

# Technical trend of power film capacitors for industrial use

## [ Introduction ]

Global warming problems and energy conservation as countermeasure to it are the global themes in these recent years. Growing momentum to review energy policy at each country based upon the accident of Fukushima nuclear power plant due to occurrence of Earthquakes in northeast Japan on March 11, 2011, the demand level of renewable energy such as photovoltaic or windmill power generation is believed to grow rapidly worldwide in the near future.

Currently, inverter technology advances to be able to precisely control energy consumption to be minimized in various industrial applications and film capacitor demand is increasing. The reasons are the following features that film capacitors have.

- (1) Long life and maintenance-free
- (2) Excellent frequency characteristics plus low loss and low heat rise
- (3) High withstanding voltage property
- (4) Superior self-healing & safety performance

Picture-1: Examples of Rubycon's power film capacitors (Research & production by Rubycon Electronics Inc.) Rubycon actively works on R&D of superb power film capacitors with high performance & high reliability as well as realizing the down-sizing, light weight and low cost required by the markets.



(Picture-1: Rubycon's power film capacitors )

The following section describes about Film capacitors' "Miniaturization", "Low ESR", & "Low ESL" points of development.

## [ Capacitor structures, equivalent circuitry ]

Metalized film capacitor is structured as follows: Dielectric plastic film is vacuum processed to metalize the electrode over the surface, is slit into a given width, then a pair of slit film is wound together, heat pressed, then wound edge is treated with metal spray and outer termination such as lead wire is welded or soldered onto the metal spray.

Major feature of metalized film capacitors is self-healing, in case some weak spot of dielectric exists or when excessive voltage is applied, an instantaneous oxidation takes place as the sparking due to the loaded energy or internally held energy and such defect symptom recovers simultaneously. In recent years, mainstream is becoming with additional safety function that applies segmentation of metalized area that increases the reliability of the capacitors.

Figure-1 indicates the structure of metalized film capacitors. The safety function is made by segmentation with many separate areas with fuse bridges among all those areas.

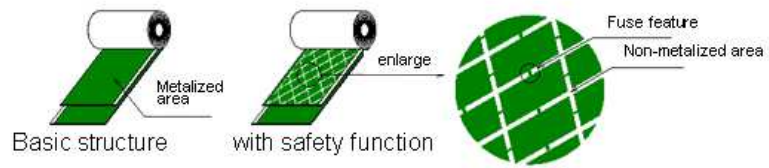


Figure-1

In case the insulation breakdown beyond the self-healing limit occurs, those fuses will melt down due to shorting current, and affected area is cut-off from the active circuit in this capacitor. Breakdown of the whole capacitor is avoided by this function.

Performance of metalized film capacitor depends highly upon characteristics of dielectric film itself, and metallization type, resistance & pattern.

Figure-2 indicates the sectional view of the metalized film capacitor. Metal spray is applied in order to connect internal electrode of metalized area to outer termination. If the connection between metal spray and internal metalized area is not adequate, ESR will rise and electric current capability suffers. Thus, the metal spray is very important technological component to determine the performance of the capacitors.

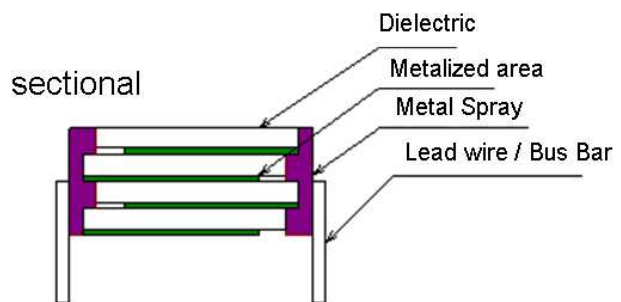


Figure-2: Sectional view of metalized film capacitor

Figure-3 indicates the equivalent circuit model of film capacitor. If it was an ideal capacitor, there would be only “C”, but actual capacitor has an IR (Insulation Resistance) and very small electric current flows. ESR (Equivalent Series Resistance) comes from dielectric resistance, contact resistance between metal spray & metalized area, bus bar terminal resistance, etc.

