How do rewriteable CDs work?

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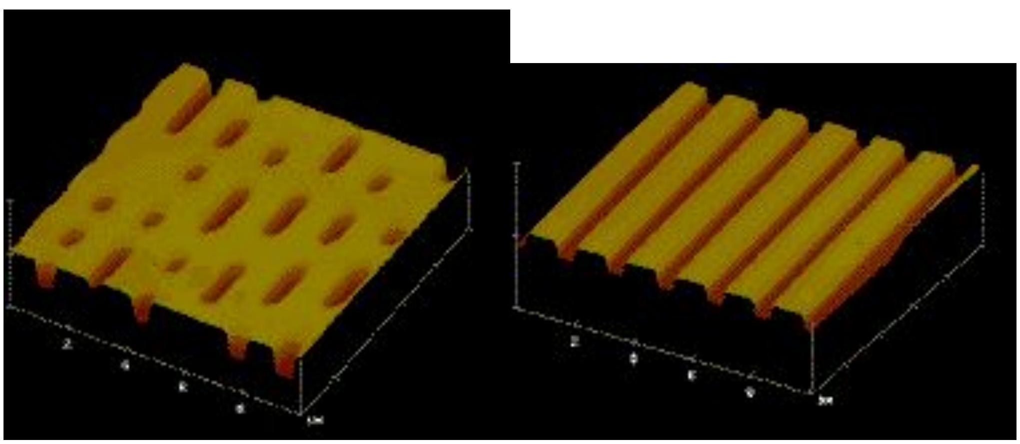
Optical substrates expert Chad R. Sandstrom of Imation Corporation provides the following explanation:



Images: COURTESY OF CHAD SANDSTROM

CD-Audio and CD-ROM were established in the early 1980s as the "new thing" to replace the venerable analog long-playing record. This digital format was very quickly accepted as the standard because it provided compact size, high fidelity and tremendous durability. But soon the consumer, accustomed to recording LPs onto magnetic tapes, demanded the same ability in the new compact disc format. New technology made that possible a few years later with CD-R (recordable CDs) and then CD-RW (rewriteable CDs).

CD-Audio and CD-ROM feature a spiral of pits on a molded plastic substrate overcoated with a reflective aluminum alloy. The regular topography on the disc (*see atomic force microscope scan, top right*) causes the reflected light to "modulate" from bright to dark as the laser beam scans from an area with no pit to one with a pit as the disc spins under the focused laser beam in the drive.

To make a recordable disc, you start with a plastic substrate that has blank grooves rather than a predefined pattern of pits. The blank grooves can keep the drive on track before the data is written. In addition to a layer of metal, the media includes a thin layer of dye. Pulsing at high power, the laser in the drive can ablate or "burn" marks in the dye. Read back with the laser at the normal, lower read power, those marks look like pits to the detectors in the drive. Because the high laser power permanently changes the dye, this format can be written only once.

For additional rewriteable capability (CD-RW), a thin layer of so-called phase-change metal replaces the dye layer. That material requires two extra "dielectric," or glassy, layers for protection. The drive employs a high-power laser to write amorphous marks in the metal layer, an intermediate-power level to write crystalline marks and a low-power level to read the recorded data. To the drive, the crystalline areas appear bright and the amorphous areas appear dark. As a result, the disc can be read in the same manner as a CD-ROM. The crystalline-to-amorphous transition is reversible. CD-RW media (*see atomic force microscope scan, bottom right*) can thus be rewritten approximately 1,000 times. In both CD-R and CD-RW, the difference between bright and dark regions is not as stark as that in CD-ROM technology. But newer drives tend to be able to read the various formats.

Gordon Rudd of Clover Systems offers this answer:

All CDs (and DVDs) work by virtue of marks on the disc that appear darker than the background and can thus be detected by shining a laser on them and measuring the reflected light. In the case of molded CDs, these marks consist of "pits" molded into the surface of the disc. Destructive interference of the laser beam caused by the difference in path length between the bottom of the pit and the surrounding "land" causes the pits to appear darker than the background. In the case of CD-Recordables (CD-Rs), the writing laser makes permanent marks in a layer of dye polymer in the disc. These marks, too, appear dark compared with the background.

CD-Rewriteable discs (CD-RWs) work in a similar fashion, except that the change to the recording surface is reversable. Instead of dye or pits, these discs feature a layer of phase-change material. This material can exist in two different solid states: crystalline or amorphous. Most solids have a crystalline structure in which the atoms are close packed in a rigid and organized array. But some materials can have an amorphous state in which the atoms are organized not into arrays but randomly, as in a liquid. A common example of such a material is ordinary window glass, an amorphous form of silica.

The phase-change material can change from one phase to the other when it is heated and cooled. The material used is chosen because the two solid states reflect light differently. The amorphous state reflects less light than the crystalline state does. Therefore, by starting with a disc surface in the crystalline state, heating with the laser can change small spots to the amorphous state, which will appear dark upon playback.

Heating the material with the laser beam above its melting point transforms it from crystalline to amorphous. The rapid cooling of the spot causes the material to freeze in the amorphous state. These spots can then be erased in a process known as annealing. This is accomplished by heating the material to a lower temperature, which transforms it back to its crystalline state. Existing data can be overwritten by turning the laser on continuously to the erase power, which will erase any existing marks. Switching the laser to a higher power, one sufficient to melt the material, enables the creation of a new mark.

Sony Electronics marketing manager Robert DeMoulin writes:

Compact Disc Recordable (CD-R) is a write-once technology. Once an area of the disc has been written to, it cannot be erased. The recordable layer is an organic cyanine or pthalocyanine dye. Initially, the organic dye has high reflectivity. When the laser is applied in write mode, however, a chemical reaction occurs that makes that "pit" less reflective than the "land" around it. During readout, the laser detects the difference in reflectivity between the "pits" and "lands" to read the data or music. CD-R discs are highly reflective--about 60 to 70 percent of light is reflected or bounced back to the photo detector or read laser. Because of this high reflectivity, CD-R discs can be read or played back in most CD players and CD-ROM drives.

Compact Disc Rewriteable (CD-RW) is a fully rewriteable media, meaning that any spot on a CD-RW disc can be rewritten up to 1,000 times (based on the current standard). Phase change technology enables this rewriteability. The recordable layer on a CD-RW disc is made up of a rare-earth metal alloy "sandwich," which includes silver, indium antimony and tellurium elements.

This combination of elements has an important property: it allows a spot on the disc to be changed by the heat of a laser from a crystalline state (high reflectivity) to an amorphous state (low reflectivity). Heated to a lower temperature or power level, the same spot changes back to crystalline state. When overwriting data, the laser is modulated first to erase (or make crystalline) the spot to be recorded and then modulated to write power.

Phase change technology does have a limitation: it has very low reflectivity (approximately 25 percent). For this reason, a typical consumer CD player won't recognize a CD-RW disc.