Question

What is a resettable (PPTC) fuse, and how does it work?

Answer

The term *resettable fuse* somewhat of a misnomer, and *self-resetting fuse* may be more appropriate when discussing PPTC fuses. A Polymer Positive Temperature Coefficient (PPTC) fuse is an overcurrent protection device that trips when a certain trip current is exceeded. In contrast with conventional fuses that need to be replaced, resettable fuses automatically reset once the overcurrent is removed. They are small, inexpensive, and come in a variety of packages: radial leaded, axial leaded, and SMT.

PPTC fuses are constructed with a non-conductive polymer plastic film that exhibits two phases. The first phase is a crystalline or semi-crystalline state where the molecules form long chains and arrange in a regular structure. As the temperature increases the polymer maintains this structure but eventually transitions to an amorphous phase where the molecules are aligned randomly, and there is an increase in volume. The polymer is combined with highly conductive carbon. In the crystalline phase the carbon particles are packed into the crystalline boundaries and form many conductive paths, and the polymer-carbon combination has a low resistance.

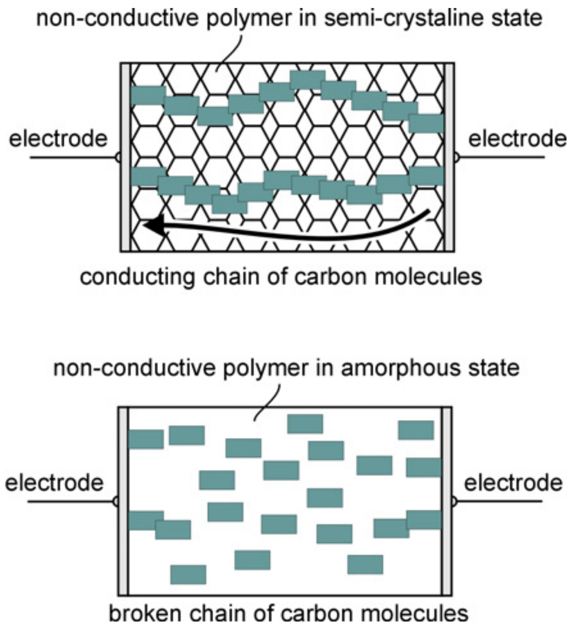

Figure 1. Top: Polymer film in semi crystalline phase and conducting chains of carbon molecules. Bottom: Polymer film in amorphous phase and broken carbon chains.

A current flowing through the device generates heat (I^2R losses). As long as the temperature increase does not cause a phase change, nothing happens. However, if the current increases enough so that corresponding temperature rise causes a phase change, the polymer's crystalline structure disappears, the volume expands, and the conducting carbon chains are broken. The result is a dramatic increase in resistance. Whereas before the phase change a polymer-carbon combination may have a resistance measured in milliohms or ohms, after the phase change the same structure's resistance may be measured in megaohms. Current flow is reduced accordingly, but the small residual current and associated I^2R loss is enough to latch the polymer in this state, and the fuse will stay open until power is removed.

The process is almost reversible, in that when the temperature falls, the polymer returns to its crystalline structure, the volume decreases, and the carbon particles touch and form conductive paths. However, the exact same conductive paths never form so that the resistance after reset is slightly different from before. The resistance of a PPTC fuse may triple or quadruple after the first reset, but thereafter changes are relatively unimportant.

The convenience of self-resetting opens many application areas where conventional fuses are impractical. For example, resettable fuses are built into battery packs for portable equipment. When the terminals of the battery are accidentally shorted, the fuse trips and protects the battery, but when the short is removed the fuse resets and the battery can be used again. With a conventional fuse one would have to replace the fuse using a spare. Setting aside the inconvenience, there is always the risk of inappropriate fuse replacement that may do more harm than good.

The concept of a self-resetting fuse of course predates this technology. Bimetal fuses, for example are widely used in appliances such as hairdryers, but these are generally large current devices. PPTC resettable fuses compete with another common overcurrent protection device, namely positive temperature coefficient (PTC) ceramic thermistors. However, PPTC fuses offer several advantages. First, they have lower resistance and therefore lower I^2R heating, and can be rated for much higher currents. Second, the ratio between open-resistance and close-resistance is much higher than with ceramic PTC fuses. For example, the resistance change in PTC thermistors is generally in the range of 1–2 orders of magnitude, but with PPTC fuses, the change may be 6–7 orders of magnitude. However, ceramic PTC fuses don't exhibit the increase in resistance after a reset.

The vast majority PPTC fuses on the market have trip times in the range 1–10 seconds, but there are PPTC fuses with trip times of a few milliseconds. Generally speaking, however, these devices are considered slow-trip fuses. Note that the blow time depends on the overcurrent, so that a fuse that may open within a few milliseconds with a severe overload, may take tens of seconds for a light overload.

Considering the fact that these fuses operate on the principle thermal-induced changes in their material properties, it is not surprising that they are sensitive to changes in ambient temperature. It is imperative that one consults the thermal derating information and guidelines that manufacturers provide.