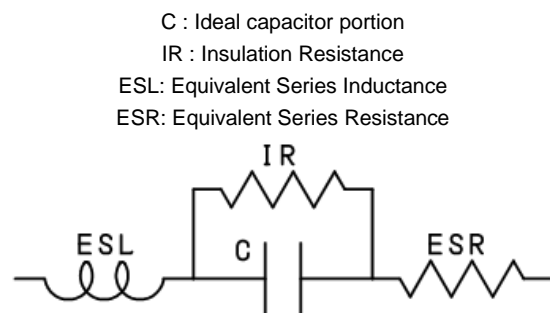


Figure-3: Equivalent circuit of film capacitor

When high-frequency current flows into the capacitor, the electric dissipation that is proportional to the ESR value as indicated in the Formula-1 below, makes the capacitor to heat up. In case the capacitor heats up more, operation condition may be limited, or the life time may suffer.

ESL (Equivalent Series Inductance) comes from the inductance of terminations and wiring to the bus bars. In case this inductance becomes high, big surge voltage is generated in the switching operation of power semiconductors such as IGBT.

Formula-1: Capacitor heat rise equation

$$P_e = I^2 R_{ESR} \quad \text{【} P_e = \text{rms Power(W)} \quad I = \text{Current flowing into capacitor(Arms)} \text{】}$$

## [ Miniaturization ]

Volume of film capacitor is almost proportional to the square of the thickness of dielectric material. Therefore, the thinner film material is the key factor to miniaturize the film capacitor. On the other hand, generally speaking, when dielectric film is made thinner, the potential gradient (the voltage to be applied to the unit thickness of the dielectric material) increases and thus, capacitor's withstanding voltage decreases and reliability degrades. In order to improve such degradation the metallization technology is important.

Rubycon focuses on research of metallization technology such as safety pattern of metalized area, optimization of metallization material and metallization resistance, etc.

Figure-4 indicates the volumetric transition history of metalized polypropylene film capacitors at the same rated voltage, with the index of 100 as the volume was in the year 2000. Due to tremendous improvement made on the metallization technology as well as some improvement made on the dielectric film itself, the volume has become about 1/10 in the past 10 years, which is huge achievement of miniaturization.

