Name:_____ Date:_____ Class:_____

Student Worksheet

Small Scale Sculpting: Guided Inquiry I

Safety
Be careful not to splash vinegar in your eyes; it is an irritant. Hot plates may cause burns.

Introduction

You will sculpt a piece of chalk with a process called *etching* by using etch mask materials and acid. You will etch features on the chalk using a process similar to that used to make computer chips—only the computer chip features are 1,000 times smaller!

Materials
- chalk of 2 mask designs
- 50 ml beaker of vinegar
- pH paper
- timer
- 6 oz cup of water
- paper towel
- caliper
- calculator

Question: How can engineers sculpt tiny features?

Prediction: *Using a chemical process, called etching, engineers sculpt on a tiny scale.*_____

_____

Procedure: Etching Chalk

1. Measure the pH of the vinegar with pH paper. Record the pH.
2. Place **Mask #1** chalk upright into the beaker of vinegar. Record your observations.
3. After 4 minutes, remove the chalk. Place it into a cup of water. Stir gently for 10 seconds. Remove the chalk. Place it on a paper towel to dry.
4. Dump used vinegar solution in sink, rinse out and refill with fresh vinegar.
5. Repeat steps 1–3 with **Mask #2**.
6. Measure the pH of the vinegar. Record the pH in the table below.

Development and distribution partially funded by the National Science Foundation

Record Your Observations

Chalk	Evidence of a chemical reaction	pH of vinegar: a) *before* experiment: __2__
Mask #1	*Constant bubbling on exposed areas of chalk; bits of white material in vinegar*	b) *after* Mask #1: __3__
Mask #2	*Bubbling on exposed areas of chalk; vinegar becomes cloudy*	c) *after* Mask #2: __4__

Analyze the Results

1. What evidence did you observe to indicate that a chemical reaction had taken place?

   gas created; particles floating in the vinegar (gas and solid formation)

2. Why was the chalk placed in the water after the vinegar reaction?

   Water stops the chemical reaction and rinses the etch products away.

3. How did constant stirring during the chemical reaction affect the resulting etch?

   Stirring should remove etch products away from the material and help provide access to the material being etched—thus more material should be etched.

Procedure: Calculating the Etch Rate

1. Carefully remove the tape off of **Mask #1.**
2. Use the caliper to measure the diameter of the masked (taped) region and the diameter of the unmasked region. Record in mm.
3. Complete the table below to calculate the etch rate of Mask #1.

Record Your Observations—Etch rate of Mask #1:

Diameter of masked region (mm)	Diameter of unmasked region (mm)	Diameter difference (mm)	½ of diameter difference (mm)	Time (min)	Etch rate (mm/min)
9.3	*7.1*	*1.2*	*0.6*	*4*	*0.15*

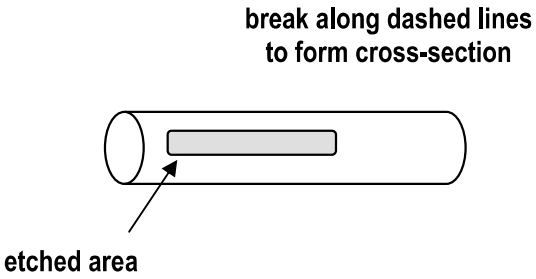
Development and distribution partially funded by the National Science Foundation

NNIN Document: NNIN-1234
Rev: 04/11

Question: What could you change to speed up the chemical etch rate?

Prediction: *concentration of vinegar; temperature of the vinegar; agitation of vinegar to allow for removal of etch products*

Procedure: Observing Sidewall Profiles



1. Carefully remove the tape from **Mask #2.**
2. Carefully break the chalk (as shown in the diagram at right) ***in the middle of the etched portion*** of the chalk. This will form a *cross section* of the chalk.
3. Hold the chalk so that the circle part of the chalk is right in front of your eye. Notice the trenches. Draw an etch sidewall profile for each "trench" that you see in the space below.

