Question

What is a mica capacitor?

Answer

Mica, a mineral, is one of the oldest dielectric materials used in capacitor construction. There are several kinds of mica, with differing properties, but mica is in general very stable electrically, mechanically, and chemically. It has a dielectric constant in the range 5–7. Mica has the interesting property that its crystalline structure is asymmetrical. The binding forces in one plane are quite strong, while the binding forces along the perpendicular plane are very weak. Because of this, it has a distinct layered structure, and it is possible to split or cleave mica into very thin, optically flat, sheets. For capacitors, mica sheets in the range 0.025–0.125 mm or even thinner are used.

There are many types of mica, but only six or so are common rock-forming minerals. Mica capacitors are normally made from *muscovite mica*, or potassium aluminum silicate, $KAl_2Si_3O_{10}(OH)_2$. It is thermally stable up to 500 °C, and has a high dielectric strength. *Phlogopite* mica, or potassium magnesium silicate, $KMg_3Si_3AlO_{10}(OH)_2$, is softer than muscovite mica and has less desirable electrical characteristics, but it may be used up to 900 °C. Mica deposits are found in Madagascar, Central Africa, South America, and India. India is probably the biggest supplier of mica.

Natural mica contains many other materials including, iron, sodium, ferric oxide, and lithium. Because of the variability in composition of natural mica, mica destined for use in capacitors must be carefully inspected and classified, which adds to the manufacturing cost. All varieties of mica are chemically very stable and inert. Mica does not react with oil, water, most acids, (the exceptions are hydro-fluoric and sulfuric acid) alkalis, and solvents.

Mica's thermal, electrical, and chemical properties make for excellent capacitors. Capacitance change with temperature range from ± 500 ppm/°C to 50 ppm/°C, depending on the construction technique. Mica capacitors exhibit very little voltage dependence, with dC/dV less than 0.1%. Mica capacitors have high Q or conversely small power factors (range 0.0001–0.0004) that are quite independent of frequency. This, combined with low inductance designs, result in capacitors that are ideal for high frequency and RF applications. Specification sheets of mica capacitors commonly show parameters plotted into the gagahertz range.

Mica capacitors are currently used in some low power RF designs, and pulse (snubber) applications, but advances in ceramic capacitor performance have slowly eroded mica's traditional edge in these areas over the years. Perhaps more importantly, mica capacitors tend to be bulky—a result of the relatively low dielectric constant. For example, a 300 pF dipped mica capacitor may be as much as 16 times larger (in volume) than a good 300 pF MLC (NPO) capacitor. This low volumetric efficiency is a serious drawback in many applications such as portable electronic equipment. Some chip mica capacitors are available, but they tend to be expensive. Mica capacitors are still indispensable in high-power RF transmitter applications. In the latter case special rectangular, cylindrical, and button-style cases are used. Another niche is high-voltage applications that are a result of mica's high dielectric breakdown and corona resistance.

Mica capacitors are available with values that range from 1–4700 pF and even up to 1 μF, but they are generally thought of as low value capacitors. Rated voltages are in the range 100–1000 V for standard dipped mica capacitors. Rated voltages for RF transmitting capacitors are up to 10 kV. Given the excellent electrical performance of mica capacitors in general, manufacturers typically market them with close tolerances (1% or better).

References

Cornell Dubilier, is a major manufacturer of capacitors, and offers a full line of mica capacitors.

Custom Electronics, is a manufacturer of high-voltage mica capacitors.

TDL manufactures high-voltage mica capacitors.

Semco is another company that manufactures mica capacitors.

The Encyclopedia Britannica on-line has some useful information on mica.

The Mineral Gallery website has a good section on mica.

Question

How are ceramic capacitors constructed?

