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Chemistry of Smartphones - A Study

[1] Tadappa Ganesh Kumar, [2] Y. Seetha Mahalakshmi
[1]Head, Department of Chemistry, CSSR & SRRM Degree and P.G. college, Kamalapuram, Kadapa, Andhra Pradesh, India
[2]Faculty, Department of English, CSSR & SRRM Degree and P.G. college, Kamalapuram, Kadapa, Andhra Pradesh, India

ABSTRACT

In the 1950s, we would have needed a whole bank of computers on an entire floor of an office building to do what you are able to do with a single smart phone today. Even a low-end smart phone has more computing power than the computer system. The number of smart phone users has increased dramatically in the decade following the release of the first iPhone. From an initial market of 122 million buyers, there are now an estimated 2.3 billion consumers worldwide; set to rise to over a third of the global population by the end of 2018. Amazingly, you can surf the Internet, listen to music, and text your friends with something that fits in the palm of your hand. None of this would be possible without chemistry, and every time you use your smart phone, you are putting chemistry into action. In this article I am explaining some of the chemistry behind smart phones, touch on some of the concepts of what is behind the screen of a smart phone, battery and get really deep into the mechanics of the smart phone and the battery.

Keywords : Rare-Earth Metals, Glass-Ceramic Material, Gorilla Glass, Resistive Touch Screens, Lithium Ion Batteries.

I. INTRODUCTION

Smart phones are a class of multi-purpose mobile computing device. We are so dependent on our smart phones that we often joke about being addicted. Smart phones give us the ability to connect with our friends and family, to news and entertainment, to websites with just a tap of a touch screen. In short: they have become a crucial part of everyday life. If we are wondering what chemistry has to do with smart phones, look at the periodic table. Of the 83 stable (nonradioactive) elements, at least 70 of them can be found in smart phones! That's 84% of all of the stable elements. Metals are what make smart phones so "smart." An average smart phone may contain up to 62 different types of metals. One rather obscure group of metals—the rare-earth metals—plays a vital role. These rare-earth metals include scandium and yttrium, as well as elements 57–71. Elements 57–71 are known as the lanthanides, because they begin with the element lanthanum. The lanthanides often appear as the first of two free-floating rows located at the bottom of the periodic table. Scandium and yttrium are included in the rare-earth metals because their chemical properties are similar to those of the lanthanides.

A single iPhone contains eight different rare-earth metals. If you examine several varieties of smart phones, you can find 16 of the 17 rare earth metals. The only one you will not find is promethium, which is radioactive. Many of the vivid red, blue, and green colors you see on your screen are due to rare-earth metals, which are also used in the phone circuitry and in the speakers. Also, your phone would not be able to vibrate without neodymium and dysprosium.

Rare-earth metals are not only used in smart phones but in many other high-tech devices, too. They are found in televisions, computers, lasers, missiles, camera lenses, fluorescent light bulbs, and catalytic convertors. Rare-earth elements are so important in the electronics, communications, and defense industries.

II. EXPLANATION- STUDY

DISPLAY

When shopping for a smart phone, the single most important feature that people look for is the display. The screen allows you to see the phone's display. If you have ever dropped your phone without damaging the screen, you were probably relieved. Smart phone screens are designed to be extremely tough. This toughness is actually the result of a serendipitous accident. In 1952, a chemist at Corning Glass Works was trying to heat a sample of glass to 600 °C in a furnace when, unbeknownst to him, a faulty thermostat caused it to be heated to 900 °C. Upon opening the door, he was glad—and surprised—to find that his glass sample was not a melted pile of goo and that it had not ruined the furnace. When he took it out with tongs, he dropped it on the floor (another accident). But instead of breaking, it bounced!

Thus was born the world's first synthetic glass-ceramic, a material that shares many properties with both glass and ceramic. Glass is an amorphous solid, because it lacks a crystalline structure (Fig. 1(a)). The molecules are not in any kind of order but are arranged more like a liquid, yet they are frozen in place. Because glass does not contain planes of atoms that can slip past each other, there is no way to relieve stress. Excessive stress forms a crack, and molecules on the surface of the crack become separated. As the crack grows, the intensity of the stress increases, more bonds break, and the crack widens until the glass breaks.