Record Your Observations

Sidewall profile of Wide Trench (Mask #1)	Sidewall profile of Narrow Trench (Mask #2)

Analyze the Results

1. Compare the etch depth of **Mask #1** to that of **Mask #2.** Why is there a difference in etch rate between the two pieces of chalk? Explain.

   The narrow trench depth is difficult to measure, so have the students compare depths qualitatively. The wide trench should be deeper because the etch products are more easily removed and thus more material is exposed to the vinegar. The narrow trench should be more shallow because the etch products get trapped in the confined space.

2. Compare the sidewall profiles of the wide trench and the narrow trench.

   The narrow trench has sidewalls that slope away from the masked edge. The wide trench has straighter, more vertical sidewalls.

Development and distribution partially funded by the National Science Foundation

NNIN Document: NNIN-1234
Rev: 04/11

3. Explain why the chalk did not etch straight down by using factors that contribute to the chemical reaction taking place.

Sidewalls should slope slightly away from the masked edge. This is caused by the etch products getting in the way of the chemical reaction.

Draw Conclusions

List the factors that may affect the etch rate of chalk in vinegar.

temperature of vinegar; concentration of vinegar; agitation of vinegar

Development and distribution partially funded by the National Science Foundation

NNIN Document: NNIN-1234

Rev: 04/11

Name:_____ Date:_____ Class:_____

Student Worksheet

Small Scale Sculpting: Guided Inquiry II

Safety

Be careful not to splash vinegar in your eyes; it is an irritant. Hot plates may cause burns.

Introduction

Your goal is to design an etch process that not only has a fast etch rate but also a vertical sidewall. Tomorrow you will be given 5 minutes to etch and produce an etched chalk sample. Today, find out as much information as you can.

Materials

- chalk with Mask #1
- 50 ml beaker of vinegar
- digital timer
- 6 oz cup of water
- paper towel
- caliper
- calculator

Question:

How can I make a fast etch rate with vertical sidewalls?

Prediction: Choose 2 factors of the chemical reaction to change. Be sure to explain how each factor affects the chemical reaction (with a fresh piece of chalk with the Mask #1 design).

The warm vinegar should speed up the chemical reaction but to prevent too much etching under the mask, we will only etch in warm vinegar for 2 minutes. We will then etch the rest of the 2 minutes at room temperature. Stirring the mixture will get the etch products out of the way so that a constant etch rate will occur.

NNIN Document: NNIN-1234
Rev: 04/11

Procedure: Design an Etch Process

Describe your etch process in detail below:

Description of etch process:

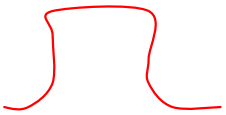
- *2 minutes etch in warm vinegar (40°C)*
- *2 minutes in room temperature vinegar*
- *stirring the whole etch time*
- *rinse in water*

Total etch time:
4 min.

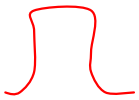
Etch rate calculation:

(9.2 – 7.2) / 2 = 1.0 mm
1.0 mm / 4 min = 0.25 mm/min

Diagram of sidewall profile:



Record Your Observations

Etch factor tested	Etch rate (mm/min)	Sidewall profile (sketch diagram)	How does the factor affect the chemical reaction?
Warm vinegar	*0.28 mm/min*		*The warm vinegar etched the chalk much faster than room temperature vinegar.*

Roll your chalk on an ink pad. Then, roll the inked chalk in the space below to print the design:

Development and distribution partially funded by the National Science Foundation

NNIN Document: NNIN-1234

Rev: 04/11

Analyze the Results

1. Was your etch rate faster than yesterday? If so, by how much?

   The etch rate was faster than yesterday's control by 0.1 mm/min.

2. Were your sidewalls vertical? If not, describe what they look like.

   There was a little undercutting and the sidewall was curved along the bottom.

Draw Conclusions

What may have caused results of the etch to turn out differently from what you expected?

We may have left it in the warm etch too long and got the undercutting.

Development and distribution partially funded by the National Science Foundation

NNIN Document: NNIN-1234

Rev: 04/11