

Fracture-resistant Ceramics (the Corelle® plate)

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Abstract:

Ceramics are known to be strong in compression but weak in tension. The cause of this behavior is that in tension, there is no plastic deformation that could stop a crack—rather, once a crack forms, it continues to propagate and causes failure. Current research is focused on developing tougher ceramics, but one everyday example, developed in 1970, shows the possibilities. This example is the Corelle® plate. In this demonstration, the toughness of Corelle® is shown, and the instructor can then lead a discussion to help the students understand that the behavior is directly related to the process used to make the plates.

Objectives: The student will be able to
Demonstrate the toughness of Corelle® plates
Show the causes of the observed behavior
Relate the behavior to the design and processing of the structure

MatEd core competencies addressed (most important in bold)

- 7E Illustrate the general nature and behavior of ceramics and glasses
- 7J Demonstrate how materials properties are used in engineering design**
- 14A Distinguish structure, properties and behavior of glass
- 15A Differentiate structure, properties and processing of ceramics
- 16A Distinguish effects of processing and manufacturing variable on materials properties

Key Words: Glass, ceramic, failure, Corelle®, design

Type: Class demonstration

Time Required: Demonstration takes 5 minutes; discussion 5 minutes for introductory students to 15 minutes for advanced students.

Grade Levels:

Grades 4 – college, with increasing focus on causes possible for the more advanced students.

Equipment and Supplies needed:

Supply of Corelle® plates (preferably new, available commercially); an old one could also be used at the end of the demonstration and discussion if you want one to break. Space where the plate can be banged on a table or dropped on the floor (caution as they do break in some cases).

Instructor background and notes

Corelle® plates are made of a 3-layer structure of glass. The inner core is a glass with a high coefficient of thermal expansion, while the top and bottom layers are a clear glass glaze that has a lower coefficient of thermal expansion. The plate is manufactured at high temperature, with all three layers bonded together. Upon cooling, the inner core layer contracts more than the outer layers. This causes the outer layers to be placed in compression while the inner core is in tension. The compressed outer layer resists any cracks since the molecules are pressed together by the compression in the layer. In this case, cracks will generally not form unless a very high stress is applied.

However, Corelle® plates do break. They are safe in the microwave because the microwave energy does not interact with the glass structure. They are not safe in the broiler or on the stovetop since heating the plate will remove the differences in stress between layers (and broiler and stovetop both cause uneven heating as well). Further, the glass structure is subject to a phenomenon called ‘slow crack growth’, not uncommon in glasses and ceramics, whereby surface scratches (perhaps due to the use of eating utensils) start a shallow surface irregularity, which grows with time (each time the plate is stressed). This is why Corelle® is guaranteed against breakage for only 2 years (when originally marketed, the 2 year guarantee was not there and Corning had to replace a lot of plates). The guarantee and other general precautions are given on the back of the plate.

Generally, banging the plate on a table or lectern will not cause breakage. For a new plate, dropping the plate on the floor seldom causes breakage. When the Corelle® plate is older, dropping on the floor may cause breakage, especially on an uneven concrete floor. If dropping on the floor, it is better to drop it so it will hit flat rather than on an edge. It is also best to remove bits of sand from the floor, as a point contact enhances potential of failure. When the plate does break, be aware that it breaks into many sharp pieces, as you might expect from a glass structure. This is because once a crack reaches the core structure, which is under tension; the crack propagates rapidly, which may cause a noisy failure. This is why the plate should be kept away from the students when banging or throwing. However, some demonstrators throw the plate into an unused corner of a room hoping it will fail, since the failure is one that the students will remember for a long time!!

Experimental process: Note that this is a demonstration to be undertaken by the instructor or an advanced student only!

1. Use the plate to get the students’ attention by banging it on a table or lectern.
2. Show the students the plate, identify it by name, and ask if any of them have these plates at home—many do or have had them and will remember them (especially if

- they broke at home).
3. Bang the plate on the table or lectern again and ask why it does not break.
 4. Ask the students if the plate will break if dropped on the floor. Then drop it.
Discuss the result.
 5. Now read the back of the plate: “not for broiler or stovetop use.” Ask the students why this could be a problem.
 6. Explain the structure and processing of the plate to the students. Ask the students again why the plate does not break. Also re-ask the question in #5.
 7. Now read the part on the back with the 2-year guarantee. Ask the students why that is there. Explain slow crack growth and ask students if the same would occur in other ceramics (it does).
 8. (For advanced students) Discuss the effects one would expect if the process for manufacture of the plate were not carefully followed. Focus on material choice, bonding process for the layers, cooling process from processing temperature.
 9. For fun (if you are brave), take an old Corelle® plate and throw it into an unused corner of the room (or outside on a patio) to see if it can be broken. Discuss the results. And bring a broom.

Further study:

1. Using a book on ceramic engineering or materials science, develop the precise process for forming the plate.
2. Do Internet research on Corelle® and write a report on what is available that describes the processing involved with the processing of Corelle®.
3. What other methods can you find that are used to produce tough ceramics? Why are they not used for dinnerware?
4. What other applications of this layered glass process can you think of? Be specific and as creative as you can.

Reference

Technology of Corelle: www.Corelle.com/index.asp

Evaluation

Student evaluation questions (discussion or quiz):

1. Why does the plate usually not break?
2. What is it in the design of the structure of the plate that keeps it from breaking?
3. What causes it sometimes to break?
4. What other objects could you design that could use the same principles to avoid breakage?

Instructor evaluation questions:

1. At what grade level was this module used?
2. Was the level and rigor of the module what you expected? If not, how can it be improved?
3. Did the activity work as presented? Did they add to student learning? Please note any problems or suggestions.

4. Was the background material sufficient for your background? Sufficient for your discussion with the students? Comments?
5. Did the activity generate interest among the students? Explain.
6. Please provide your input on how this module can be improved, including comments or suggestions concerning the approach, focus and effectiveness of this activity in your context.

Course evaluation questions (for the students)

1. Was the activity clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions?
4. Was the instructor able to answer your questions?
5. Was the importance of materials testing made clear?
6. What was the most interesting thing that you learned?