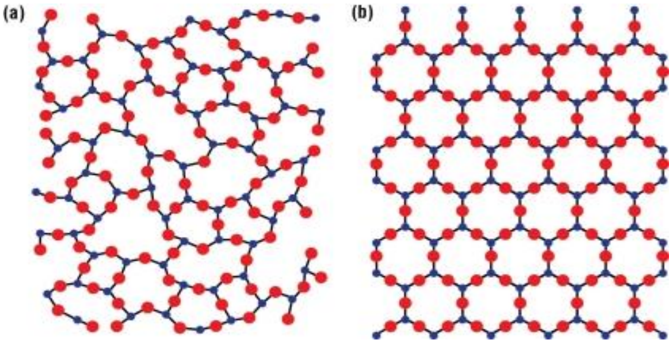

Figure 1. Comparison of the chemical structures of (a) an amorphous solid made of silicon dioxide (glass) and (b) a crystal of silicon dioxide (ceramic)

Ceramics, on the other hand, tend to be crystalline (Fig. 1(b)), and they are often characterized by ionic bonds between positive and negative ions even though they can also contain covalent bonds. When they form crystals, the strong force of attraction between ions of opposite charges in the planes of ions makes it difficult for one plane to slip past another. Ceramics are therefore brittle. They resist compression, but they can break when they are bent.

The combination of glass and ceramic forms a material that is tougher and stronger than each of the materials by themselves. A glass-ceramic is formed by overheating the glass, so a portion of its structure is transformed into a fine-grained crystalline material. Glass-ceramics are at least 50% crystalline, and in some cases, they are more than 95% crystalline.

This amazing glass-ceramic material is so resistant to heat that it has been used in the nose cones of supersonic-guided missiles used by the military. As a result of the success of glass-ceramic materials, the Corning Glass Works Company undertook a large research effort to find ways to make ordinary transparent glass as strong as glass-ceramic products. By 1962, Corning had developed a very strong type of chemically strengthened glass, unlike anything ever seen before. This super-strong glass would eventually make its way to nearly every smart phone screen. It is so strong it goes by the name, Gorilla Glass. Laboratory tests have shown that Gorilla Glass can withstand 100,000 pounds of pressure per square inch! Gorilla Glass is composed of an oxide of silicon and aluminum—also called Aluminosilicate glass—along with sodium ions (Fig. 2).

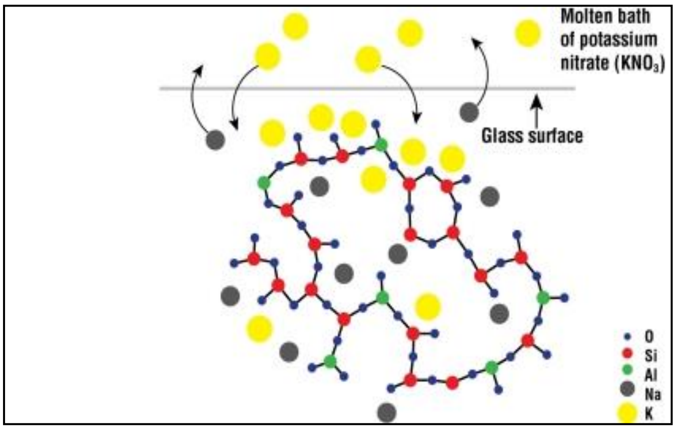

Figure 2. Gorilla Glass Structure

Gorilla Glass, which is used in smart phone displays, is a type of glass that is strengthened by the addition of potassium ions, which replace smaller sodium ions. But Gorilla Glass gains its tremendous strength through one final step, in which the glass is chemically strengthened. The glass is put into a molten bath of potassium salt, usually potassium nitrate, at 300 °C. Because the potassium ions are more reactive than sodium ions, they displace them. Potassium atoms are bigger than sodium atoms, and the same holds true for ions—potassium ions are much larger than sodium ions. Therefore, these potassium ions take up more space in the glass than do sodium ions. In the same way, as the larger potassium ions push against each other, the glass is compressed. Compressed glass is very strong. As a result of this compression, a lot of elastic potential energy is stored in the glass, much like the elastic potential energy that you might find in a compressed spring.

