



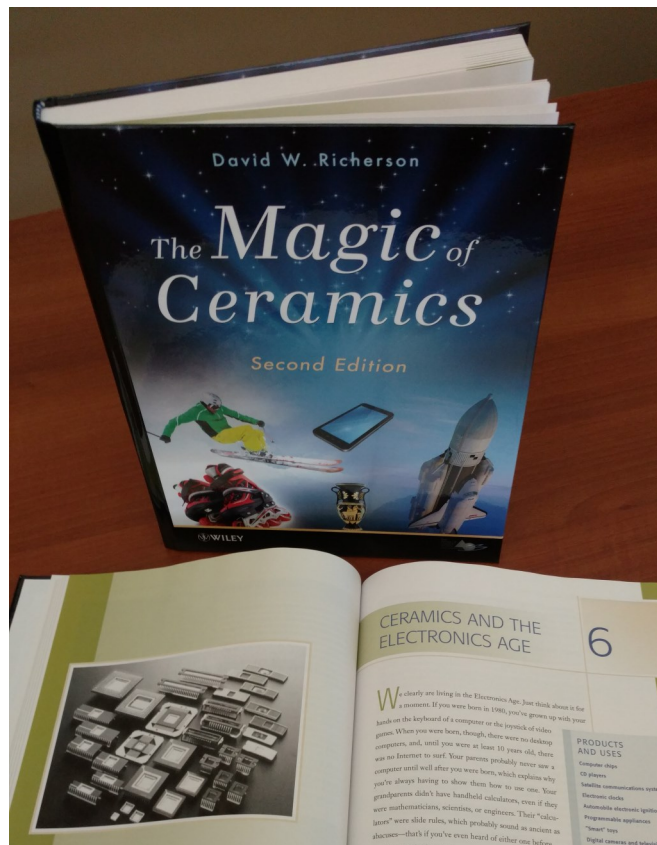
CERAMIC AND GLASS INDUSTRY  
FOUNDATION

# Study Guides

for

## *The Magic of Ceramics*

by David W. Richerson



---

## ***The Magic of Ceramics – Table of Contents***

Introduction: Ceramics are Amazing Materials!	1
Chapter 1: Our Constant Companions	2
Chapter 2: From Pottery to the Space Shuttle	3
Chapter 3: The Beauty of Ceramics	5
Chapter 4: Ceramics and Light	7
Chapter 5: Amazing Strength	9
Chapter 6: Ceramics and the Electronics Age	11
Chapter 7: Piezo Power	13
Chapter 8: Medical Miracles	14
Chapter 9: Ceramics and the Modern Automobile	16
Chapter 10: Heat Beaters	18
Chapter 11: The Hardest Materials in the Universe	20
Chapter 12: Energy Conservation and Conversion Efficiency	22
Chapter 13: From Pollution Control to Zero Pollution	24
Chapter 14: What's New and What's Coming	26



---

## ***The Magic of Ceramics -- Study Guide, Chapter 1***

1. Identify several traditional ceramics.
2. Identify several advanced ceramics.
3. Identify at least 10 ceramic items that might be found in your bedroom.
4. Identify at least 10 ceramic items that are present in most bathrooms.
5. Do you ever wear ceramics? What are a few examples?
6. Identify at least 10 ceramic items that you might encounter in the kitchen.
7. What other ceramics might you find in a house?
8. What ceramic items might you see on your way to school or work?
9. What are some ceramic applications that you might encounter at school or work?
10. What are some other uses of ceramics that you might encounter at the supermarket, at the doctor, or while you are participating in sports?

---

## ***The Magic of Ceramics -- Study Guide, Chapter 2***

1. Traditional ceramics started as crafts and evolved into industries over the centuries. List some examples of traditional ceramics.
2. Modern ceramics are high technology ceramics that were invented during the past century. List some examples of modern ceramics or the products they make possible.
3. Of the applications of ceramics listed in Figure 2-1, name three that you find surprising, amazing, or intriguing.
4. Why were ceramics important to the metals ages?
5. The chamber or furnace in which ceramics are fired is called a kiln. What were some important advances in kilns?
6. What is a glaze and why is it special?
7. Approximately when was glazing first discovered or invented?
8. What did the potter's wheel make possible?
9. Who developed the first kilns capable of firing around 1200° C?
10. What did these higher temperature kilns make possible?
11. When and where was porcelain first developed?
12. When was porcelain finally duplicated in Europe?

