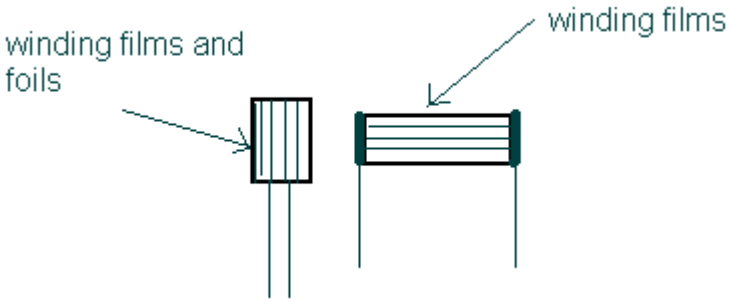
FILM CAPACITORS

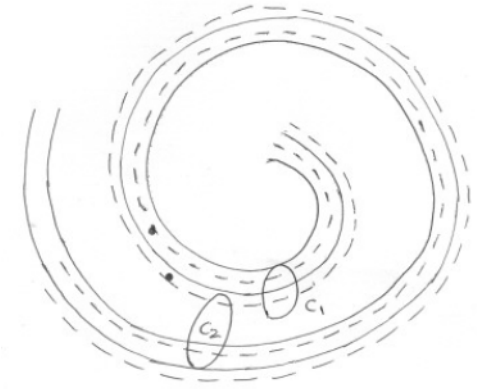
Metallized film Capacitors

Difference between film foil capacitors and metallized film capacitors:

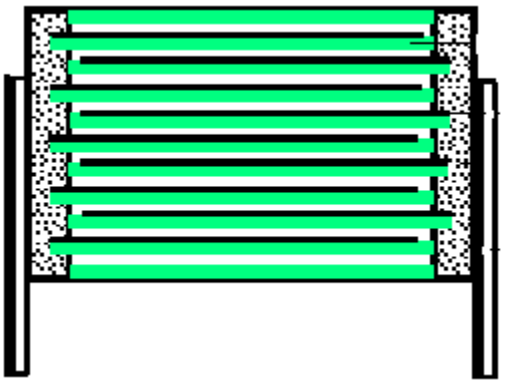
Mylar capacitors are inductive capacitors and metallized film capacitors are non inductive type.

Since the current flows through the wound construction in the mylar capacitors, high inductance is formed in mylar capacitors. But in Metallized capacitors current flows parallel from one end to another end, so self inductance is very less.

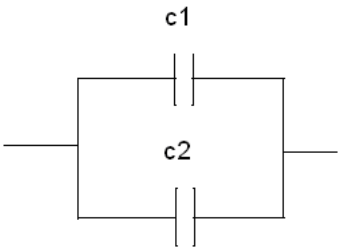




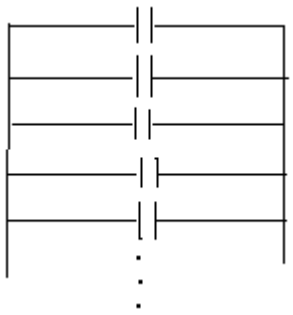
(a) Mylar capacitor



(b) Metallized capacitor

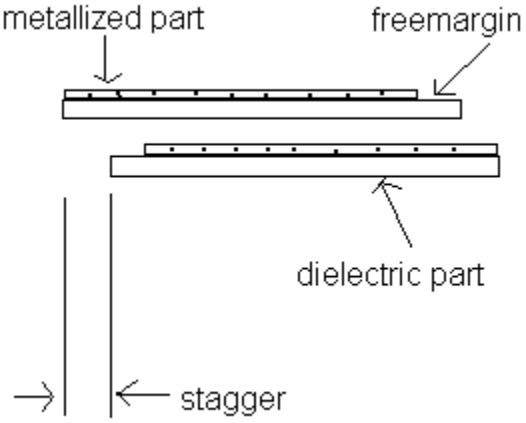


(c) Capacitance formed in mylar



(d) Capacitance formed in metallized capacitor

The metallized film consists of a dielectric on which the metal of 0.03 micron is vacuum deposited .This will give self healing property to the capacitor. The aluminum foil is used for de-metallization of film to make good sealing.

