ELECTRICITY GROWS IN BEAKERS

Creating and Testing Lab-Fabricated Rochelle Salts

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ABSTRACT

Due to the current physical limitations on piezoelectric crystal synthesis methods and efficiency, piezoelectric crystals are mainly used in small systems such as watches, clocks, microphones, and sound and movement sensors. If their production and growth is someday maximized and streamlined, they may be used as alternate sources of power. Here we investigate synthesis, seed-crystallization, and confirmation test methods of potassium sodium tartrate tetrahydrate, commonly known as Rochelle Salts. Through previously-published methods, we titrated sodium carbonate into the suspension of potassium bitartrate, precipitating potassium sodium tartrate out of solution to form the initial seed crystals. Using traditional seeding methods, we then created larger and larger crystals. In order to verify that the correct reaction took place and that our Rochelle salts were pure, we conducted a composition test using an XRD. Finally, we designed and built a compressive test rig which we then used to confirm the piezoelectric characteristics of our crystals.

PIEZOELECTRIC EFFECT

The Piezoelectric Effect is the electric charge that accumulates in certain solids in response to applied physical stress. The Piezoelectric Effect is reversible in that applying an electric charge can produce mechanical vibrations. This reversal of the Piezoelectric Effect is also known as the Reverse or Converse Piezoelectric effect.

On an atomic level, the positive and negative poles within the unit cell are in their natural relaxed state, which results in the crystal giving off a zero net-charge. However, when a piezoelectric crystal is deformed, the unit cell's poles are physically moved out of balance, aligning positive poles with positive poles and negatives with negatives, giving the whole crystal a non-zero net-charge. This sudden charge is what produces the voltage.

SYNTHESIS METHODS

Figure Set 1: Washing soda was titrated into a suspension of cream of tartar. When the reaction was complete we cooled and filtered the resulting solution.

CHEMICAL REACTIONS

$$2NaHCO_{3\,(s)} \xrightarrow{heat} Na_2CO_{3\,(s)} + CO_{2\,(g)} + H_2O_{(g)}$$

To convert baking soda (sodium bicarbonate) to washing soda (sodium carbonate), we placed 500 g of sodium bicarbonate into a heat-resistant dish and spread it in an even layer. We then put the dish in a furnace which was programmed to heat at 65C, 120C, 175C, and finally 230C for one hour each. The chemical reaction is displayed above.

$$Na_2CO_{3\,(s)} + KHC_4H_4O_{6\,(s)} \longrightarrow NaKHC_4H_4O_{6\,(s)} + H_2O_{(l)}$$

We first suspended 200 g of cream of tartar (potassium bitartrate) in 250 mL of distilled water. After heating the suspension in a double-boiler setup, we then titrated in a teaspoon of sodium carbonate. The sodium carbonate reacted with the potassium bitartrate, forming bubbles in the suspension, which acted as our reaction indicator. When the bubbles stopped forming and the solution had changed from milky-white to clear, we filtered the solution and placed it into a refrigerator to let it crystallize.