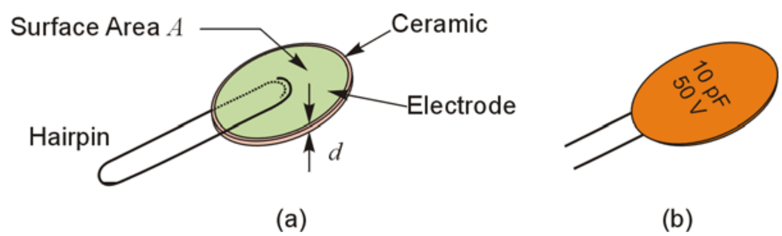
Answer

Dipped Ceramic Capacitors. The simplest ceramic capacitor consists of a square or circular shaped ceramic with electrodes attached (see figure). The capacitance is given by

$$C = \frac{\varepsilon_0 K_d A}{d}$$

where A is the area of the two plates, ε_0 is the dielectric permittivity of vacuum, K_d is the dielectric's dielectric constant and d is the distance between the two plates.

Manufacturing starts with finely powdered base ceramic material that are pressed into dies and fired at high temperatures. Individual capacitors may be cut from large sheets of ceramic material. The capacitor electrodes (i.e. the plates) are attached by screen printing a mixture of silver, finely powdered glass, and a binder on both sides of the disk, and firing the ceramic element again. This evaporates the binder, and the melted glass binds the silver to the ceramic surface. Next, hairpin wires are clipped onto the capacitor and it is dipped in solder. Once cooled the capacitor is dipped into paint, marked, and the lower ends of the hairpin cut off. Clearly the whole process lends itself to automation, and dipped ceramic capacitors are very inexpensive. Capacitor characteristics depend on the type of ceramic used.

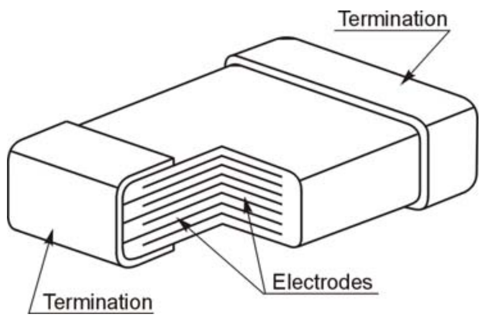


Dipped ceramic capacitor construction. (a) Capacitor after electrode and hairpin attachment. (b) Capacitor after dipping and marking.

Monolithic/Multilayer Ceramic Capacitors. MLC capacitors are marvels of modern material science. Manufacturing MLC capacitors is considerably more complicated than manufacturing dipped ceramic capacitors. First, the base ceramic material is mixed with a binder and fashioned into thin sheets. Electrodes are painted onto one side of the sheets using a paint that consists of a liquid binder with fine metal particles in suspension. The metals that are used include gold, palladium, platinum, and silver alloys. The reason for using these metals is that when the base ceramic is fired, oxygen is required for the ceramic proper to form. If one uses a metal such as iron, for example, it would oxidize completely during the firing process. Precious metals do not have this problem, but is a major cost component of monolithic ceramic capacitors. However, recently some manufacturers have reported using nickel and copper for the electrodes. This promises to reduce the cost of the raw materials, but at the expense of more elaborate manufacturing processes.

Once the ink is dry, the sheets are stacked on top of each other. The painted electrodes are arranged so that alternate electrodes exit from opposite ends. The top- and bottom-most layers do not have painted electrodes. The laminated layers are then compressed and fired, which sinters them into one monolithic structure.

Next, the ends are terminated, often using silver. For leaded capacitors, wires are attached, and finally the capacitor is encapsulated in plastic and marked. In the case of chip capacitors, the silver end terminations are covered with tin to aid soldering. The whole capacitor may be covered with lacquer.



A surface-mount (chip) MLC.

References

- Kemet. A major manufacturer of MLC capacitors. The site has several good technical articles, including electron microscope photographs of cross sections of MLC capacitors.
- Panasonic. A major manufacturer of a wide array of electronic products and components, including MLC capacitors.
- AVX is a major capacitor manufacturer and has an extensive line of MLC chip capacitors.