13. When was decorative tile first made?
14. What were a couple innovations that made mass production of decorative tiles possible?
15. What is meant by the term “microstructure”?
16. How is glass different from a single crystal or a polycrystalline material?
17. What were some ancient techniques for producing an item made of glass?
18. When was glass blowing invented?
19. What category of materials conducts electricity?
20. What categories of materials generally do not conduct electricity, making them good electrical insulators?
21. What are some uses of single crystal ceramics?
22. What is a “refractory”?
23. Manufacture of automotive spark plugs was the first large-scale use of modern ceramics. What were some of the advances between 1903 and 1940?

---

### ***The Magic of Ceramics -- Study Guide, Chapter 3***

1. When and where were early decorations applied to pottery?
2. What was the nature of these decorations?
3. What is “incising”?
4. Name a benefit of a two-chamber kiln to early decorated pots.
5. When and where were lead-based glazes developed?
6. What was the advantage of a tin-based glaze?
7. What was special about Greek pottery?
8. What was the main glass innovations from the Roman Empire?
9. When and where were decorated pots first produced in China?
10. How were these made?
11. How old is the earliest pottery from the Americas?
12. How did American pottery differ from pottery of the Middle East and China?
13. What happened to ceramics during the Middle Ages?

- 
14. What allowed ceramics innovations to continue in China and Islamic countries during the Middle Ages?
  15. When and where did porcelain emerge?
  16. What is enamel?
  17. What is slip casting?
  18. What is lusterware?
  19. What is sgraffito?
  20. When did interest in ceramic art become strong again in Europe?
  21. When and how did fine ceramics become available to average people, rather than to only the wealthy?
  22. When were European and English pottery techniques introduced in North America?
  23. What innovation in glassmaking was accomplished in the U.S.?
  24. What was the advantage of the Industrial Revolution to ceramics?
  25. What was a negative of the Industrial Revolution?
  26. What are your thoughts regarding the creations shown in Chapter 3? Which ones do you find the most interesting or beautiful?



---

## ***The Magic of Ceramics -- Study Guide, Chapter 4***

1. Explain why a metal is opaque, but some ceramics and plastics are transparent.
2. Explain the meaning of refraction.
3. Approximately how much glass is produced each year in the world?
4. Why is glass so special?
5. What inventions made fiber-optic communications possible?
6. Why is an optical fiber better than copper wire?
7. How many nanometers thick is a human hair?
8. How much of the electromagnetic spectrum is visible to our eyes?
9. Explain how electrons and light interact in a ceramic to cause color.
10. Explain why a ruby appears red to us.

11. Explain why silicon is opaque and also why it is able to convert sunlight to electricity.
12. What is phosphorescence?
13. Name a couple examples of phosphorescent ceramics.
14. What is an electroluminescent lamp?
15. What is a light emitting diode (LED)?
16. Why are LEDs important?
17. When was the first laser invented?
18. What was the role of ceramics in the first laser?
19. What is a photodiode sensor?
20. How is it combined with PLZT to make flash-blindness goggles possible?
21. What is the float glass process and why was it so important?

---

## *The Magic of Ceramics -- Study Guide, Chapter 5*

1. What is a compressive stress?
2. What is a tensile stress?
3. Explain why ceramics are strong in compression and weaker in bending or tension.
4. What is silicon nitride?
5. What are some uses for gas turbine engines?
6. Why is silicon nitride tougher than most other ceramics?
7. What is an advantage of silicon nitride cutting tools?
8. What is the key function or purpose of a bearing?
9. What improvements do silicon nitride bearings provide compared to metals?
10. What is zirconia?
11. Explain the meaning of the term “toughness”.
12. How is toughness increased in a ceramic?
13. What are some uses (products) of transformation-toughened zirconia?
14. What are the purposes or functions of the **fibers** in a composite such as fiberglass?

15. What are the purposes or functions of the **matrix** in a composite such as fiberglass?
16. What are some applications of fiberglass?
17. When were composites with carbon fibers reinforcing epoxy developed?
18. What are some important applications?
19. Polymer matrix composites only have low temperature capability. What materials are used to make composites with high temperature capability?
20. What temperatures can some ceramics withstand? Give a couple examples.
21. Explain the meaning of the term “thermal expansion”.
22. Explain why Hale believed glass would be a better material for the mirrors of very large telescopes.
23. How long did it take to build the 200-inch Palomar telescope?
24. Why did it take so long?
25. Launching a large telescope into orbit was a difficult challenge. What were a couple of the key innovations that made the Hubble Telescope possible?