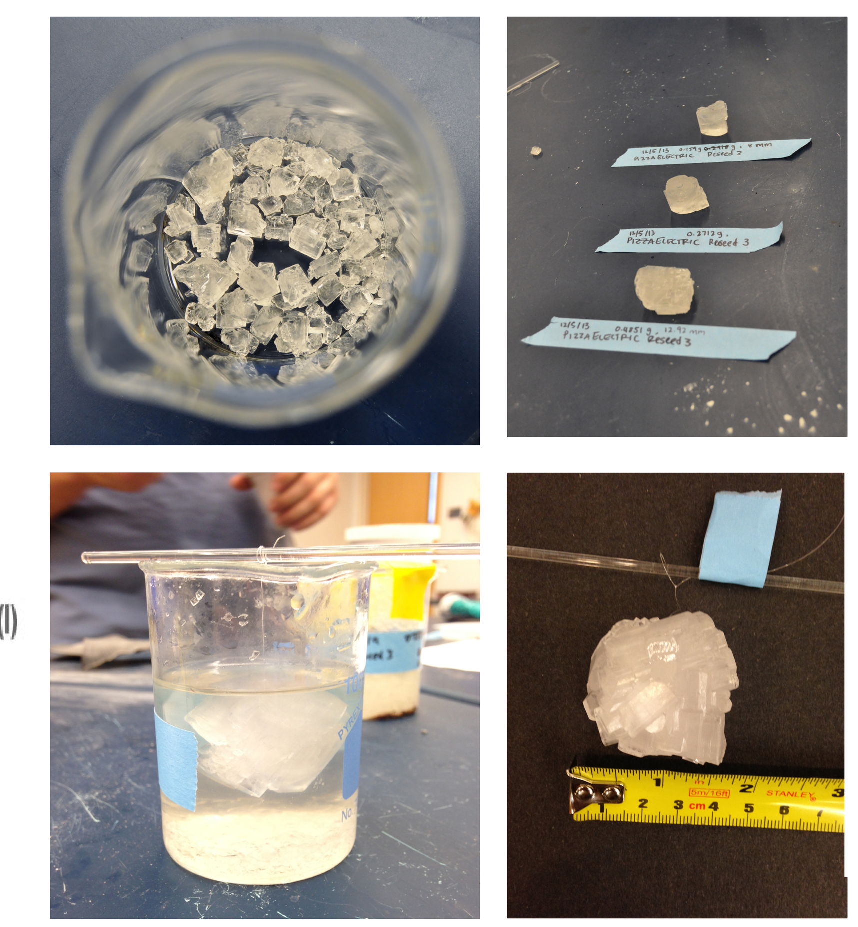


Figure Set 2: Small seed cystals were then re-seeded into larger ones.

SEEDING METHODS

In order to create crystals large and strong enough to test in the compressive test rig, we had to use the technique called seeding. Seeding is the process by which a small seed crystal is tied to a nylon string and is submerged into a solution which will then crystallize around the seed. Placing the seed and solution in a refrigerator yielded the best results.

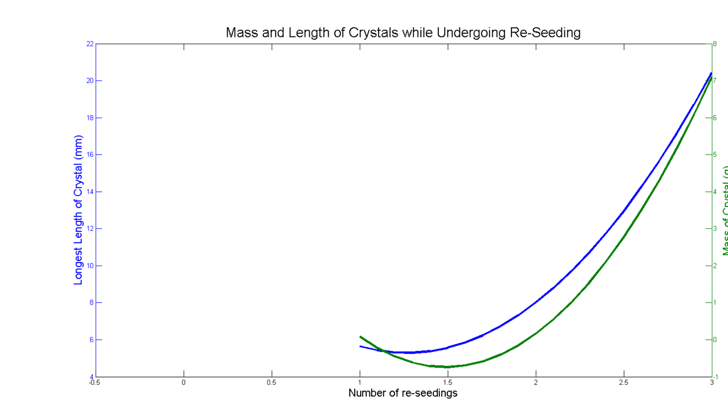
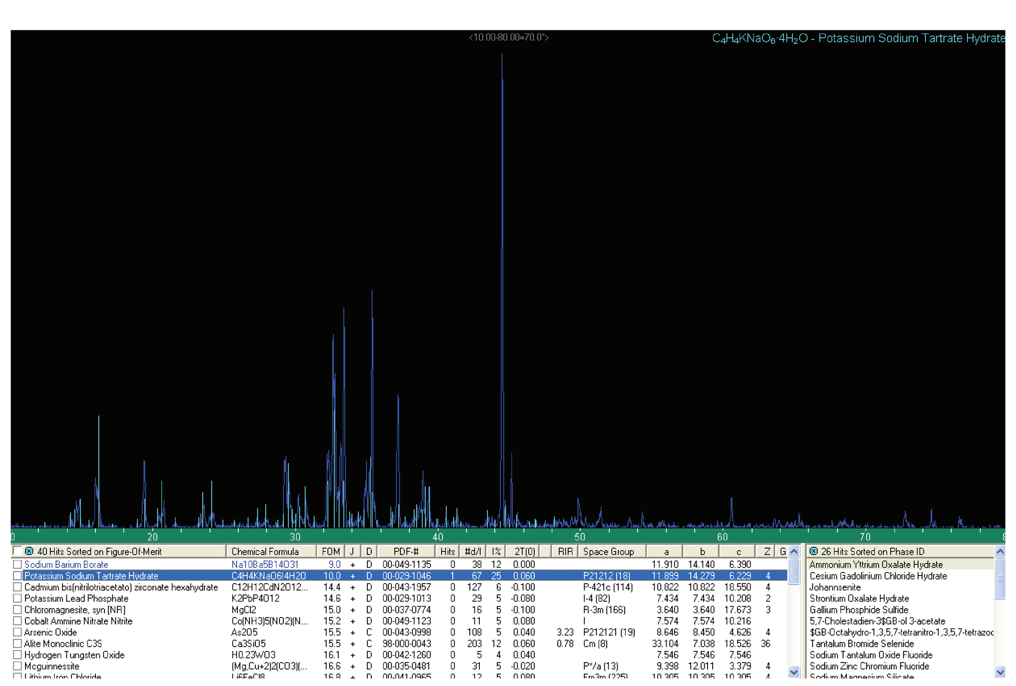


Figure 3: We monitored the lengths and masses of the seeds in each of the three seeding rounds we completed.

