



CeraPlas™ piezo plasma generator

October 2014

## Cold plasma from a single component

**Cold atmospheric pressure plasma promises decisive benefits in a wide range of industrial and healthcare applications. With the new CeraPlas™, TDK offers a plasma generating component that is more compact, easier to integrate, and more efficient than conventional plasma generating technologies.**

The interest in cold plasma technology is growing across a wide range of industries: It not only enables one to manipulate the surface properties of materials in a multitude of ways without causing damage or destruction, it can be used to clean and disinfect surfaces and spaces.

As one of the four fundamental states of matter, plasma is formed when air or gas is ionized. Plasma possesses conductive properties that are similar to those of metals and depend on the input parameters such as energy, pressure, process gas composition, or the addition of primer substances.

Plasma treatment is already implemented in numerous applications in almost all industrial branches. For an increasing amount of these applications a cold (non-thermal) atmospheric pressure plasma is required – especially in both industrial and healthcare applications such as surface treatment, cleaning, disinfection and odor reduction, to name just a few.

Plasma sources require high voltages to operate and thus also need high-voltage transformers or RF generators in the GHz range. For manufacturability and safety reasons, the high-voltage power supply and the plasma generating unit in these sources are typically designed in separate housings. Safety measures are necessary to protect users from exposure to the high voltages. Existing solutions are therefore often rather bulky. In addition, they can only use a limited selection of process gases. The market however is demanding high-performance solutions for cold, atmospheric pressure plasma generation that are compact, lightweight and easy to handle. The ideal product solution is battery-driven and supports a wide range of process gases.

### Single component solution

A completely new kind of component called CeraPlas™ meets these requirements. Developed in TDK's competence center for ceramic components in Deutschlandsberg, Austria, the new CeraPlas leverages, among other things, the know-how accumulated over many years in the volume manufacturing of piezo actuators and in multilayer ceramic technology. The development of CeraPlas is being conducted in close cooperation with relyon plasma, a leading manufacturer of plasma sources in Germany.

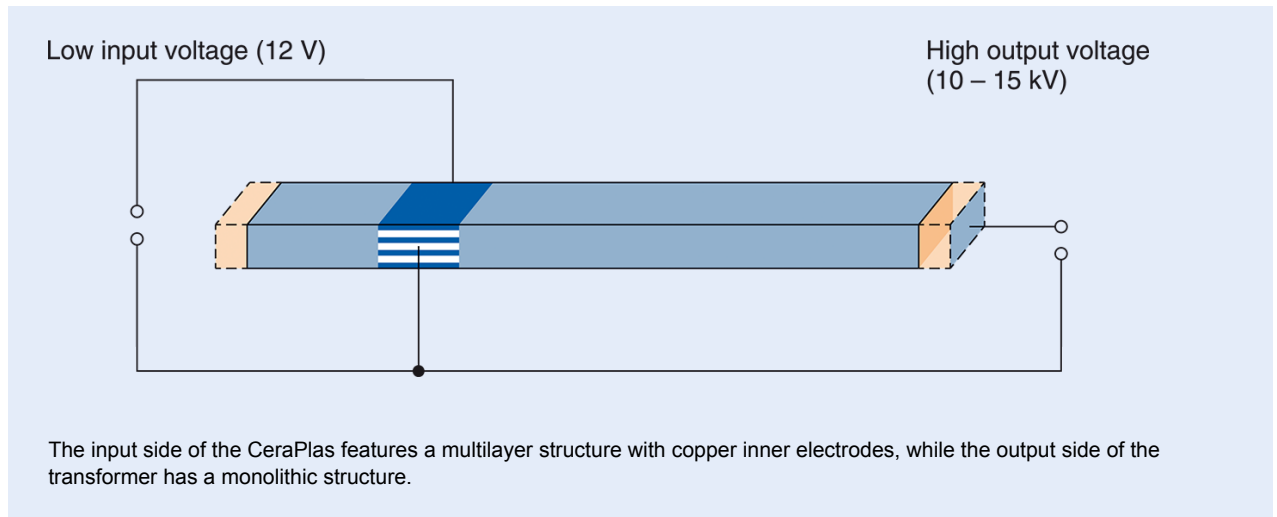
CeraPlas is a new piezoelectric component that enables the very efficient generation of cold atmospheric pressure plasma and uniquely combines the voltage transformation and plasma generation in a single component. As a piezoelectric transformer, the CeraPlas is able to generate the necessary high voltages; at the same time, the plasma generation takes place at the output side of the component.