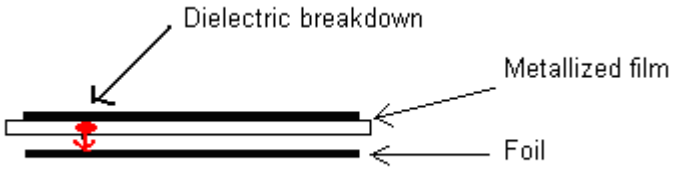


(a) construction of metallized capacitor

In mylar construction (inductive type), the lead wires provide supply to the whole foil. As the current flowing in a wound construction, the inductance of the mylar capacitor is very high. While in metallized capacitor, the supply is given in horizontal position sprayed with metal powder and welded at both the ends shown in fig (b). though it has an internal inductance, its value is very low because of parallel inductance in each layer.

Free margin is a small portion of metallized film where there is no metal layer. This type of construction is made on metallized film to provide the isolation between the two films during spraying.
Stagger is the slip between the two films to make the spraying process effective. That is spray particles will be deposited on the metal layer effectively.

Self-healing Property:



From the figure, if a dielectric breakdown occurs in a metallized film, there is no possibility of short circuit of metal on film and foil because the metal on film vaporizes. So the capacitor regains its operational ability. This property is called as Self-healing.

Advantages and Disadvantages of metallized capacitor:

- High reliability due to self-healing property
- Small size
- But current carrying capability is low
- Expensive
- Low insulation resistance and more power dissipation comparing to mylar capacitors
- Insulation resistance decreases and dissipation increases due to aging.

Winding:

Winding is the process of rolling the foils and films in a cylindrical shape and then covering them with an insulating film. The tension of films are maintained to avoid shrinkage or break of film. The pressure roller is used to avoid air gaps between films so as to make the winding effective. Aluminum foil is fed from one end for the purpose of film de-metallization. De-metallization is done at the sealing area to ensure effective sealing.

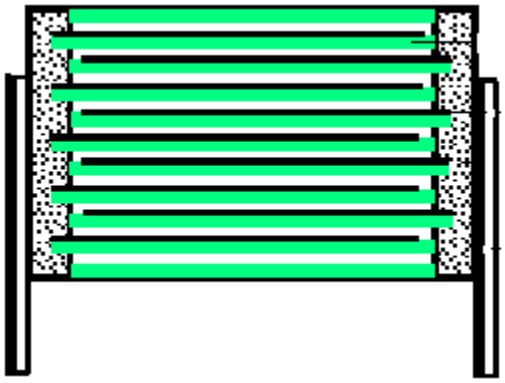
De-metallization is the process by which a high current is passed through film, so as to evaporate the metal layer. That evaporated metal particles will be deposited on the thick aluminum foil.

De-metallization length: outer diameter of capacitor*20 +/- 5mm.

Types of construction:

- Normal construction
- Series construction

Normal construction:



In this type of construction, only one capacitance is formed in one layer.

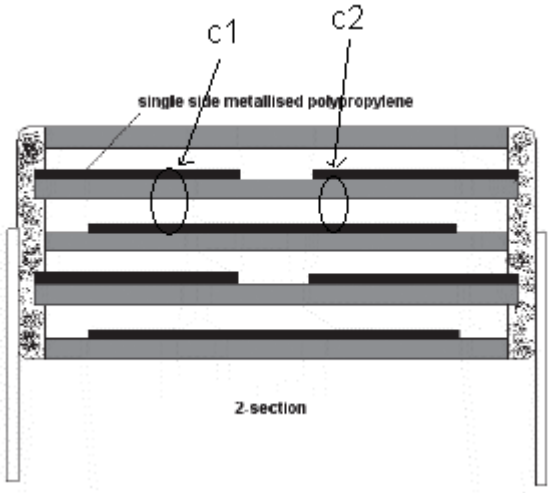
Series construction:

These types of construction are to withstand higher voltages. In order to increase the rated voltage of a capacitor, we have to increase the thickness of the film (increases the size of capacitor). So without increasing the film thickness rated voltage increased by internal series construction and an approximation in the increase of size.

