Phones with cords! Phones that just ring! Phones too big to fit into a pocket! Phones with no games or digital cameras! Old-fashioned phones will soon be just a 20th century memory. Cell phones have arrived everywhere, and in Africa, they are transforming a continent.

In fact, in many parts of the African continent, there has never been land-line service. Cell phones are the first telephones many people have ever had. Since it's easier to build a few cell phone towers than miles and miles of old-fashioned phone lines, cell phones are causing technological "leapfrogging" by bringing wireless communication to people who never even had wires.

But, to one part of the continent, cell phones have brought problems and dangers. The Democratic Republic of Congo is a huge country, one-and-a-half times the size of Alaska. Nearly 60 million people call it home. Sitting in the middle of central Africa, Congo is rich in mineral wealth such as diamonds, gold, copper—and a rare mineral called coltan. Coltan is a mineral containing the element tantalum (Ta). Why is this important? Because tantalum is found in almost every cell phone, and without tantalum, cell phones might not exist.

Some scientists think up to 80% of the coltan in the earth's crust is beneath the Congo. Yet most of the coltan used in cell phones is mined in Australia. Coltan could make the Congo rich, but, during the 1990s, it fueled a brutal civil war.

Why is tantalum so important to cell phones? Why didn't Congo's tantalum make the Congolese people wealthy? The answers to these questions lie in a story where chemistry, physics, and world events all meet.

TANTALUM, CONGO, AND YOUR CELL PHONE

By Mark Michalovic

Inside every cell phone is a capacitor

We use tantalum to make devices called *capacitors*, and your cell phone won't work without them. A capacitor allows electrical energy to be stored up slowly over a period of time and then releases it when a big burst of energy is required. Camera flashes illustrate how capacitors work. When a flash is required, your camera produces a bright burst of light for just a split second. This burst requires more power than small camera batteries can provide. So in most cameras, the batteries slowly feed their energy into a capacitor over many seconds or even minutes. Then, when you take a picture, the capacitor releases all of the stored energy at once, allowing the flash to shine brilliantly for an instant. Cell phones use capacitors for many tasks, such as filtering out interference from radio signals.

How capacitors work

You can make a very simple capacitor by connecting two wires to a battery: one wire to the positive terminal and the other to the negative terminal. Next, you connect each wire to a different metal plate. If the plates are held parallel to each other, very close but not touching, current will flow through the wires. Electrical current is the movement of electrons from atom to atom in a conducting material, like copper. You can think of the battery as a kind of "electron pump" for moving electrons through the wire. In our simple capacitor, the battery "pumps" electrons from the metal plate attached to the positive terminal of the battery, through the wires, through the battery itself, and through the other wire to the other plate. After a while, there will be a large accumulation of electrons on the metal plate attached to the negative terminal. Because an electron has a negative charge, there will be a big buildup of negative charge on the metal plate attached to the negative terminal. Meanwhile, there is a lack of electrons on the metal plate attached to the positive terminal; thus, a positive charge develops there (see Figure 1).

TONY FERNANDEZ

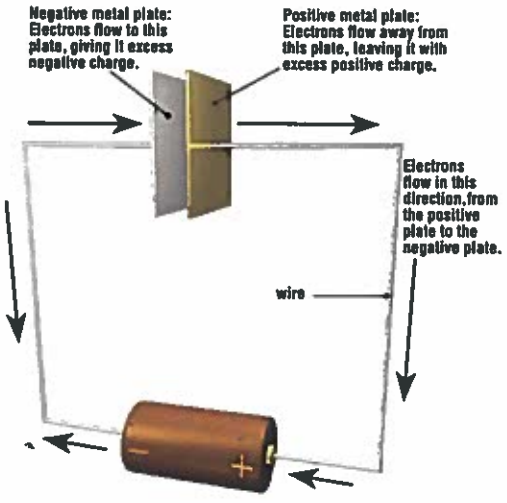


Figure 1. Schematic of a simple capacitor.

