How Photocopiers Work

by Ann Meeker-O'Connell

Walk into almost any business office, and you'll probably find a photocopier ("copier") with a line of people waiting to use it. For most businesses, small or large, the copier has become standard equipment, much like having a desk to work at and a chair to sit in.

Photo courtesy Xerox

A typical business photocopier from Xerox

What if you had to resort to making carbon copies of important documents, as many people did before copiers came along? Or worse, imagine how tedious it would be if you had to recopy everything by hand! Most of us don't think about what's going on inside a copier while we wait for copies to shoot neatly out into the paper tray, but it's pretty amazing to think that, in mere seconds, you can produce an exact replica of what's on a sheet of paper! In this edition of **HowStuffWorks**, we will explore what happens after you press "Start" on a photocopier.

The Basics

The human-end of making a copy begins with a few basic steps:

- Open the copier lid
- Place the document to be photocopied face-down on the glass
- Select the options you want (number of pages, enlargements, lighter/darker)
- Press the Start button

What happens inside the copier at this point is amazing! At its heart, a copier works because of one basic physical principle: **opposite charges attract**.

As a kid, you probably played with static electricity and balloons. On a dry winter day, you can rub a balloon on your sweater and create enough static electricity in the balloon to create a noticeable force. For example, a balloon charged with static electricity will attract small bits of paper or particles of sugar very easily.

A copier uses a similar process.

- Inside a copier there is a special **drum**. The drum acts a lot like a balloon -- you can charge it with a form of static electricity.
- Inside the copier there is also a very fine black powder known as **toner**. The drum, charged with static electricity, can attract the toner particles.

There are three things about the drum and the toner that let a copier perform its magic:

- The drum can be **selectively** charged, so that only parts of it attract toner. In a copier, you make an "image" -- in static electricity -- on the surface of the drum. Where the original sheet of paper is black, you create static electricity on the drum. Where it is white you do not. What you want is for the white areas of the original sheet of paper to NOT attract toner. The way this selectivity is accomplished in a copier is with light -- this is why it's called a **photocopier**!
- Somehow the toner has to get onto the drum and then onto a sheet of paper. The drum selectively attracts toner. Then the sheet of paper gets charged with static electricity and it pulls the toner off the drum.
- The toner is **heat sensitive**, so the loose toner particles are attached (fused) to the paper with heat as soon as they come off the drum.

The **drum**, or belt, is made out of **photoconductive** material. Here are the actual steps involved in making a photocopy:

- The surface of the drum is charged.
- An intense beam of light moves across the paper that you have placed on the copier's glass surface. Light is reflected from white areas of the paper and strikes the drum below.
- Wherever a photon of light hits, electrons are emitted from the photoconductive atoms in the drum and neutralize the positive charges above. Dark areas on the original (such as pictures or text) do not reflect light onto the drum, leaving regions of positive charges on the drum's surface.
- Negatively charged, dry, black pigment called **toner** is then spread over the surface of the drum, and the pigment particles adhere to the positive charges that remain.
- A positively charged sheet of paper then passes over the surface of the drum, attracting the beads of toner away from it.
- The paper is then heated and pressed to fuse the image formed by the toner to the paper's surface.

This diagram helps see the process:

When the copier illuminates the sheet of paper on the glass surface of a copier, a pattern of the image is projected onto the positively charged photoreceptive drum below. Light reflected from blank areas on the page hits the drum and causes the charged particles coating the drum's surface to be neutralized. This leaves positive charges only where there are dark areas on the paper that did not reflect light. These positive charges attract negatively charged toner. The toner is then transferred and fused to a positively charged sheet of paper.

Inside a Photocopier

If you take a photocopier apart, you might be overwhelmed by how many different parts there are. However, the actual photocopying process relies on only a few, key pieces:

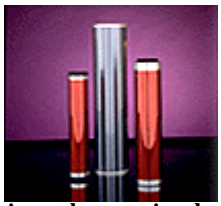
- **Photoreceptor drum** (or belt)
- **Corona wires**
- **Lamp and lenses**
- **Toner**
- **Fuser**

In the following sections, you'll learn about each of these parts.

Photoreceptor Drum

The **photoreceptor drum** (or, in some photocopiers, belt) is the heart of the system. A drum is basically a metal roller covered by a layer of **photoconductive** material. This layer is made out of a **semiconductor** such as selenium, germanium or silicon. What makes elements like selenium so cool is that they can conduct electricity in some cases, but not in others. In the dark, the photoconductive layer on the drum acts as an insulator, resisting the flow of electrons from one atom to another. But when the layer is hit by light, the energy of the photons liberates electrons and allows current to pass through! These newly freed electrons are what neutralizes the positive charge coating the drum to form the latent image.