Types:

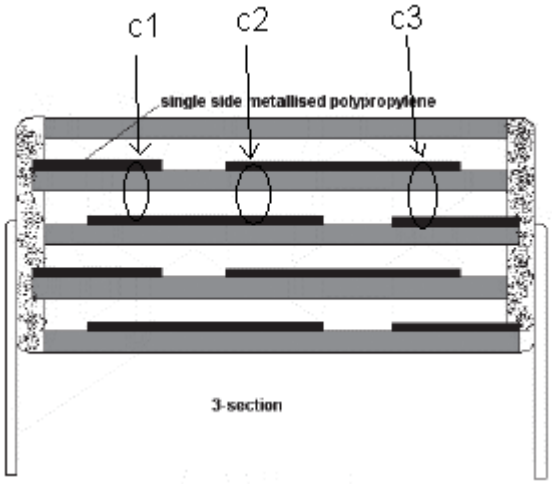
- Two section
- Three section
- Four section and so on.

Two section:



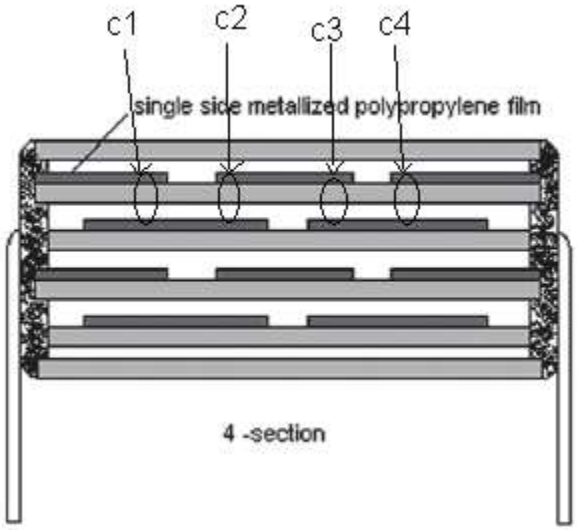
In this type of structure, there are two capacitance formed in series in a single layer.

Three section:



In this type of structure, three capacitances are formed in a single layer.

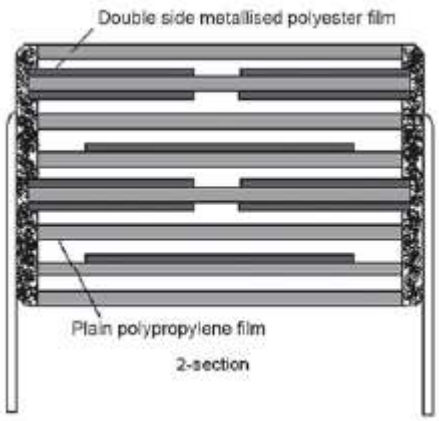
Four section:

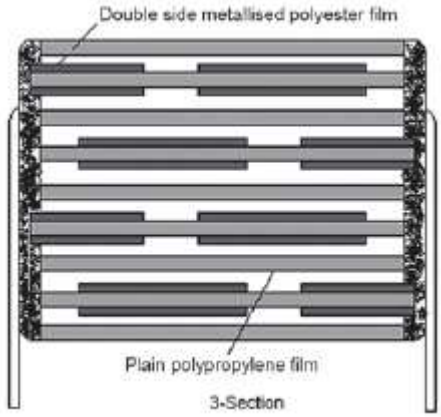


In this type of construction, there are four capacitances are formed in a single layer.

Special type of construction:

The current carrying capability is low in metallized film. It depends on the volume of metal layer. As the metal layer is 0.03micron, the resistance of the metal layer is high. So the current flow is low. In order to increase the current carrying capability, the thickness of metal should be increased then lesser the resistance and less dissipation. So different types of constructions are used. But thickness affects the self-healing property, so optimum thickness should be used.





The charging current through the capacitor is given by,

$$I=C*dV/dt$$

Where dV/dt is the rate of change of voltage with respect to time, which is during charging. So if the charging time is very less, the current flow will be more.

Pressing:

It is the process of removing the air gap in capacitors.

Types:

- Cold pressing
- Hot pressing

Cold pressing:

It is done for piece for capacitors with low capacitance value. We opt cold pressing when the capacitor film width is less than 7mm with 5% tolerance and for capacitors of greater than 7mm with 10% tolerance. In this method, the pieces are fed by bowl feeder and then pressed by means of impact load. It is pressed in the jig. The pressure required is less. It is not suited for high capacitance value as it leads to capacitor open in this case.

Hot pressing:

It is done for high capacitance values, to remove the air completely that is to ensure effective pressing. The capacitors are arranged in a jig and placed between the pressing plates. The pressing temperature, pressure and time are kept optimum to avoid capacitor open or tan delta failure.