The air between the plates does not conduct electricity. That means it does not let the electrons flow across the gap between the plates. We call the air a *dielectric* or *insulator*. In most capacitors, a solid insulator is used instead of air. Because a dielectric (the air) doesn't conduct electricity, the electrons that build up on the negative plate can't jump across the gap to the positive plate and complete the electrical circuit. So we're left with a large buildup of negative charge on one plate and a large buildup of positive charge on the other.

Now let's say we took the battery out of our home-made capacitor device and replaced it with a light bulb. Because all of those electrons that had built up on the negative plate were "pumped" there by the battery, removing the battery removes the only thing keeping those electrons in place. By replacing the battery with a light bulb, we are letting all those electrons flow backward, through the wires, through the light bulb, and back to the positive plate until there are no extra electrons left on the negative plate. Both plates become electrically neutral. This flow of electric charge is called *discharging*. While it took some time for all those electrons to build up on the negative plate (charging), the electrons will flow back all at once (discharging), and the energy of those moving electrons will make the light bulb burn brilliantly for just a split second. Then, when there are no more extra electrons left on the negative plate, the light bulb will go out.

Of course, our homemade capacitor is way too large to fit inside your average flip phone. To make capacitors small enough to fit inside cell phones, scientists and engineers had to figure out ways to make capacitors very tiny. The capacitors in cell phones are so small that they are known as "pinhead capacitors."

In cell phones, where smaller is better, tantalum is the only real choice for making capacitors. Tantalum is clearly very special, but unfortunately, very rare.

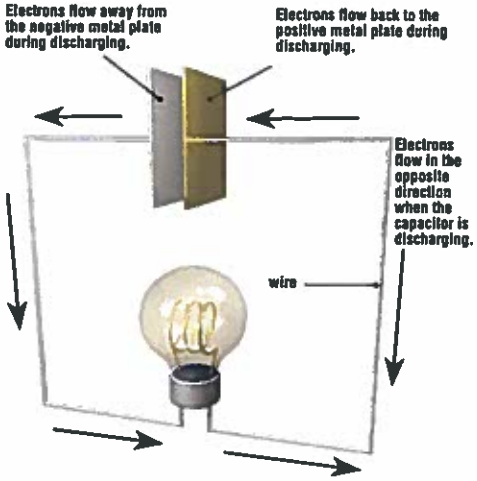
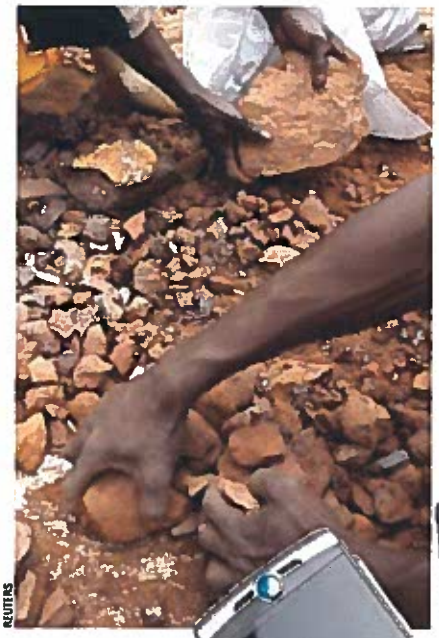


Figure 2. Schematic of a simple capacitor discharging.

Tantalum metal most often occurs in the form of a mineral called *tantalite*, a compound of tantalum, iron, manganese, and oxygen. It is often found mixed with a similar mineral called columbite. The mixture of these two ores is called columbite-tantalite, or coltan, for short. Coltan is not a very common substance in the earth's crust. With the ever-increasing manufacture of cell phones, scarce coltan becomes more precious every day. The Congo, as a rich source of coltan, must be prospering greatly. Unfortunately, this is not the case.

Coltan wars

In 1997, a civil war broke out in the Congo. With the country in chaos, foreign armies invaded. Some of the armies were from Uganda and Rwanda, two nations just



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east of the Congo. The Ugandans and Rwandans took control of the parts of the eastern Congo, which held the richest deposits of coltan. Many tons of coltan were mined and smuggled out of the country by the invaders, who sold the coltan to foreign companies. Although Congolese men worked mining the coltan and earned some money by doing so, much of the money ended up in Uganda and Rwanda rather than in the pockets of the Congolese people. Worse still, there were reports the Rwandan army was using prisoners as slave labor to mine the coltan.