It's easy to imagine how you might project a copy of an image on a photoreceptive belt that has roughly the same dimensions as the sheet of paper containing the image. A problem emerges when you think about doing the same thing on a thin, cylindrical drum. How can the surface area of the drum possibly match the real estate on a sheet of paper? The solution is to simply rotate the drum while you're making a copy. If you rotate the drum in lockstep with the movement of the light beam across the original document, you can build the image strip by strip. After one strip of light is focused onto a corresponding swath of the drum, the drum rotates to expose a fresh area of the photoconductor. Meanwhile, the previously exposed



Various photocopier drums

region of the drum swings into contact with the toner, and then with the paper.

Because the length of a standard printed page is a lot larger than the circumference of the drum in a modern photocopier, one full rotation of the drum will only replicate a small piece of the page. The drum actually has to be cleaned, recharged with ions, exposed to photons, and sprinkled with toner multiple times in order to duplicate the entire original. To the casual observer, the process appears continuous, because it's all seamlessly coordinated inside the photocopier as the drum rotates.

Corona Wires

For a photocopier to work, a field of positive charges must be generated on the surface of both the drum and the copy paper. These tasks are accomplished by the **corona wires**. These wires are subjected to a high voltage, which they subsequently transfer to the drum and paper in the form of static electricity.

Photo courtesy Xerox

The corona wire uses static electricity to coat both the photoreceptive drum and the copy paper with a layer of positively charged ions.

One of these wires is stretched parallel to the drum surface and charges the photoconductive surface with positive ions, and the other wire is positioned to coat the paper's surface as the paper shoots by on its way to the drum.

Lamp and Lenses

Making a photocopy requires a **light source** with enough energy to boot electrons out of the photoconductive atoms. What wavelengths of light can do this? It turns out that most of the visible spectrum of light contains enough energy to drive the process, especially the green and blue end of the spectrum. Anything lower than the red portion of the visible spectrum doesn't have enough gusto to activate the photoconductor. And, although UV light has more than enough firepower to make a photocopy, it can be very damaging to our eyes and skin. This is why photocopiers use a plain old **incandescent** or **fluorescent** bulb to flash light onto the original document.

A strong lamp illuminates the sheet of paper to be copied.

When the lamp in the copier is turned on, it moves across the inside of the copier, illuminating one strip of the paper at a time. A mirror attached to the lamp assembly directs reflected light through a lens onto the rotating drum below. The lens works just like the one on your camera. It allows you to focus a copy of the image in a specific place. Although you can't really focus the image on a photocopier to make the final product more or less blurry, you can change the distance between the lens and the original or between the lens and drum to either **reduce** or **magnify** the size of the original image on your copy.

Toner

Toner is sometimes referred to as **dry ink**, but toner isn't actually ink at all! Ink is a pigmented liquid. Toner is a fine, negatively charged, plastic-based powder. The black color in photocopier toner comes from pigments blended into the plastic particles while they are being made.

In your photocopier, toner is stuck on larger, positively charged beads and stored inside a toner cartridge. When toner-coated beads are rolled over the drum, the toner particles find the positively charged ions on the unexposed areas on the drum's surface much more attractive than the weakly charged bead. The same particles are subsequently even more drawn to the electrostatically charged paper. The plastic in the toner lets you keep it from jumping ship once you've finally got it on the paper; all you have to do is apply heat to the toner, and the plastic particles melt and fuse the pigment to the paper.

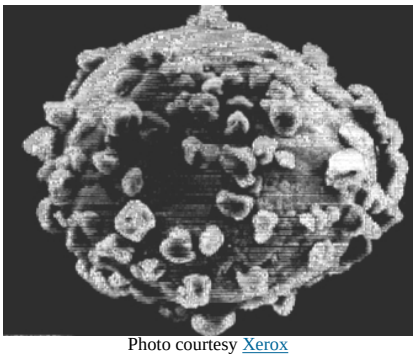


Photo courtesy Xerox

A small bead coated with particles of toner

The Fuser

The fuser provides the finishing touches that make the toner image on a sheet of paper permanent. The fuser has to do two things:

- Melt and press the toner image into the paper
- Prevent the melted toner and/or the paper from sticking to the fuser