TOUCH SCREEN

As every smart phone user knows, the screen on a smart phone is far more than just a tough piece of glass. It is a screen that responds to your touch—aptly named a touchscreen—giving you a personal connection to your phone.There are two basic categories of touchscreens. The first category of touchscreens, called resistive touchscreens, can be touched with any type of material and they will still work. A pencil works just as well as a finger. You can activate the screen even if wearing gloves. Resistive touchscreens are found in an automated teller machine (ATM) and at checkout counters in stores, where you sign your name for a credit purchase on the display screen.

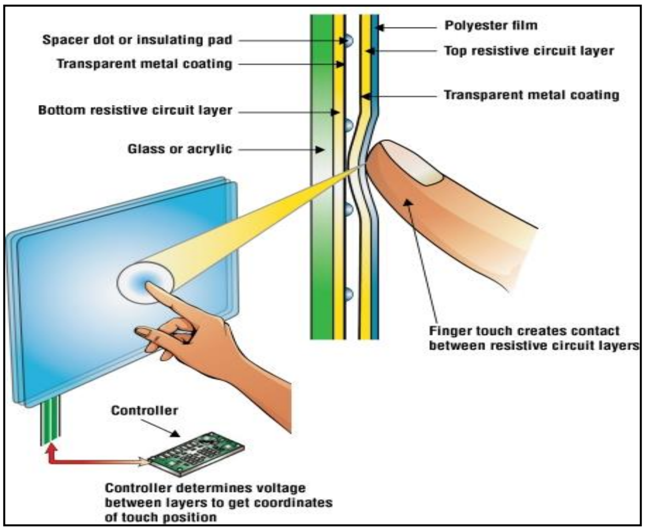

Figure 3. Structure of Touch Screen

Resistive touch screens are composed of two thin layers of conductive material under the surface (Fig. 3). When you press down a resistive touch screen, it physically indents, causing the two layers to touch, completing the circuit and changing the electrical current at the point of contact. The software recognizes a change in the current at these coordinates and carries out the action that corresponds with that spot. Resistive touch screens are also known as pressure-sensitive screens. Only one button at a time can be pressed. If two or more buttons are pressed at once, the screen does not respond. (Figure 3). When a finger presses down on a resistive touch screen, the top and bottom resistive circuit layers are pressed against each other, causing the two transparent metal coatings (left and right) to touch. This leads to a change in the electrical current at the point of contact, which allows a controller within the smart phone to determine the position of the point of contact.

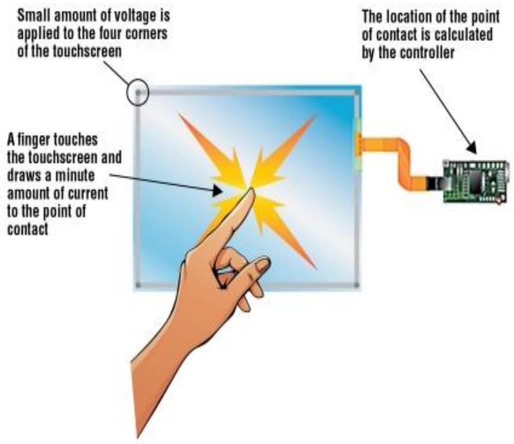

Figure 4. Capacitive Touch Screen

Smart phones use the second basic category of touchscreens, called capacitive touchscreens (Fig. 4), which are electrical in nature. A capacitor is any device that stores electricity. When a finger presses down on a capacitive touchscreen, a very small electrical charge is transferred to the finger, creating a voltage drop on that point of the screen. A controller within the smart phone processes the location of this voltage drop and orders the appropriate action.

