CeraDiode

General technical information

Date: August 2008

1 Microstructure and conduction mechanism

CeraDiodes are bidirectional transient voltage suppressor devices made of ceramic oxides and built with a multilayer structure. Each layer consists of numerous ZnO grains. Each point of contact between the zinc and oxide grains thus acts as a micro CeraDiode, comparable to a Zener diode. The large number of micro CeraDiodes makes this component much more rugged with respect to ESD then a semiconductor diode, which has only one available pn-junction.

Sintering zinc oxide together with other metal oxide additives under specific conditions produces a polycrystalline ceramic whose resistance shows strong dependence on voltage.

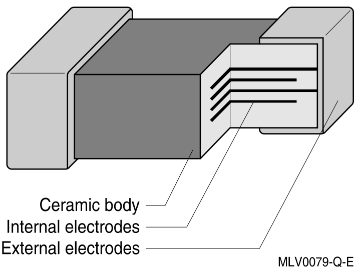

Figure 1

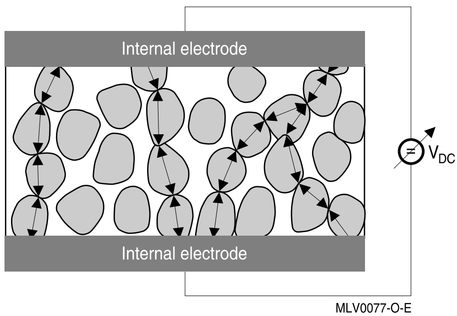

Figure 2

Figures 1 and 2: Internal structure of a CeraDiode

Figure 2 shows a simplified form of the conduction mechanism of the EPCOS CeraDiode. The zinc oxide grains themselves are highly conductive, whereas the inter-granular boundary formed from other oxides is highly resistive. Only at the contact points of zinc oxide grains does the sintering produce “micro pn-junctions”, comparable to symmetrical Zener diodes (protection level approx. 3.5 V).

The electrical behavior of the CeraDiode results from the number of micro pn-junctions connected in series or in parallel. The physical dimensions of the CeraDiode determine its electrical properties:

- Twice the ceramic thickness produces twice the protection level because twice as many micro pn-junctions are arranged in series.
- Twice the area produces twice the current handling capability because twice the number of current paths are arranged in parallel.
- Twice the volume produces almost twice the energy absorption capability because there are twice as many absorbers in the form of zinc oxide grains.

The series and parallel connection of the individual micro pn-junctions in the sintered body also explains its high electrical load capacity compared to normal semiconductors. Whereas the power in semiconductors is dissipated almost entirely in the thin pn-junction area, in a CeraDiode it is distributed over the entire oxide, i.e. uniformly throughout the component volume. Each oxide contains energy absorbers in the form of zinc oxide grains with optimum thermal contact. This permits high absorption of energy and thus exceptionally high surge current handling capability.

Another advantage of the inner structure of the CeraDiodes is that their parasitic inductances are very low, which results in response times of < 0.5 ns. Semiconductor diodes have a greater parasitic inductance, with typical response times of between 0.8 and 3 ns.

The shape, thickness and number of internal electrodes can be varied to achieve the electrical characteristics required to satisfy individual customer needs.

2 ESD (standard to IEC 61000-4-2)

The trend towards even smaller components and ever lower signal levels increases the susceptibility of electronic circuits to interference due to electrostatic disturbance. Simply touching the device may lead to electrostatic discharge causing functional disturbance with far-reaching consequences even to the point of component breakdown. Studies have shown that the human body can be charged up to 15 kV on an insulated floor (e.g. synthetic fiber carpeting).

In order to safeguard immunity to interference and thus ensure CE compliance, measures are needed to prevent damage due to electrostatic discharge (ESD). This applies to both the circuit layout and to the selection of suitable overvoltage protection.

IEC 61000-4-2 describes the test procedures and specifies various severity levels:

IEC 61000-4-2 Test Level	Test voltage (contact discharge)	Test voltage (air discharge)
1	2 kV	2 kV
2	4 kV	4 kV
3	6 kV	8 kV
4	8 kV	15 kV

Figure 3 shows the discharge circuit and Figure 4 the waveform of the discharge current with an extremely short rise time of 0.7 to 1.0 ns and amplitudes of up to 45 A. Secondary effects caused by this edge steepness are high electrical and magnetic field strengths.

In the ESD test, at least ten test pulses are applied with the polarity to which the device under test is most sensitive.