For **MPET/PP-MPP** (film/foil), 120+/-5 degrees
For **PET NI** film/foil type, 170+/-5 degrees
For **MPP/PP NI**, 100+/-5 degrees

Masking:

Masking is the process of covering the lateral faces of a pressed capacitor with a tape. It is done to avoid the deposition of metal particles during spraying. That is the deposition is done only at the sides in order to make welding.

Spraying:

Spraying is the process of making end contacts with the metallized layer. First zinc is sprayed on the sides as the composition of metal film is same. Then it is coated with tin zinc, as tin zinc has better properties for welding than zinc.

Parameters of spraying:

Gun height should not be high to make fine particle spraying 180+/-5mm for zinc and 130+/-5 for tin zinc. Wire feeding speed is 6.46 m/min for zinc spray.

Note: These gun height parameters are maintained by us using TAFA spray gun. The Gun height can be kept minimum in order to increase the efficiency but the temperature of the particle at the surface of the capacitor should not be more than 90 degrees and pressure is also controlled for fine particle size.

De-masking and De-burring:
In this process, the masking tape is removed and then the capacitors are poured in a machine, which is rotated fastly for some time then all the burrs due to spraying is removed.

Welding, Pinching and silicon:

Welding of lead wires to the sides is done by spot welding. Depending on the application either copper or steel wire is used. Steel wire is used in dc applications and copper for ac applications. For copper, tanδ is less and conductivity is high compared to steel, but costlier than steel. Pinching is the process of sticking the wound capacitors on a aluminium bars, in order to make the other manufacturing process easier and to produce the capacitors in bulk. The bowl feeder mechanism is used to feed the capacitors in an uphill movement to the linear feeder. The bowl feeder operated by electromagnetic vibration at a constant frequency. There is a photo sensor which controls the overflow of capacitor. These sensors are controlled by a fiber optic amplifier.
Silicon is applied to the lead wires. In metallized capacitors hardener is not used. It prevents sticking of epoxy powder to the lead wires during powder coating process.

Pre heating:
The capacitors are placed in an oven at 100 to 115 deg Celsius. This will make the capacitors fit for wax to impregnate effectively. The sealing will be good.

Wax impregnation:
The capacitors are impregnated with wax at 110 deg Celsius, so that the epoxy powder will adhere effectively to the capacitors.

Powder coating:
The capacitors are allowed to move through the coating machine. The powder is fluidized by applying compressed air. The squeeze plate moves up and down. When it opens, the capacitors are dipped in the fluidized epoxy powder. It is hammered to remove the extra powder on it. This will give good and even finishing. The dipping is done 3 times to make the process effective. The powder coating temperature is 38 to 42 deg Celsius. Otherwise the density of powder coating gets affected. The dust is collected separately.

Powder cutting and marking:
The epoxy powder which is in the lead wire is removed by moving the leads against toothed rollers and brushes. The marking is done on the same machine. The inkjet mechanism is used for marking purpose.

Curing:
The capacitors are cured at 110 deg Celsius in an oven to make the coating and marking effective. Unlike mylar, here we are not using UV curing. The reason is, in metallized the curing is done after the marking which makes the marking effective.

Testing:
Testing machine has a bowl feeder like pinching machine and same principle is used. Capacitors are fed in an uphill movement, finally an arm picks up the capacitors one by one and arranging it on a running chain slots and testing is done. There are various types of tests. They are,

- Out of Tolerance test (OTR)
- Capacitor Open (CO)
- Flash Over test (FO)
- Tested Voltage test (TV)
- Insulation Resistance test (IR)
- Tanδ test

Out of Tolerance test:
If the capacitance value is within the tolerance limit it will fall in the c2 bin. If the capacitance value is less than the lower limit, it will fall in the c1 bin. If it is higher it will fall in the c3 bin.

CO test:
Capacitor open: The capacitance value for e.g. 0.10 microfarad, the value must be more than 0.07μF. That is the capacitance value should be more than 70% of the rated capacitance value. CO bin collects these rejects.

Flash over test:
In this the impact voltage of 2 times the rated voltage is applied for one minute and the process abnormalities are checked. Welding defects and sealing defects etc are checked and the rejects fall in FO bin.

TV test:
Tested voltage: In this the voltage two times the rated voltage is applied gradually in steps. That is slowly increasing from minimum to maximum (twice the rated voltage). The abnormalities are checked and rejected.

