Sintering Ceramic Materials:
A Module Developed for Hands-On Learning

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Description:
This document is a lesson plan for a short module describing the sintering of ceramic materials for STEM outreach. Colorado State science standards addressed by the module are included. The module is readily adapted for students in grades 1-12. The module was originally drafted for presentation to children aged 7-13 at the Rocky Mountain Camp for Dyslexic Children, thus activities are largely hands-on, driven by physical concepts, and do not rely heavily on reading or writing skills.

Science Standards Addressed (From the Colorado Department of Education)
http://www.cde.state.co.us/scripts/allstandards/COSTandards.asp?stid=7&stid2=0&glid2=0

Standard 1 - Physical Science
- High School: Outcome 4: Atoms bond in different ways to form molecules and compounds that have definite properties.
- 6th Grade: Outcome 1: All matter is made of atoms, which are far too small to see directly through a light microscope. Elements have unique atoms and thus, unique properties. Atoms themselves are made of even smaller particles.
- 6th Grade: Outcome 2: Atoms stick together in well-defined molecules or be packed together in large arrangements. Different arrangements of atoms into groups compose all substances.
- 6th Grade: Outcome 3: The physical characteristics and changes of solid, liquid, and gas states can be explained using the particulate model.
- 6th Grade: Outcome 4: Distinguish among, explain, and apply the relationships among mass, weight, volume, and density.
- 3rd Grade: Outcome 1: Matter exists in different states such as solids, liquids, and gases and can change from one state to another by heating and cooling.
- 1st Grade: Outcome 1: Solids and liquids have unique properties that distinguish them.

Standard 3 – Earth Systems
- 3rd Grade: Outcome 1: Earth’s Materials can be broken down and/or combined into different materials such as rocks, minerals, rock cycle, formation of soil, and sand – some of which are usable resources for human activity.
Objective: Introduce the fundamental concepts of ceramic materials to the students and the various applications of ceramics in society. Explain and demonstrate the concept of sintering, a common processing technique for ceramics.

Materials:
- For Ceramics/Sintering Introduction:
  - Ceramic Vegetable peeler (any other easily obtainable materials from the sintered product list)
  - Photo book of ceramic products
- For Student Activities:
  - Perler Beads – ~100 beads/student
  - Perler Bead boards – one/student
  - Parchment Paper
  - Iron (a travel size iron would probably be a good option)
  - Bowls to contain Perler Beads
  - Heat proof surface to iron on

Procedure:

1. Introduction to Ceramic Materials/Processing

Begin with a discussion about the long history of ceramics and the wide range of applications. Give examples through picture and/or actual ceramic objects (pictures provided at the end). Explain the standard types of processing materials and lead into sintering.

Background information

Ceramic materials have been around for a long time. The production of clay ceramics dates back to 24,000 BC, but in the years around 14,000 BC, the first ceramic tile was created beginning the production of application based ceramics [1]. Today ceramics cover a wide breadth of properties and applications spanning from vegetable peelers and knives to graphite tennis racquets and space shuttle tiles. These materials are generally made by taking powders of the material and forming them into simplistic or complex shapes through different ceramic forming techniques such as extrusion, pressing, and casting, to form what is known as a green body. These green bodies are made up of particles that are packed together but not bonded together. This can be thought of as a sand castle, in that the sand castle holds it shape even though the sand is not bonded together. Common to almost all forming techniques is the fact that the green body produced has a low density and little to no strength. To increase the density and strength of the ceramic, it goes through a process known as sintering. Sintering is the process of heating the green body up to high temperature for a certain length of time in order to provide the energy necessary for the ceramic particles to bond together, reducing the number of pores, increasing
the density of the ceramic, slightly shrinking the part and dramatically increasing the strength [2].

For more information on the forming techniques please visit http://www.morgantechnicalceramics.com/downloads/animations
**Introduction Talking Points**

- Ceramics is an ancient field as some of the first ceramic pieces made resembling animals and humans were made back in 24,000 BC. (Image provided)
- Today, ceramics cover a wide range of materials going from coffee mugs to space shuttle tiles and other high tech applications. (Images provided)
- These materials are made by combining a metal with another element which is usually oxygen, carbon, nitrogen or boron in order to make a powder.
- Some of the big advantages of ceramics are that they usually have high melting temperatures and that they are usually very hard.
- The biggest drawback to ceramics is that they are often brittle meaning that they easily break if dropped.
- One of the most important processes in the making of a ceramic is called sintering which is a process where the ceramic powder is heated up to really high temperatures for a specific period of time. (Image provided)
- Sintering causes the density and strength of the material to increase by causing the ceramic particles to bond together.
- To sinter ceramics, it takes very high temperatures and industrial equipment, but we can use plastic to demonstrate the principle at a much lower temperatures.

2. **Activity**
   a. Separate large bowls of various colored Perler beads. Hand out one bowl for each group/table to share.
   b. Give one Perler bead board to each student. Demonstrate how the beads fit onto the pegs.
   c. Encourage the students to make a design of their choice.
   d. Establish a station with an iron set to medium heat. As the students finish have them bring their boards over to be “sintered.”
   e. Place the parchment paper over the beads and run the iron over the paper to heat up the beads for approximately 10 seconds or until the beads have fused together. Depending on the age range, the teacher or assistant may be required to do this part.
   f. Task the students to look closely at how the beads bond together and think about how this could be used to combine small ceramic particles into larger pieces.
   g. When everyone has finished their board, challenge the students to think about how the results might vary. Some example questions are given below.
   h. All finished. Let the students take their “sintered” designs home.
Discussion Questions:

1. How does temperature affect the Perler beads? What would happen if the heat was applied for longer times? What would happen if more heat was applied to the materials?
2. Using the iron, what would happen to the holes of the beads if you continue to heat them? Would the beads eventually close? Would the structure become solid with no gaps?
3. Did you use more than one color? Why? Are you still able to bond the beads together? Sometimes different types of ceramic particles can be sintered together to improve the performance of the material.
4. If you left out some beads, would your design be stronger or weaker?
5. What temperatures do space shuttle tiles have to withstand? What temperature do you think the powder and pellet found in the picture book were sintered at?
   a. Answer: Space Shuttle Tile- 1648°C or 2998°F [3]
   b. Answer: Powder and Pellet- 1500°C or 2732°F

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References:


List of Sintered Ceramic Products:

- Ceramic vegetable peeler, kitchen knives
- Ceramic knife
- Automotive Parts/Aerospace Parts
  - Engine components including brakes, gears, and bearings
    - Ceramic Brake Pads
- Aerospace tiles

- Ceramic Tiles

- Floor/Roof Tiles
- Toilets/Sinks/Tubs
• Plates/Coffee Mugs/Pottery
- Some sports equipment
  - Graphite tennis rackets, golf clubs, fishing poles
  - Ceramic putter face plates
• Sintering Illustration
  o “Un-Sintered” Sand Castle

  o Sintered Brick
• Pre-Sintered Powder and Sintered Ceramic