Foreigners weren't the only ones stealing coltan. Antigovernment Congolese rebel armies mined coltan, too. They smuggled it out of the country and sold it on the black market. The rebels then used the money to buy weapons. Meanwhile, the various armies fought each other over control of the coltan mines.

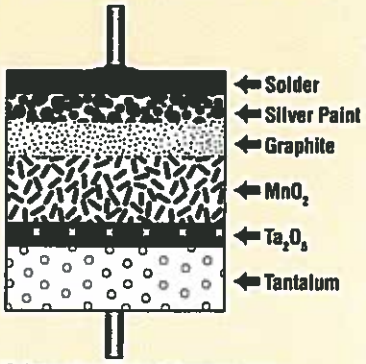
As news spread that people were killing and dying over Congo's coltan, people started calling the coltan stolen from Congo "blood tantalum." In Europe, a group organized under the banner, "No Blood on My Cell Phone." This organization called for a boycott of Congolese coltan. In 2001, manufacturers like Nokia and Motorola demanded that their suppliers only sell them capacitors without "blood tantalum." Thus, manufacturers of capacitors started to refuse coltan from the war zones, and air freight companies refused to transport Congolese coltan. As a result, coltan mining in Congo nearly stopped altogether. To this day, only a small amount of coltan from the Congo ends up in cell phones. Most likely, your cell phone contains capacitors made from Australian, Canadian, or Brazilian coltan.

In 2002, the foreign armies left the Congo, but the civil war raged on. Even today, the country sustains an uncertain peace. What's more, all that coltan—the coltan that isn't being stolen any more—is now just sitting in the ground. No one is mining it . No one is selling it. And the Congolese people—many unemployed, many poor—aren't profiting from their valuable resource.

Although there remains hope for better days in the Congo, problems remain to be solved, problems that only a strong and stable government can tackle. Even if coltan mining does start again, some people fear that most of the money from the coltan will end up in the hands of foreign mining companies instead of staying in the Congo. With this problem eliminated, the Congo may finally benefit from the unique chemistry of the element in the ground beneath their feet.

What makes tantalum special?

Tantalum has a special property that suits it for the production of the miniscule capacitors needed for cell phones. Most metals spontaneously oxidize, form compounds with oxygen, in air. For example, aluminum oxidizes so quickly that any piece of aluminum exposed to the air is quickly coated with a thin layer of aluminum oxide (Al_2O_3). This coating makes aluminum resistant to corrosion as it forms a protective cover over the aluminum metal surface. Tantalum resembles aluminum in that it also oxidizes easily. Any piece of tantalum exposed to air gets coated with a thin layer of tantalum (V) oxide (Ta_2O_5). Unlike tantalum metal, tantalum (V) oxide does not conduct electricity. This means that a layer of tantalum, when, covered with an oxidized surface and placed in contact with another piece of foil made of tantalum or some other metal, will form a nice capacitor. A layer of manganese (IV) oxide serves as the cathode, which collects the current across the insulating layer when the capacitor discharges. The current is passed on through the conductive graphite and metal layers and onto the circuit via a wire. The tantalum (V) oxide forms a dielectric (insulator), while metal (often silver) and the tantalum layer are the plates of the capacitor.



Schematic of a tantalum capacitor.

In a capacitor, the closer the plates are to each other, the more electrical charge the capacitor will be able to store. Tantalum (V) oxide is an extremely good insulator. This means that even a very thin layer of tantalum (V) oxide on the surface of a layer of tantalum metal can act as an effective dielectric for a capacitor. Since this oxide layer is so thin, the metal "plates" of this capacitor can be very close together. This means a small tantalum capacitor can hold more electrical charge than a larger capacitor made from another metal.

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Mark Michalovic is an education consultant for the Chemical Heritage Foundation in Philadelphia, and is an adjunct professor of chemistry at Camden County College." His last article, "The Race for Iodine," appeared in the December 2006 issue.