Glass, being an insulator, does not conduct electricity. Even though glass contains ions, they are locked into place, stopping electricity from flowing through. So, the glass screen must be coated with a thin transparent layer of a conductive substance, usually indium tin oxide, which is laid out in crisscrossing thin strips to form a grid pattern.This conductive grid acts as a capacitor, storing very small electrical charges. When you touch the screen, a tiny bit of this stored electrical charge enters your finger—not enough for you to feel but enough for the screen to detect. As this electrical charge leaves the screen and enters your finger, the screen registers a voltage drop, the location of which is processed by the software, which orders the resulting action. This tiny bit of electrical current enters your finger because your skin is an electrical conductor—primarily due to the combination of salt and moisture on your fingertips, creating an ionic solution. Your body actually becomes part of the circuit, as a tiny bit of electricity flows through you every time you use the touchscreen on your phone.

BATTERY

The majority of today's phones use lithium ion batteries. These batteries tend to use lithium cobalt oxide as the positive electrode in the battery (though other transition metals are sometimes used in place of cobalt), whilst the negative electrode is formed from carbon in the form of graphite. It will also have an organic solvent to act as the electrolytic fluid. The lithium in the positive electrode is ionised during charging of the battery, and moves into the layers of the graphite electrode. During discharge, the ions move back to the positive electrode. The battery itself is usually housed in an Aluminium casing.

ELECTRONICS

A wide range of elements and compounds are used in the electronics of a phone. The chip, the processor of the phone, is made from pure silicon, which is then exposed to oxygen and heat in order to produce a film of silicon dioxide on its surface. Parts of this silicon dioxide layer are then removed where current will be required to flow. Silicon does not conduct electricity without being 'doped' with other elements; this process involves the silicon being bombarded with a variety of different elements, which can include phosphorus, antimony, arsenic, boron, indium or gallium. Different types of semiconductor (P or N) are produced depending on the element used, with boron being the most common type of P-type dopant.

The micro-electrical components and wiring in the phone are composed mainly of copper, gold, and silver. Tantalum is also used, being the main component of micro-capacitors. A range of other elements, including platinum and palladium are also used, but detail on the specific applications of these was a little tricker to track down! Solder is used to join electrical components together – this was, in years past, usually composed of tin and lead, but in recent years lead-free alternatives have been sought, many of which use a combination of tin, silver and copper.The microphone and speaker of the phone both contain magnets, which are usually neodymium-iron-boron alloys, though dysprosium and praseodymium are often also present in the alloy. These are also found in the vibration unit of the phone.

CASING

The elements present in the phone casing will depend on whether the case is metal or plastic, or a mix of the two. Metal casings can be made of magnesium alloys, whilst plastic casings will, of course, be carbon based. The casing will often also contain flame retardant compounds – brominated flame retardants are still often used, but efforts are being made to minimise the use of these, and so other organic compounds that do not contain bromine are now more frequently employed.

The silicon dioxide layer on the semi-conductor device prevents current from flowing in areas of the semiconductor where this is not desired, namely between the transistors (essentially a form of switches) and the silicon. Transistors are constantly getting smaller and smaller, and as they do so, there is also a requirement for the insulating layer between them and the silicon to become thinner. However, this is limited by the size of silicon atoms, and the fact that, once down to about 5 atoms thick, the layer leaks current and becomes inefficient.To combat this, hafnium based layers were utilised instead; this also requires use of a different material for the transistors, with both titanium nitride and titanium Aluminium nitride being employed. To connect the transistors with the interconnecting copper layers in the semi-conductor, tungsten is used as a contact. Tungsten also finds use outside the semiconductor device, as weights for the vibrating motors within the phone. The strive to improve the semiconductor devices still further is ongoing, and the possibility of introducing group III-V element compounds into the transistor structure, such as GaAs, InP and InAs, is a possibility that could allow electron mobility to improve, and in turn allow semiconductors to become smaller still.

III. CONCLUSION

Smart phone technology is evolving at a dizzying pace. You can now use your smart phone to check your blood sugar, adjust your home's thermostat, and start your car. Twenty years ago, no one envisioned that people would someday take more pictures with their cell phones than with their stand-alone cameras. It is anyone's guess what will come next. Thanks to the intersection of chemistry and innovation, the possibilities are limitless.

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