11.1 Introduction

Ceramics are defined as any inorganic, nonmetallic solid processed or used at high temperatures. Things such as pottery, sanitary whiteware, tiles, table china and the like fit this category, but we often overlook the more "high tech" applications of these (largely) oxides, carbides and nitrides. Many are of great industrial interest due to their unique mechanical properties like durability, wear resistance, machinability, and strength. Ceramics also include materials like glass, graphite, and cement (concrete).

The physical and mechanical properties of ceramics stem from their atomic bonding and crystal structure. This bonding can be ionic or covalent, or intermediate between the two. The absence of free electrons is responsible for making most ceramics relatively poor conductors of electricity and heat. There are many crystal structures for ceramics. These structures are often low in symmetry, which gives some of the materials interesting electromechanical properties. For example, piezoelectricity, the formation of a static electrical charge upon elastic deformation, is exploited to make certain ceramic sensors and transducers.

Ceramic materials are at the core of the materials revolution and form the basis for many high-tech developments in the electronics and communications industries. Ceramics are typically made from raw materials that are relatively abundant and inexpensive (like sand and clay). Traditional ceramics such as pottery, glass, construction materials, and refractories are found nationwide and are commonplace in consumer products. Advanced ceramics with exceptional performance characteristics are found in high-tech applications, such as ceramic engine parts, glass fibers for high bandwidth telecommunications, bioceramics for medical implants, ceramic lasers for cutting and shaping, ceramic sensors, insulators, capacitors, resistors, and opto-electronic devices for integrated electronics, and lightweight refractories for heat protection in space.

11.2 Experiment

In this experiment you will be examining the structure of an alumina (AL2O3) electrical insulator substrate. The structure observed will show the microcrystalline nature of the material. You should be able to determine the average grain size of the material, as well as the deviation from this mean.

Sample Preparation

1. Obtain an alumina wafer and attach it to a specimen stub using a sticky tab.
2. Orient the stub in the AFM so that it can be probed.

Instrument Settings

Follow the operating procedures in Chapter 3 to collect three images. Set the operational parameters for the AFM as follows for each of the three images:

Setting	**Magnification**		
	Low	**Medium**	**High**
On the Controller:			
Reference force (nA)	7.0	7.0	7.0
Magnification	X1	X2	X5
In the Configuration Menu			
Data points (X and Y):	256	256	256
Substeps	8	8	8
Scan Range (X and Y):	300000 Å	150000 Å	60000 Å
Scan Range (Z):	Auto	Auto	Auto
Sample Delay (msec):	.2	.2	.2
Retrace Delay (msec):	.2	.2	.2
Scanline Delay (msec):	0	0	0
Frame Delay (msec):	150	150	150
Data Type:	Topographic	Topographic	Topographic
Z-Gain	1	1	1
Approximate scan time*	(~3.5 min)	(~3.5min)	(~3.5min)

* = Calculated by the True Image software.

11.3 Discussion and Comparison Images

What you should see

You should be able to see an apparently randomly rough surface at each of the magnifications. Notice the grain sizes in the image.

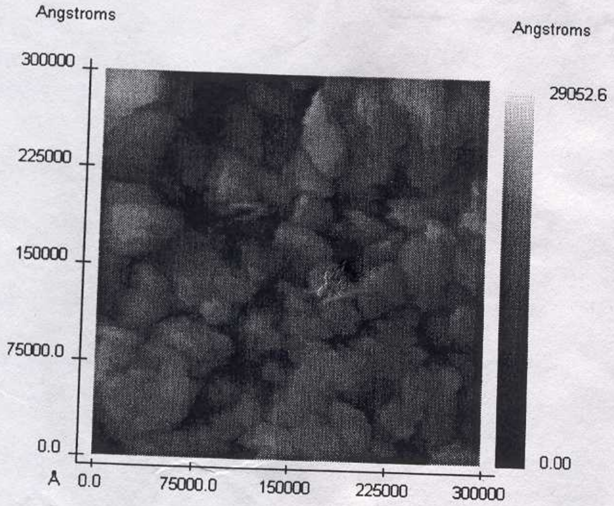

Figure 11.1. Image of an alumina (AL2O3) electrical insulator substrate.

To view a three dimensional perspective of the current image, Select *3-Dimensional* from the *Display* menu.

Images for comparison

Compare your images to the ones stored in the image directory:

- Low mag: ceram1.img
- Medium mag: ceram2.img
- High mag: ceram3.img

Measurement of Grain Size

Using the Cross Section software found under the Analysis menu place some analysis lines (cross section areas) on the image. Place cursors on the peaks in the section, which can be used to estimate the grain size of the material, using the Section Analysis button. Compare the grain size measurements for a variety of cross sections and at all the magnifications used.

11.4 References

Encyclopedia Britianica, 1993.

11.5 Questions

1. Why would AFM imaging of a ceramic surface be superior to other types of high resolution imaging techniques such as electron microscopy?

2. The heat shield tiles for the space shuttle are made of ceramic materials. What differences would you expect to find in them before and after a mission? How would AFM imaging help you in this analysis?