EEStor Corporation

ENERGY EVERYWHERE

EEStor Capacitor Advantages for Green Energy:

AUTOMOTIVE, WIND & SOLAR

Company offers smaller, more cost-effective technology for replacement of film capacitors in green energy sector

EESTOR ADVANTAGES FOR THE MULTI-BILLION DOLLAR FILM CAPACITOR MARKET FOR RENEWABLE ENERGY SYSTEMS

EEStor offers smaller, more cost-effective technology for transport, solar, wind, and geothermal energy designs

EEStor Corporation (TSXV:ESU) has disclosed the development of a hybrid ceramic capacitor dielectric material based on EEStor's Composition Modified Barium Titanate (glass-CMBT) with significantly higher permittivity than traditional capacitor materials. EEStor's glass-CMBT dielectric material can compete effectively in the global $2.3 billion plastic film capacitor market[1]. High growth is expected in the industrial capacitor market driven by demand for DC link capacitors, DC/AC inverter capacitors, boost converter capacitors, pitch and nacelle control capacitors, and snubber circuit capacitors utilized in next generation infrastructure, power supply, propulsion, wind, solar, wave and geothermal energy systems.

Capacitors based on EEStor's glass-CMBT (EEStor Capacitors) have the same capacitance in a significantly smaller volume than plastic film capacitors manufactured from polypropylene dielectric.[*] The EEStor replacement for power film capacitors is up to 92% smaller than the size of the power film capacitors they are designed to replace. The smaller volume for EEStor Capacitors for the same capacitance means less raw material consumed for each farad of capacitance. This significantly lowers the cost per farad and creates more choices for the design engineer due to the increased volumetric efficiency of the finished capacitor. In addition, ceramic capacitors are more cost effective when compared to plastic film capacitors because ceramic dielectric materials have feedstock materials that are abundant in supply and relatively inexpensive when compared to metallized plastic films.[2]

*Although film Capacitors have very low DF, an important consideration favoring film capacitors in some applications, for most applications in the market, including the green energy applications highlighted in this document, the higher DF of the EEStor Capacitor is not an issue.

Third Party Testing and Validation

EEStor Capacitors have been tested extensively over a 3-month period by three independent parties - Intertek, Radiant Technologies and MRA Laboratories. These results confirm capacitors manufactured with EEStor's glass-CMBT would be significantly smaller in size and more cost effective when compared to existing capacitor dielectric technologies, offering a licensed manufacturer of EEStor Capacitors a competitive advantage in the high-tech economy. To learn more about test results, visit https://www.eestorcorp.com/.

Applications for Power Film Capacitors

Power film capacitors are used in power grid distribution systems for power transmission and distribution. Power film capacitor applications in the fast-growing green energy sector also include capacitors in solar, wind, and wave energy generation systems to condition the electrical energy generated by the generators and deliver it to the electrical power grid. This requires DC- link capacitors, snubber capacitors, and boost converter capacitors, all of which are addressable by EEStor's smaller, less expensive glass-CMBT technology.

Every solar or wind generation system has an inverter as does every electric or hybrid electric car and bus. Power film capacitors are used in these systems in three ways – filtering to reduce harmonics in the wave form, snubbing to dampen spikes due to switching, and DC links supplying high currents and filtering excess ripple currents. With increasing worldwide demand for green technologies, the market for power film capacitors is expected to increase to $2.7 billion by 2023[3]. To illustrate the advantage of EEStor dielectrics, a case study has been prepared to compare commercial power film capacitors with DC link capacitors built with EEStor dielectrics.

Direct Comparisons of EEStor Capacitors to Commercial Technology

EEStor Capacitors were compared to commercial DC link metalized film capacitors and were found to offer significantly reduced size and cost benefits. DC link capacitors that are made from aluminized plastic film are not as cost effective to produce as ceramic capacitors of the same size. This cost advantage is further increased by the drastically reduced size of equivalent EEStor Capacitors compared to current capacitors available to the market.

Volume/Size

Capacitor: voltage, size	1100V, 100 µF	500V, 100µF
WIMA Film Capacitor Volume	235.6 cm^3	-
Panasonic Film Capacitor Volume	-	112.7 cm^3
EEStor MLCC Volume	61.75 cm^3	8.70 cm^3
% larger than EEStor Capacitor	281%	1195%

EEStor's capacitors are cheaper per farad to manufacture because of cheaper material costs and less material required per farad.

Lifetime Expectancy

Both types of capacitors have comparable long expected lifetimes. EEStor's glass-CMBT dielectrics were independently tested and found to be stable with temperatures ranging -45°C to +85°C.

Cost

Based on the size findings above, material costs for commercial DC link metalized film capacitors will be up to 1,195% more than the cost of EEStor CMBT-glass based capacitors. Material costs for EEStor Capacitors represent a significant savings for manufacturers. EEStor solutions are significantly cheaper per farad for the same performance and lifetime as the currently available technology. This drastically lower cost makes EEStor technology a disruptive technology for the rapidly growing power film capacitor market segment.

Promising Markets

The existing market for film capacitors is $2.3 billion globally. Anticipated growth is projected to reach $2.7 billion by 2023. This growth is driven by electrification of the transportation sector and an increase in renewable grid applications, that in turn increase demand for DC link capacitors, DC/AC inverter capacitors, boost converter capacitors, pitch and nacelle control capacitors, and snubber circuit capacitors in propulsion, wind, solar, wave and geothermal energy systems. These trends are expected to continue to accelerate providing rich opportunities for further growth beyond 2023.