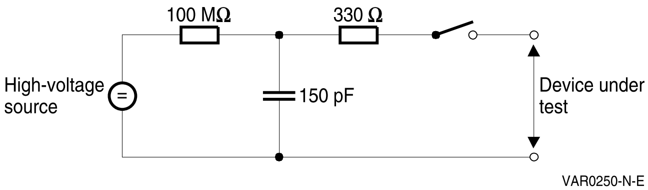

Figure 3: ESD discharge circuit to IEC 61000-4-2

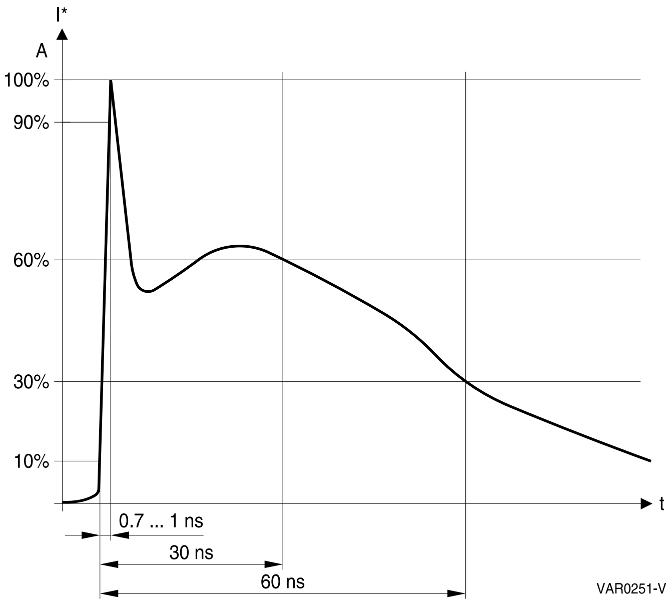

Figure 4: ESD discharge current to IEC 61000-4-2

3 Temperature derating of CeraDiodes

Derating is the intentional reduction of maximum ratings in the application of a device. CeraDiodes are derated at higher operating temperatures as they offer a huge volume for energy absorption due to their millions of pn-junctions. This results in constant high ESD protection performance up to 85 °C. In contrast, semiconductor diodes have only one pn-junction for energy absorption. Their ESD protection performance thus declines after 25 °C.

For operating temperatures exceeding 85 °C the following operating conditions of CeraDiodes

- voltage
- surge current
- energy absorption

have to be derated according to Figure 5.

Figure 5 also shows the advantage of CeraDiodes over semiconductor diodes. Derating already starts at 25 °C for the latter, whereas it starts only after 85 °C for CeraDiodes.

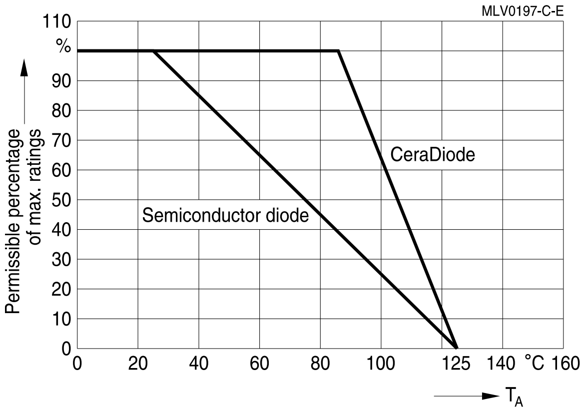

Figure 5: Temperature derating for CeraDiodes and semiconductor diodes

4 Surge current capability of CeraDiodes

CeraDiodes are designed for ESD protection. Depending on their individual construction, however, some CeraDiodes can also cope with surge current.
In the latter case, the maximum permissible ratings for surge current and thus for energy absorption depend on the pulse shape, pulse duration and the number of times this load is repeated during the overall lifetime for both CeraDiodes and semiconductor diodes. CeraDiodes designed to handle surge current have in most cases greater surge current capability than semiconductor diodes, as shown in Figure 6.

Figure 6 shows the change of reverse breakdown voltage V_{BR} @ 1 mA over increasing surge current (8/20 µs pulse) for a single CeraDiode CDS4C12GTA and a single semiconductor diode from a competitor (assessment criterion: breakdown voltage V_{BR} @ 1 mA and operating voltage $V_{DC,max}$ = 12 V as limit).
The breakdown voltage V_{BR} @ 1 mA of the semiconductor diode degrades after a surge current pulse of 20 A and the diode is destroyed. In contrast, the CeraDiode has a constant breakdown voltage of V_{BR} @ 1 mA up to 35 A.

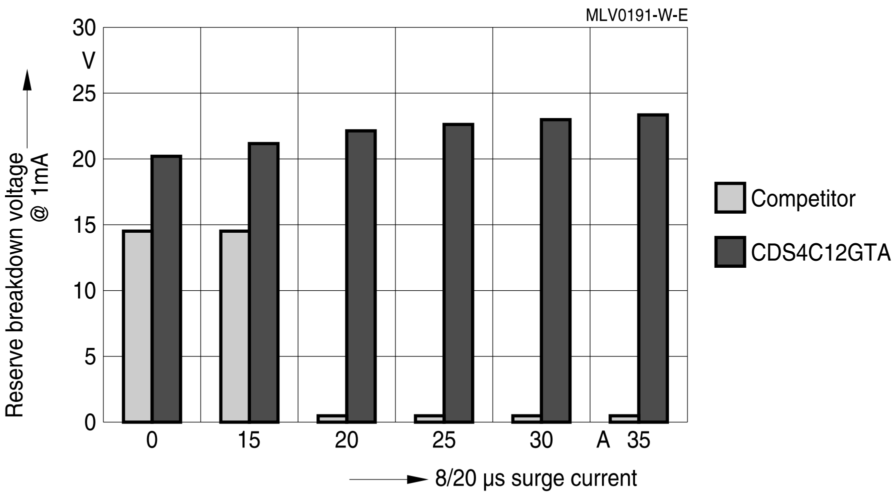

Figure 6: Surge current capability of CeraDiodes and semiconductor diodes in comparison

For surge current capability of CeraDiodes, see data sheet.

5 Specified and typical capacitance values

In the data sheets we differentiate between specified (e.g. maximum) and typical capacitance values. Specified capacitance values represent a specific product characteristic. Typical capacitance values have an informational character, serve to provide a rough comparison of technically similar products and are not subject to outgoing inspection. The typical value range of parameters is not defined with specific upper and lower limits. Please contact your EPCOS representative if you have special requirements regarding specified values and tolerance ranges.