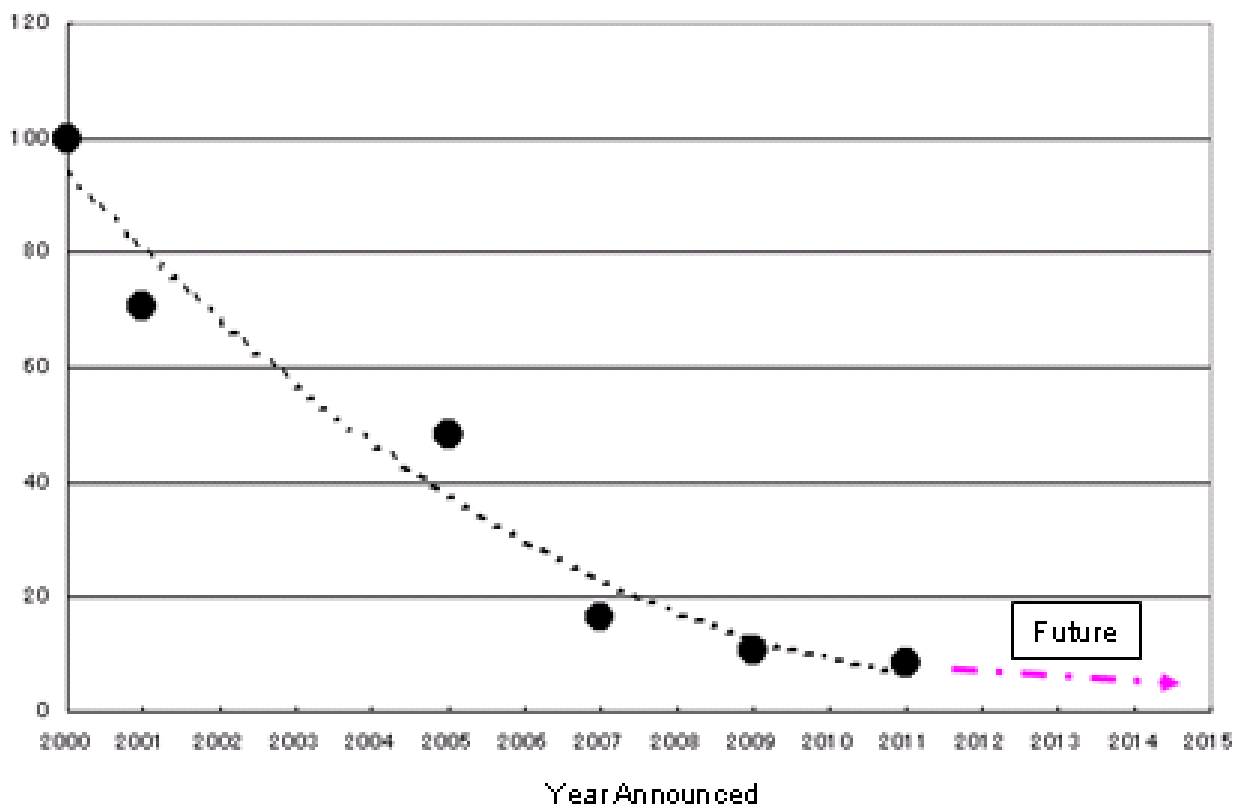


Figure-4: Volumetric transition of metalized polypropylene film capacitor

## [ Low ESR ]

Equivalent Series Resistance (ESR) is mainly formed by metallization material (metal itself) and contact resistance between metalized area and metal spray. The key point of capacitor's design and manufacturing is how to reduce such resistance.

As described earlier in this report, power film capacitors are recently equipped with the safety function, but if the safety function design is not perfect, then issues come up like higher ESR due to

interference of current flow at the fuse feature, or like operation of safety function does not work as expected. Thus, the researches are conducted on metallization pattern development, optimization of metallization material and condition, metal spray material and spray technology for improvement of connection between metalized area and metal spray, etc. at various suppliers,

### [ Low ESL ]

When large capacitance is necessary for the use in filtering applications, it is common to make a module by connecting multiple capacitors in parallel with bus bars. However, ESL WILL become high due to the inductance of the bus bars.

To lower ESL, various improvement techniques are used such as optimization of bus bar locations so that the magnetic bundles are offset as current flows in the bus bars, and change of bus bar material or in thickness, etc.

### [ Product line-up ]

Rubycon offers 3 product series, MPC, MPV & HVC, as shown in the table-1 to be used in the various needs in the industrial equipment.

- (1) Rectangular shaped MPC series (for inverter filtering and snubber circuit)
- (2) Cylindrical plastic case MPV series (for inverter filtering)
- (3) Module type HVC series (EV, HEV & other inverter filtering)

Series Name	MPC	MPV	HVC
Appearance			
Features	Miniature Special terminals are available	Cylindrical element implemented	Large capacitance is available with internal elements connected in parallel
Main applications	Inverter filtering Snubber circuit	PV inverter Wind mill inverter	EV & HEV inverter Various inverter filtering
Voltage and Capacitance Range	200VAC / 1uF to 100uF 1600VDC / 0.47uF to 2.2uF	250 to 1200VDC / 47 to 1500uF 250 to 800VAC / 47 to 1500uF	250 to 2000VDC 100 to 2200uF
Category Temperature Range	-40 to +85C	-40 to +85C	-40 to +85C (+105C)

Table-1: Rubycon's power film capacitor series, features and applications

### [ Future efforts ]

Inverter devices currently use silicone semiconductors mainly, and some silicone carbide (SiC) semiconductors will be out in practical use in the future. It is believed that further miniaturization, higher temperature and better performance will be required on the power film capacitors to be used

there.

Rubycon actively involves with further research in functional thin film metallization technology and developing future power film capacitors with higher voltage, miniaturization, lower ESR and lower ESL.

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