About EEStor

EEStor is a developer of high energy density solid-state capacitor technology utilizing the company's patented Composition Modified Barium Titanate (CMBT) material. The company is focused on licensing opportunities for its technology across a broad spectrum of industries and applications.

The Company's success depends on the commercialization of its technology. There is no assurance that EEStor will be successful in the completion of the various enhancement phases underway to warrant the anticipated licensing opportunities in the technology. Readers are directed to the "Risk Factors" disclosed in the Company's public filings.

Bibliography

1. High Voltage Capacitors: World Markets, Technologies & Opportunities; 2016-2021; Dennis M. Zogbi, Paumanok Publications, Inc
2. Understanding the Global Market for Aluminum Electrolytic Capacitors, Dennis M. Zogbi
3. https://www.marketresearchfuture.com/reports/film-capacitor-market-4178

Appendix

Side-by-Side Comparisons of EEStor and Commercial Film Capacitors

Comparison to 1100 volt WIMA 100 microfarad DC link capacitor

For this comparison, a WIMA DC link was used with a size of 5 cm diameter x 12 cm high => 19.635 cm^2 x 12 cm =235.6 cm^3.

EEStor layer 344-2B from the Intertek phase 8 report has a thickness of 32 microns with a relative dielectric constant (K) of 282 at 39.1 volts/micron and a K of 325 at 31.3 volts/micron, linear interpolation gives a K of 304 at 35 volts/micron. This is a 1100 volt capacitor, thus 1100 volts divided by the layer thickness of 32 microns results in 34.38 volts/micron. The MRA phase 7 report shows that the resistivity of the sample is 8.32 $x10^{10}$ ohmmeters. Adding an 18 micron electrode between layers of the dielectric and using the IEC/EN form factor for the MLCC of 203153 with a height of 15.3 mm results in a MLCC with the following characteristics:

Package Length =	20.30	mm
Package Width =	15.30	mm
Package Height =	15.30	mm
Dielectric Thickness =	32.00	µm
Conductor Thickness =	18.00	µm
k =	304	
Dielectric Resistivity =	8.32E+10	Ω-m
Voltage =	1100.00	V
Field =	34.38	V/µm
One Layer Area =	3.1059	cm2/layer
Number of Layers =	306	layers
Total Area of Layers =	950.4054	cm2
Part Volume =	4.7520	cm3
Layer Specific Capacitance =	8.4	nF/cm2
One Layer Capacitance =	26.11	nF/layer
Total Capacitance =	7,990.5	nF
Total Resistance =	2.80E+07	Ω
Leakage Current =	39,267.05	nA
Time Constant =	224	sec

Each MLCC will have a capacitance of 7,990.5 nanofarads and a volume of 4.752 cm^3.

100 microfarads is 100,000 nanofarad, so 100,000/7990 is 12.5 which means 13 MLCCs will be needed to get to 100 microfarad. 13 x 7990 nanofarads is 103,870 nanofarads or 103.87 microfarads. The final volume of the EEStor capacitor is 13 x 4.752 cm^3 = 61.75 cm^3.

Compare that to a current commercial DC link capacitor of 5 cm diameter x 12 cm high = 19.635 cm^2 x 12 cm = 235.6 cm^3. The commercial capacitor is 281% larger than the EEStor capacitor for the same voltage and capacitance.

Comparison to 500 volt Panasonic 100 microfarad DC link capacitor

For this comparison, a Panasonic 500 volt film capacitor was used.

Data from Intertek phase 8 report shows that layer 344-2B had a relative dielectric constant (K) of 218 at 54.7 volts/micron and a K of 245 at 46.9volts/micron, linear interpolation gives a K of 234 at 50volts/micron. This is a 500 volt capacitor so dividing the layer thickness by 10 microns results in 50 volts/micron. The MRA phase 7 report shows that the resistivity of sample 344 is 8.32 x 10^{10} ohmmeters. Adding an 8 micron electrode between layers of the dielectric and using the IEC/EN form factor for the MLCC of 203153 with a height of 15.3 mm results in a MLCC with the following characteristics:

Package Length =	20.30	mm
Package Width =	15.30	mm
Package Height =	14.00	mm
Dielectric Thickness =	10.00	µm
Conductor Thickness =	8.00	µm
k =	234	
Dielectric Resistivity =	8.32E+10	Ω-m
Voltage =	500.00	V

Field =	50.00	V/µm
One Layer Area =	3.1059	cm2/layer
Number of Layers =	778	layers
Total Area of Layers =	2416.3902	cm2
Part Volume =	4.3483	cm3
Layer Specific Capacitance =	20.7	nF/cm2
One Layer Capacitance =	64.32	nF/layer
Total Capacitance =	50,041.0	nF
Total Resistance =	3.44E+06	Ω
Leakage Current =	145,215.76	nA
Time Constant =	172	sec

So 2 MLCCs would be needed to reach 100 microfarads at 500 volts (2 x 50,040= 100,080 nanofarads or 100 microfarads). Those 2 capacitors would have a combined volume of 8.6966 cm^3. The Panasonic 500

volt, 100 microfarad capacitor has a volume of 112.7 cm^3. The commercial capacitor is 1195% larger than the EEStor capacitor for the same voltage and capacitance.