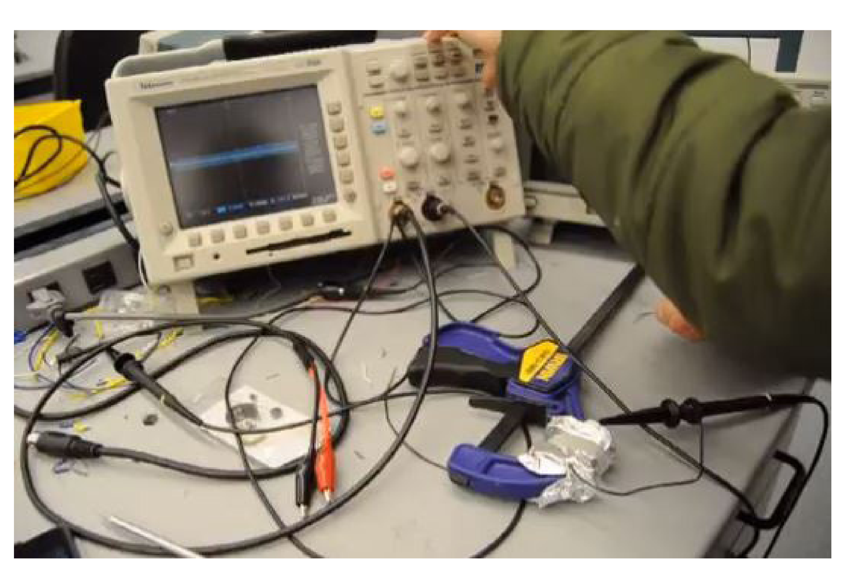
TESTING METHODS

XRD



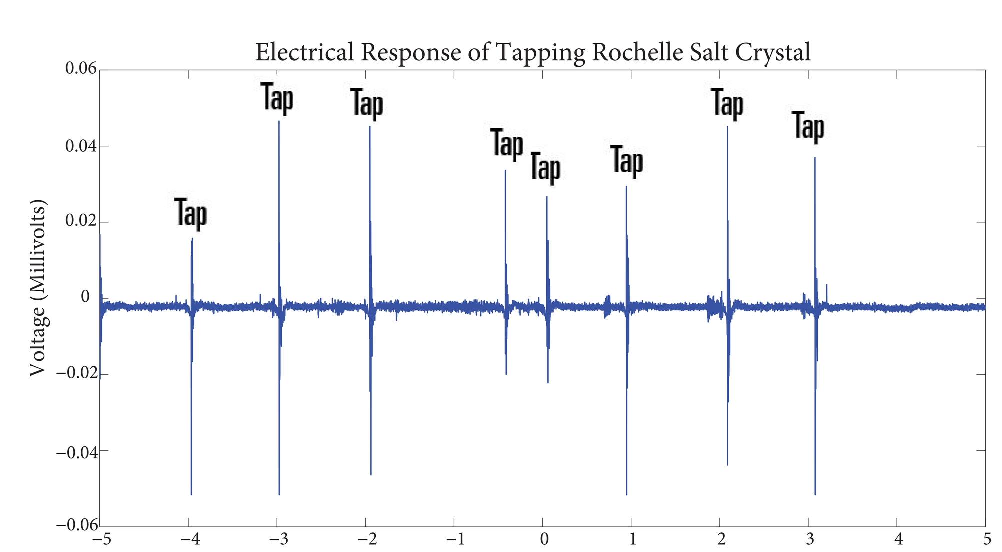
We crushed some of our crystals to a fine powder and tested the crystal structure in the X-ray Diffractometer. The closest match to the sample's diffraction pattern was that of potassium sodium tartrate tetrahydrate, which is the chemical formula of Rochelle Salts verifying our chemical reaction was successful.

