Power Capacitor Technologies for WBG Power Semiconductors

In the field of power electronics conventional semiconductors based on Silicon are increasingly being replaced by wide band-gap (WBG) technologies based on GaN and SiC. These demand a great deal from the passive components – particularly the DC link capacitors. TDK is designing innovative solutions, enabling the advantages of the new semiconductors to be fully exploited, particularly in high-frequency switching applications. **Dr. Lucia Cabo and Fernando Rodríguez, Aluminum & Film Capacitors Business Group, TDK Electronics, Munich, Germany**

For switched applications in power electronics such as power supplies and converters, WBG semiconductors offer the advantage that they can be operated with switching frequencies in the triple-digit kHz range. At the same time, they feature steep pulse edges, thereby achieving greater energy efficiency. Due to these high switching frequencies, film capacitors are increasingly being used as DC link capacitors. In order to minimize the lead lengths, and thus the parasitic inductances, the capacitors are connected directly to the WBG modules by means of busbars. The problem here is that WBG semiconductors are operated with high barrier termination temperatures, which can also be conducted via the busbars to the DC link capacitors. The temperature limit of conventional film capacitors with a dielectric of biaxially oriented polypropylene (BOPP), however, is only 105°C.

New dielectric for high-temperature

TDK has succeeded in developing a dielectric that can also be used continuously at high temperatures. This involves a combination of two basic materials. One component is semicrystalline polypropylene, which is ideal for processing into films; the other is amorphous cyclic olefin copolymer (COC), which can tolerate high temperatures. The resulting dielectric (COC-PP) can be used at temperatures in excess of 125°C with considerably lower derating, while retaining the good self-healing properties of BOPP and comparable dielectric constant. In addition, this enables extremely thin films of just 3 µm to be manufactured. Figure 1 shows the significantly improved shrinking and derating behavior of COC-PP in comparison with conventional BOPP.

Outstanding performance

Like all capacitors, film capacitors also feature a complex ESR, a series connection comprising an ohmic and a capacitive part. Accordingly, this produces a frequency-dependent resistance that increases sharply as the frequencies rise. This rise is essentially caused by inhomogeneous impedances, skin effects and winding geometries, leading to unwanted resonances and electromagnetic effects. The result is a heating of the capacitor. This has a particularly negative effect if the internal design of a capacitor consists of several windings. Different internal lead lengths and other factors then lead to a pronounced frequency-dependent current

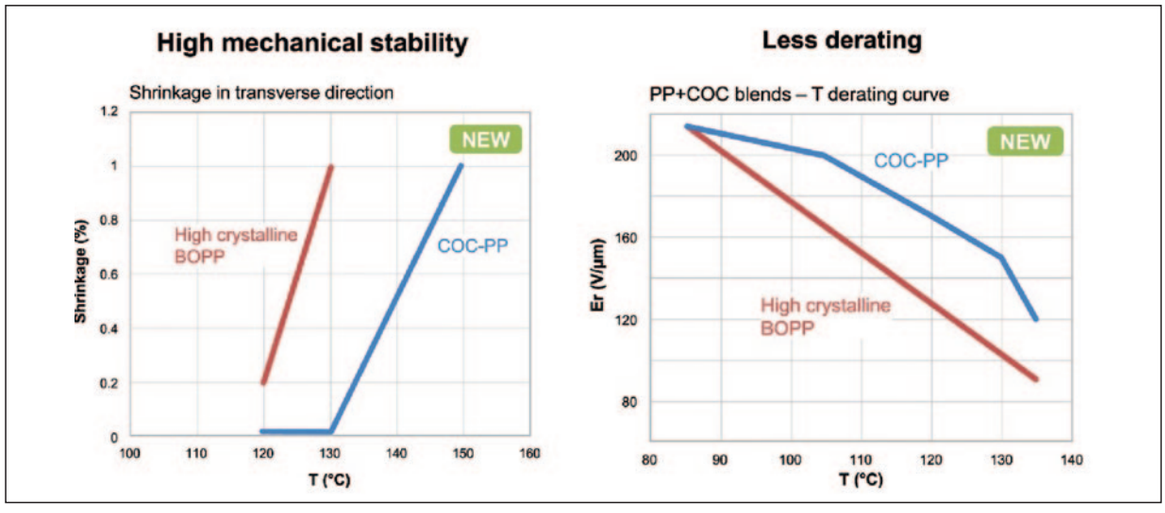

Figure 1: **At temperatures of up to 130°C the new COC-PP material exhibits no shrinkage in a transverse direction (left), voltage derating of the new material is also significantly better (right)**

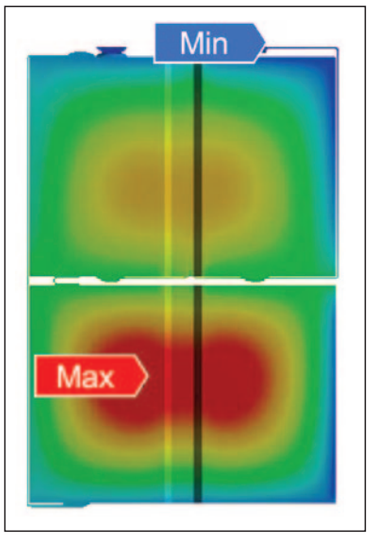

Figure 2: **A frequency of 5 kHz produces a significant inhomogeneous distribution of current, and therefore losses, over both windings**