---

## ***The Magic of Ceramics -- Study Guide, Chapter 6***

1. What are the primary carriers of electricity in a metal wire?
2. What is the pressure that forces electricity to travel through a metal wire?
3. What term is used to describe the amount of electricity that flows through a wire?
4. How do we control the amount of electricity that flows through a wire and an electrical circuit?
5. What happens if electricity is forced through a wire or material that is an electrical resistor?
6. What are some important applications of this effect?
7. What is a semiconductor?
8. What was the importance of the vacuum tube?
9. When was it invented?
10. When was the radio widely available to the average person?
11. When was black and white TV introduced? Color TV?
12. What were the limitations of vacuum tubes?
13. When was the transistor invented?

14. Explain why the transistor was such an important breakthrough.
15. Explain the importance of the integrated circuit (IC).
16. Explain the difference between LSI and VLSI.
17. What products did VLSI make possible?
18. Describe the complexity of a silicon chip such as used for your desktop computer.
19. What is “doping”?
20. List the key steps in fabrication of an IC chip.
21. Describe a “hybrid package” and its purpose.
22. What is an important task for a capacitor?
23. How does a ceramic “block filter” make the cellular phone possible?
24. Why were ceramic superconductors considered such an important breakthrough?
25. What are some applications of ceramic magnets?

---

## ***The Magic of Ceramics -- Study Guide, Chapter 7***

1. What is the amazing magic of a piezoelectric material?
2. When was piezoelectricity first described and by whom?
3. What were some of the earliest applications of piezoelectricity?
4. What are some underwater uses of piezoelectric ceramics?
5. How are piezoelectric ceramics used in industry?
6. How does a piezoelectric material act as a sensor to detect pressure or vibration?
7. What are some uses for piezoelectric ceramics to prevent vibration?
8. What are some other applications of piezoelectric ceramics?

---

## ***The Magic of Ceramics -- Study Guide, Chapter 8***

1. What were two early medical uses of ceramics?
2. What requirements must be met for the repair or replacement of a body part with a material such as a ceramic?
3. What is a bioceramic?
4. When were ceramics first used to replace teeth?
5. What material was used?
6. What are some materials that have been used for hip replacements?
7. Explain how ceramics have greatly improved bone restoration.
8. In what ways are ceramics involved in eye repairs?



9. Identify some important uses of ceramics in making medical diagnoses.
  
  
  
  
  
  
  
  
  
  
10. Why are ceramics important for the CAT scan?
  
  
  
  
  
  
  
  
  
  
11. Describe the impact that the endoscope has had on medicine.
  
  
  
  
  
  
  
  
  
  
12. Explain how ceramics are used in the treatment of liver cancer.
  
  
  
  
  
  
  
  
  
  
13. What are some uses of ultrasonics in medicine?

## *The Magic of Ceramics -- Study Guide, Chapter 9*

1. Before reading this chapter, go outside to your or a family member's car. Look into the engine compartment, under the car, at the passenger compartment, and at the exterior. List at least 10 items that are metal, 10 items that are organic, and 10 items that are ceramic. Do you see any composites?

<b>Metals</b>	<b>Organics (Polymers)</b>	<b>Ceramics</b>	<b>Composites</b>

2. By 1970, how much air pollution was being produced in the U.S. by motor vehicles?
3. Explain how an oxygen sensor works.
4. Explain how a catalytic converter works.
5. How are materials involved in the electronic engine-control system?
6. What materials have been used for water pump seals?



---

## ***The Magic of Ceramics -- Study Guide, Chapter 10***

1. Why do we need materials that can withstand high temperatures?
2. What are the steps in converting metal from mined ore to a finished product?
3. How are ceramics important in preparing ore for extraction of the metal? What are the special characteristics of the ceramics that make them useful?
4. When aluminum oxide is separated into aluminum and oxygen during electrolysis, what happens to the oxygen?
5. What are the benefits of recycling aluminum?
6. What is the temperature inside a modern blast furnace?
7. How does a basic oxygen furnace convert iron to steel?
8. What novel method is used to make ceramic filters for screening out debris in molten metals?
9. How has the ceramic oxygen sensor improved steel making?
10. What is the purpose of a heat exchanger?

11. How are metals formed into complex shapes?
12. What might be an advantage of extruding a metal while hot rather than trying to work it into a shape at a low temperature?
13. Most metal parts require heat treating. What are some important roles of ceramics in heat treating?
14. How large is a furnace for making window glass?
15. How much glass can be produced per day in such a furnace?
16. How are ceramics used in conjunction with a catalyst in chemicals and petroleum processing?
17. How have refractory brick linings been replaced since 1960 to speed up the firing cycle and to reduce energy consumption?
18. About how many high temperature ceramic tiles cover the surface of the Space Shuttle?
19. What special characteristics have been designed into Space Shuttle tiles?