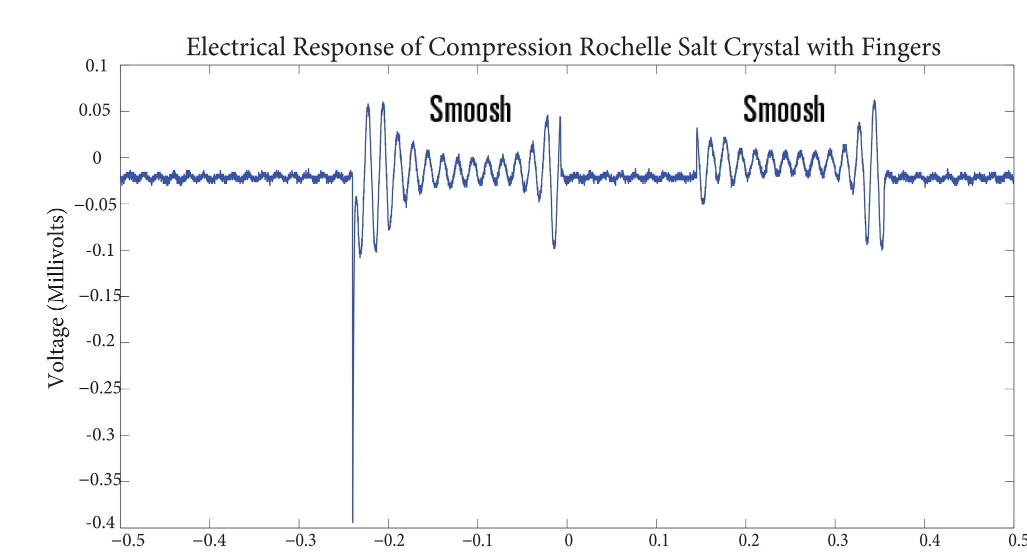
COMPRESSIVE RIG SET-UP

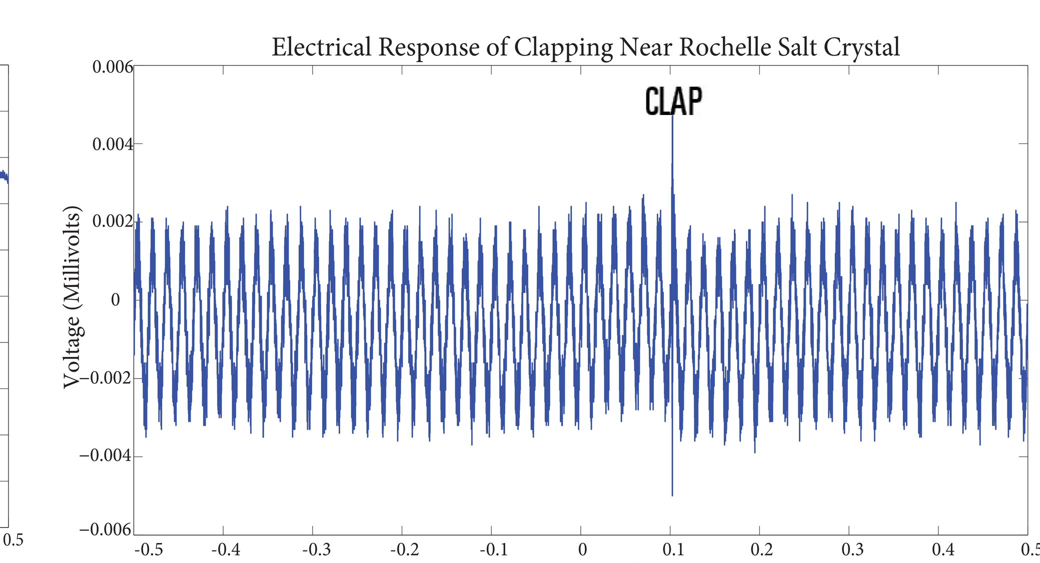


We placed a large crystal in a clamp between two leaves of conductive, aluminum foil. The foil leaves served as electrodes and enabled us to easily make electrical contact with the crystal and ensure conductivity. We then attached the oscilloscope ground to one leaf, and the probe to the other leaf. We then created an oscillation in the crystal. This we did by tapping it, squeezing the clamp, tapping the table, or clapping.

PIEZOELECTRIC EFFECT TEST







When we mechanically deformed the crystal inside the compressive test rig, we saw the corresponding voltage produced on the oscilloscope output. This means that the crystals are piezoelectric and produce a voltage in response to mechanical stress.

The voltage produced oscillates because voltage is only produced as the crystal deforms. Therefore, a crystal held under constant compression will not output a constant voltage. Electrical potential will only be created as the crystal actively, physically deforms. Therefore, it it is flux of position, not pressure nor force, that governs the magnitude of the voltage produced by deformation.

Above are three captures depicting the output voltage generated of the crystals when three methods of vibration are applied.

CONCLUSION

We successfully reacted washing soda and cream of tartar into Rochelle salt. The crystals we grew from the reacted solution exhibited piezoelectricity. We were able to confirm piezoelectricity by measuring the electrical potential response of our crystals in response to physical deformation. We verified the chemical composition of our crystals through XRD testing. Both tests confirmed that the crystals synthesized are piezoelectric Rochelle salt.