, only published experiments are presently showing promise to make a superhydrophobic (contact angle >120°) coating that can withstand high temperatures, allows light to pass through, and withstands long term exposure to UV radiation.

2. Materials and Methods

2.1a Design of corrosion reactor

An insulated simple distillation was utilized to condense the distillate after a boiling treatment. The heat exchanger consisted of an aluminum sample placed directly on a 350°F hot plate with 250 mL sample water. The experiments were run with distilled water or synthetic water (2 mg/L NaCl and 1 mg/L $CaSO_4$). Samples were taken every ~35mL.

2.2a Analytical Methods

Fluorescence excitation-emission matrix (F-EEM, Horiba Aqualog) and total organic carbon TOC (carbon analyzer Shimadzu TOC-L) tested for the presence of oil and other organics in the captured water. The aluminum surface itself was tested before and after the experiment for corrosion, pitting and scaling using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) (S-3400N Type II Hitachi High-Technologies Corp).

2.1b. Design of Hydrophobic Coating

An experiment was carried out to test the efficiency of using TiO_2 as a simple hydrophobic glass coating. Varying concentrations of TiO_2 were dissolved in 25 ml of DI water, applied to clean glass microscope slides, and kept at 80 °C overnight.

2.2b Analytical methods

Transparency was measured using absorbance readings from a Hatch DR 5000 UV-Vis Laboratory Spectrophotometer and the following formula, Total transmittance % = 1-(absorption+ reflection). Hydrophobicity was measured by observing contact angles with a goniometer.

3. Results and Discussions

3a. Corrosion Reactor

As shown in Figure 1 and Figure 2, minimal pitting and corrosion are evident on the aluminum surface. While the etched aluminum surface was only exposed to DI water, the corrosion comes from oxidation on the metal's surface. When comparing the etched aluminum exposed to DI water to that exposed to synthetic water, as shown in Figure 3 and Figure 4, the etched aluminum has a crystal-like layer of NaCl and $CaSO_4$, as evidenced by the EDX data (Table 1). After the synthetic water boiling experiment, the crystal layer could easily be removed with a slight touch.

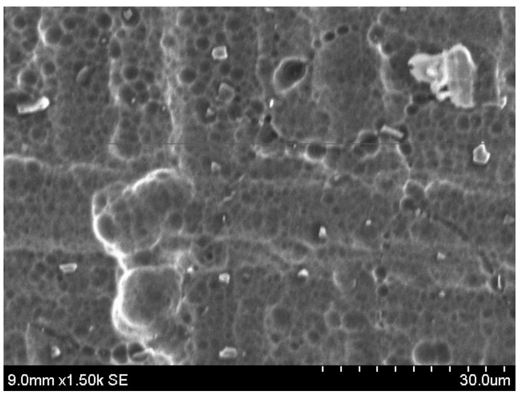

Fig. 1 Etched aluminum before DI water distillation experiment. SEM image at 1500x magnification

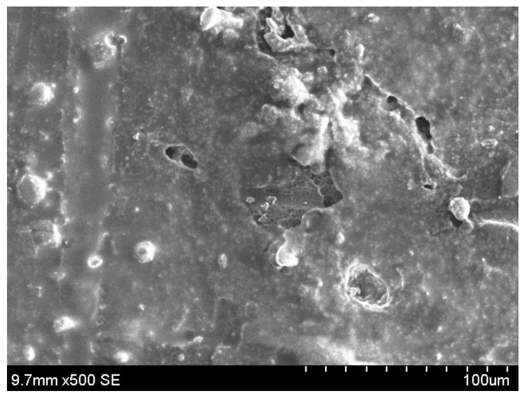

Fig. 2 Etched aluminum after DI water distillation experiment. SEM image at 500x magnification

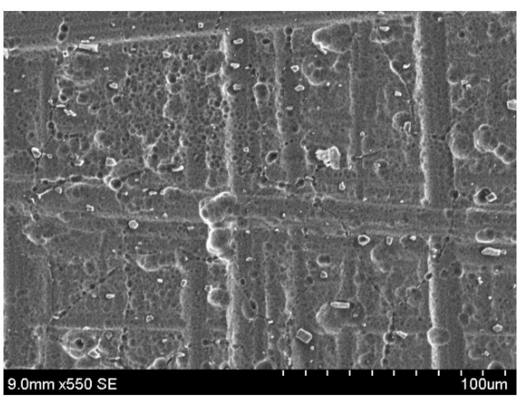

Fig. 3 Etched aluminum before synthetic water distillation experiment. SEM image at 550x magnification

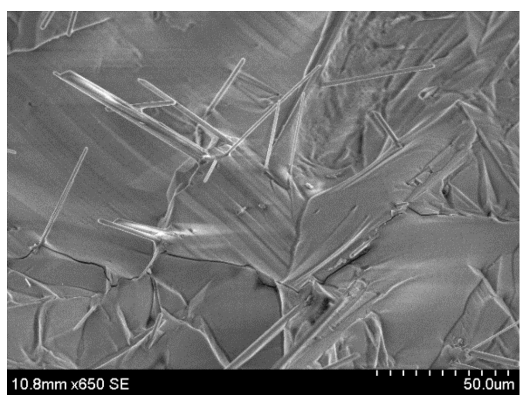

Fig. 4 Etched aluminum before synthetic water distillation experiment. SEM image at 650x magnification

Element	Etched after DI	Etched after

	boil	synthetic boil
Na	0.09%	18.07%
Cl	0.02%	57.32%
C	32.73%	1.85%
Ca	0.02%	11.51%
S	0.01%	7.22%
O	23.08%	3.60%

Table1. Elemental analysis of aluminum surfaces after boiling experiments

Concentration (M)	Contact angle (°)	Transparency
0.000	18.2	
0.003	22.1	97.90%
0.013	22.1	98.15%
0.028	21.7	97.08%
0.038	22.75	95.96%
0.050	19.33	96.66%
0.075	19.75	92.52%

Table 2. TiO_2 treated microscope slide samples

The presence of Na, Cl, Ca, O, and S gives evidence of scaling, corrosion, and oxidation on the surface of the metal. In early experiments, excessive amounts of Si (from silicon grease used to seal the corrosion reactor) were found on the surface of the aluminum which resulted in a need to change the corrosion reactor design.

3b. Hydrophobic Glass Coating

The proposed TiO_2 treated glass slides did not show notable increases in hydrophobicity, despite the concertation that remained functionally transparent.

4. Conclusions and Future work

These experiments resulted in data and observations that showed that the corrosion reactor is working properly and that the etching can withstand boiling. In future experiments, replacing the aluminum surface with other metals that have corrosion-restraint properties before the etching like stainless steel may show improved long term corrosion resistance. It will be important to test the integrity of the etching by adding constant supply of water for a multi-day experiment to mirror the real-life conditions that the etched metals will be exposed to in the solar still. In regards to the hydrophobic glass coating finding a coating that can withstand high temperatures, allows light to pass though, and will as not breakdown after long term exposure to UV radiation will be essential to improve the efficiency of the solar still. These experiments are a part of a larger 2-year project for solar still improvement coordinated with U.S. Bureau of Reclamation & NM Water Resources Research Institute.

References

[1] I. CC Technologies Laboratories, Corrosion Costs and Preventive Strategies in the United States, (2002).