---

## ***The Magic of Ceramics -- Study Guide, Chapter 11***

1. What is the hardest material?
2. How much harder are ceramics than typical metals?
3. What is a cermet?
4. What was the major limitation of early ceramic cutting tool inserts?
5. Name several ceramics with higher toughness that were successfully used as cutting tools.
6. What ceramic coatings have been successful in increasing the life of metal-based cutting tools?
7. What did Tracy Hall achieve in 1954?
8. What temperature and pressure did Hall need to achieve?



---

## ***The Magic of Ceramics -- Study Guide, Chapter 12***

1. How much has our energy consumption increased since 1950?
2. What effect has this had on airborne pollutants?
3. What are the key pollutants that result from burning fossil fuels?
4. How is fiberglass insulation produced?
5. Give an example of the benefit of using fiberglass insulation in homes and buildings.
6. What types of lighting consume less electricity per amount of light emitted than incandescent bulbs?
7. How much more efficient are CFL and LED lighting?
8. What are some uses of LED lighting?
9. How many LEDs were produced by Showa Denko per month in 2008?
10. What has been done since 1965 to improve the fuel efficiency (miles per gallon) of automobiles?



11. Have technology advances kept up with population growth? Explain.
  
12. What can students do, even in the elementary grades, to solve the problems of air pollution?
  
13. How does a ceramic igniter replace a pilot light in a gas appliance?
  
14. What is a heat exchanger?
  
15. How can a heat exchanger make a process more efficient?
  
16. How are ceramics necessary in the nuclear power industry?
  
17. How does a fuel cell work?
  
18. How does it conserve energy and reduce pollution?

---

## ***The Magic of Ceramics -- Study Guide, Chapter 13***

1. What was the primary goal of the Clean Air Act of 1970?
2. Describe the ceramic honeycomb for an early catalytic converter.
3. Compare the exhaust emissions of a 1968 automobile (before the catalytic converter) with those of a Tier 1 automobile.
4. How much have total tailpipe emissions been decreased between 1965 and 2010?
5. What are the health problems associated with diesel vehicle emissions?
6. What is being done to reduce pollution from diesel vehicles?
7. How are ceramics involved in water and sewage treatment?
8. What are the roles of ceramics in hydroelectric power generation?
9. How much concrete was required for the Three Gorges Dam in China?
10. Describe the growth in the use of wind to generate electricity.

- 
11. How are ceramics involved in wind energy?
  12. The amount of energy reaching the earth from the sun is enormous, yet we are only converting a very small percentage to clean electric power. Why?
  13. What is a p-n junction?
  14. Explain how a simple silicon crystalline solar cell works.
  15. What are the advantages of an amorphous silicon solar cell?
  16. What are the disadvantages?
  17. How can a layered amorphous solar cell achieve higher efficiency?
  18. Identify two more thin film solar cell approaches. What are their advantages and disadvantages?
  19. Describe a tandem solar cell. How can it achieve higher efficiency than single-junction cells?

---

## ***The Magic of Ceramics -- Study Guide, Chapter 14***

1. Compare the size of a nanometer, an Angstrom, and a typical atom.
2. What are some reasons that building a material at the nanoscale might result in unique and improved properties?
3. How are nanoparticles synthesized?
4. Fine particles tend to agglomerate into grape-like clusters that are very difficult to compact into close-packed arrangements. Describe two ways to overcome this.
5. What is biomimetics?
6. Explain how silicon carbide single crystal whiskers are grown by the VLS process.
7. Describe how gold was used as a catalyst to grow an oriented array of ZnO nanowires.
8. Describe hydrothermal synthesis of nanorods of ZnO.
9. What is the key difference between a diamond structure and a graphite structure? How does this result in the enormous difference in behavior/properties of these two pure carbon materials?
10. What is graphene?
11. What is a carbon nanotube?
12. What is an atomic force microscope (AFM) and how do ceramics make it possible?

13. Describe the integrated circuit chip that first made the hand-held calculator possible in 1971.
14. Describe the integrated circuit chip that made the microprocessor (Central Processing Unit or CPU) in 1979 that made hard drives, printers, and modems possible.
15. Describe the integrated circuit chip in 1992 that made possible the notebook computer.
16. By 2008, how many transistors could be built into a single chip?
17. How was the technology to miniaturize IC chips applied to flash memories?
18. Compare the memory storage of a 1980 flash memory with that of a 2008 flash memory.
19. What is a charge-coupled device?
20. Compare the capability of a CCD digital image in 1971 to that in 2010.
21. Explain the importance of glass technology to the digital electronics revolution.
22. What is Gorilla Glass?
23. All of these ceramics advances made our miniaturized cell phone possible. After reading all the chapters of *The Magic of Ceramics*, can you now list all of the ceramic technologies in your cell phone?