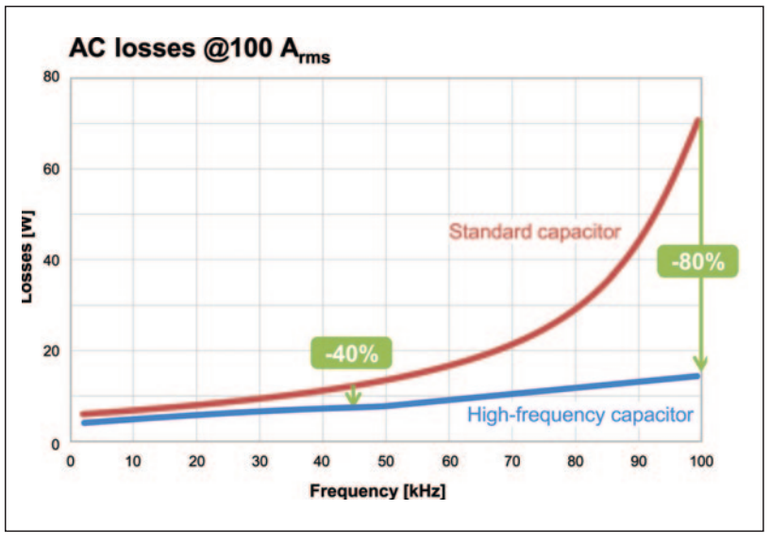

Figure 3: **At high frequencies the new HF power capacitors exhibit a dramatic reduction in power losses in comparison with conventional capacitors**

distribution across the individual windings, as shown in Figure 2.

With the aid of CAD and FEA (finite element analysis) simulation software HF (high-frequency) power capacitors with an optimized internal design have been developed. Even at the high frequencies and temperatures at which WBG semiconductors are operated, these capacitors offer high performance with low losses, thanks to a minimized ESR (Figure 3).

The new B25640* series of HF power capacitors of the (Figure 4) is especially tailor-made for SiC semiconductors. With rated voltages of between 700 and 2200 V DC and capacitance values from 370 to 2300 µF, the capacitors are suitable for the new generation of converters for traction, industrial drives and renewable energy applications. With the COC- PP dielectric the capacitors can also be operated without voltage derating at temperatures of up to 125°C. One great advantage of the new capacitors is their extremely low ESL value of just 10 nH. This means that, even at high, rapidly switched currents, their voltage overshoot remains very low, so that in most cases they even make snubber capacitors unnecessary (Figure 5).

Figure 4: **The new HF power capacitors are specially tailored to the requirements of WBG semiconductors**

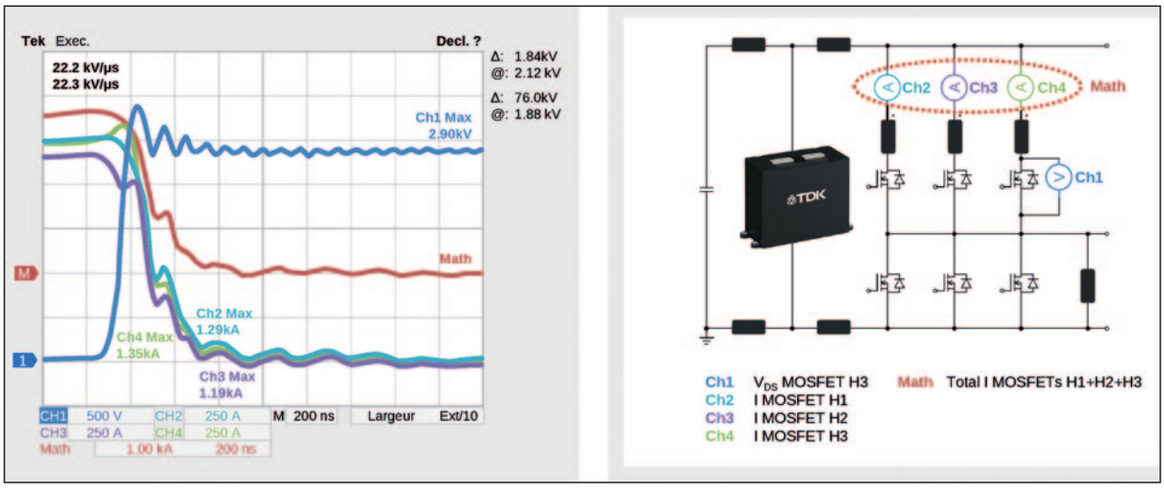

Figure 5: **The new HF film capacitor series features extremely low voltage overshoot and ringing**