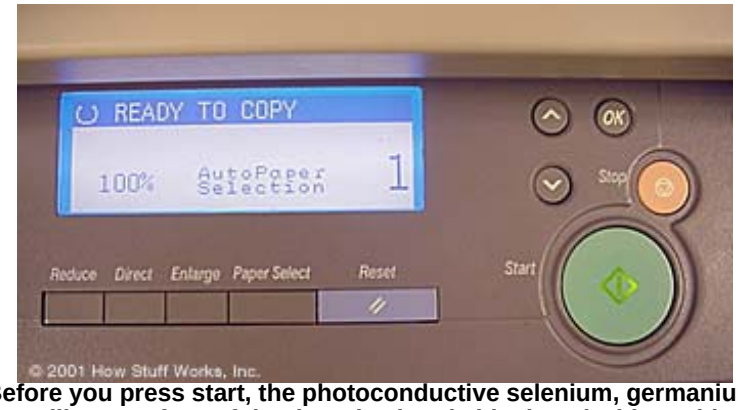
All that's required to accomplish these tasks is **quartz tube lamps** and **Teflon-coated rollers**. The sheet of paper is sent between two of the rollers. Then, the rollers gently press down on the page to embed the toner in the paper fiber. Meanwhile, inside the rollers, the lamps are on, generating enough heat to melt the toner. Why doesn't the toner melt onto the rollers instead? Just like non-stick coating prevents your dinner from becoming glued to the bottom of your frying pan, the Teflon coating the rollers keeps the toner and paper from sticking to them.

Putting It All Together

In a photocopier, the **light-induced conductivity** of the drum is exploited to create a **latent image** in the form of electrical charges on the surface of the drum. This image is made visible and transferred to paper using a special, charged toner. Here's how it all comes together to make a copy:

1. For the photocopier to work its magic, the surface of the photoconductive material must first be coated with a layer of

positively charged ions by the **corona wire**.



Before you press start, the photoconductive selenium, germanium, or silicon surface of the drum is already blanketed with positive charge.

2. When you hit the Start button, a strong lamp moves across the inside of the copier and casts light onto the paper you're copying, and the drum starts to rotate. As light reflects off of blank areas of the paper, mirrors direct it through onto the drum surface. Like dark clothing on a hot sunny day, the dark areas of the original absorb the light, and the corresponding areas on the drum's surface are not illuminated.
3. In the places that light strikes the rotating drum, the energy of the photons kicks **electrons** away from the photoconductive atoms.
4. Opposites attract -- the positively charged ions coating the photoconductive layer attract the freed electrons. The marriage of one ion and one electron produces a **neutral particle**. Charged particles remain only in places where light didn't hit the drum because it wasn't reflected from the original -- the dark spaces taken up by text and pictures on the page!

   This part of the process loosely resembles how a camera takes a picture. If you've read How Photographic Film Works, you know that when film is exposed to light, the energy of the photons causes chemical changes in the **silver halide grains** coating the film. This creates a **negative image** of what you see through the viewfinder. With a photocopier, however, you end up with a **real image** created from a pattern of positive charges left after exposure to light. And while you have to develop film using special chemical processes and print it on light-sensitive photographic paper, the photocopier produces a visible image with only dry ink, heat and regular paper.
5. **Voltage** is applied to the aluminum core of the drum. Since light renders selenium conductive, current can flow through the photoconductive layer while the drum is being illuminated, and the electrons released by the atoms are quickly replaced by the electrons that form the current flowing through the drum.
6. The exposed areas of the drum rotate past **rollers** encrusted with beads of toner. Tiny particles of toner are pressed against the drum's surface. The plastic-based toner particles have a negative charge and are attracted to areas of positive charges that remain on the drum's surface.
7. The **corona wire** passes over a sheet of paper so that the paper's surface becomes electrically charged.
8. The area of the drum freshly coated with toner spins into contact with a positively charged sheet of paper. The electric field surrounding the paper exerts a stronger pull than the ions coating the drum's surface, and the toner particles stick to the paper as the drum passes by.
9. Once the entire original has been recreated on toner in the page, the paper proceeds on through the copier to the **fuser**. The weak attraction between the toner particles and the surface of the sheet of paper can easily be disrupted. To fix the toner image in place on the paper's surface, the entire sheet is shunted through the **fuser's heated rollers**. The heat melts the plastic material in the toner and fuses the pigment to the page.

By the time you reach for your copy in the collection tray, the photocopier has already prepared for the next go-round by again cleaning off the drum's surface and applying a fresh coat of positively charged ions to it.

For more information, check out the links on the next page.

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