Insulation resistance test and tan delta:
The insulation resistance is measured by IR meter and the tan delta is measured by LCR meter. The capacitors which fail are rejected and collected separately.
In mylar this test is neglected because of no change in IR and tan delta but in metallized capacitors due to self-healing, IR decreases and tan delta increases in its life time. So it must be carefully considered.

T/F section and packing:
In this the capacitors are formed, tapped and lead cut according to the requirement.
Types of packing style:
Bulk packing
Bulk after forming and lead cutting
Ammo packing
Reel packing

Process abnormality	Increase/decrease	capacitance	Rated voltage	Insulation Resistance	Power Dissipation
winding					
Length of metallized film.	Increase	Increase, C α L	No effect	Decreases slightly, L α leakage current	Minimum increase. Since leakage increases
Width of metallized film.	Increase	Increase, C α W	No effect	Decreases slightly, W α leakage current	Minimum increase. Since leakage increases
Thickness of metal layer of metallized film.	Increase	The current carrying capability of metallized film is more. ESR is less, so dissipation is less. If increased more, self-healing property gets reduced.			
Thickness of dielectric in metallized film.	Increase	Decrease, C α 1/d	Increase, C α Q/V	Increase, since dielectric thickness more	Minimum increase, Tanδ= ω *C*ESR
Stagger	Increase	Decrease, as effective width decreases	No effect	No effect	Minimum increase because of film length increase Tanδ= ω *C*ESR
	Decrease	The capacitance value increases but the spray process will not be effective. More possibilities for capacitor open.			
Film tension	Increase	Capacitance increases but more increase will break the film	No effect	IR will reduce slightly	Minimum increase, Tanδ= ω *C*ESR
	Decrease	Decreases due air packets	Break down voltage decrease due to air packets(corona)	Insulation is poor	More due to corona

Pressing

Cold pressing

It is done for small capacitance value and a tolerance of more than 10%	Increases , C α 1/d	No effect	IR is slightly more.	Decreases

Hot pressing

jig size	Increase	Then more capacitors needed to be pressed. So the pressing will not be effective.			
Temperature	Increase	Films shrink and fails	Fails	Decreases	More
	Decrease	Decreases, C α 1/d	No effect	More	Initially less and slowly increases due to air packets.
pressure	Increase	Increases to a limit then capacitance fails due to film damage, C α 1/d	Dielectric breakdown voltage decrease	Decreases and then fails	Due to film damage dissipation increases.
	Decrease	Decreases, C α 1/d	Break down voltage decrease due to air packets(corona)	Insulation is poor	Dissipation is more (corona discharge)
Pressing time	Increase	Increase to a limit then decreases and finally damage but will work poor.	Dielectric breakdown voltage decrease	Decreases	More
Pressing time	Decrease	Decrease, C α 1/d	Break down voltage decrease due to air packets(corona)	Insulation is poor	More due to corona

Masking					
No effect on any parameters, if the masking is done correctly such that it makes the spraying process easier. It avoids spraying on main face.					
Spraying					
Spray time	Increases	No effect			Less, because of low resistance of contact
Spray temperature	Increases	Increases then Films shrink and damage	No effect	Decreases	More
Spray thickness	Increases	No effect			Less, because of more metal deposited at the end
Feeding current	Increases	More deposition of metals. Other parameters are not affected.			Less, because of more metal deposited at the end
De-masking and de-burring					
No effect but if the burr is not removed effectively then welding is not effective and possibilities of capacitor open is more.					
Welding, pinching and silicon process					
Welding	if the welding is not effective, then dissipation will be more and chances of capacitor open is more.				
Pinching	There is possibility of damage to lead during pinching, it leads to capacitor open.				
Silicon	This affects the solder ability of lead wire on PCBs.				
Pre-heating	Temperature increases	Films shrink cause permanent damage.	Fails	Decreases more and fails	-
Wax Impregnation					

Impregnation temperature	Very high	Films shrink cause permanent damage	Fails	Decreases more and fails	-
	Optimum	Powder coating will be effective			
Powder coating					
Temperature	Increases	Films shrink cause permanent damage	Fails	Decreases more and fails	-
Dip time	Increases	More powder will be coated, so size increases and other parameters are not affected.			
Curing					
Temperature	Increase	Capacitor dielectric damage. Shrinkage at foils. Capacitor open. So IR decreases.			
Curing time	Increase	Loss factor decreases but more time leads to failure			

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