### Innovative piezoelectric material

The new patented technology is based on a hard PZT (lead zirconate titanate) ceramic material, which can be co-fired with internal copper electrodes. As a result, the material set offers both a high and stable mechanical quality factor over a wide range of strain, as well as good electro-mechanical coupling and low losses.

The component is designed as a multilayer Rosen type piezoelectric transformer: The input side features a multilayer structure with copper inner electrodes, while the output side of the transformer has a monolithic structure (Figure 1).

Figure 1: Rosen type design of the CeraPlas piezo transformer and plasma generator



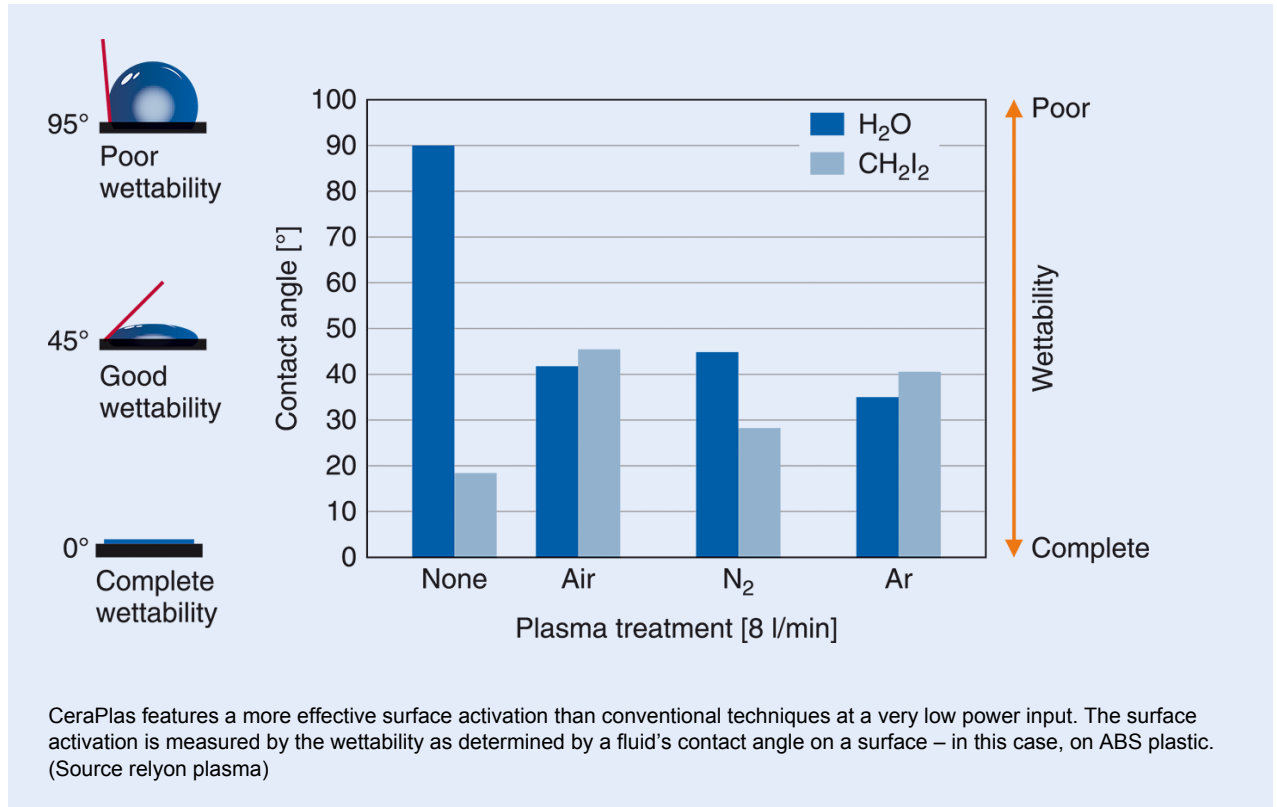
The voltage transformation is achieved at resonant frequency due to the formation of a standing acoustic wave which -transforms the low voltage from the input side to a high voltage at the mechanically coupled output side. Because the piezoelectric transformer operates at the 2nd harmonic vibration mode, it can be contacted and mounted at the vibration nodal points without disturbing its mechanical movement.

The standard DBD process used for plasma generation causes an electrical discharge between two electrodes that are separated by a dielectric barrier. With the CeraPlas, however, the discharge occurs directly on the surface of the piezoelectric transformer's output side as a result of the generated high voltage. Because the piezoelectric transformer operates here as a dielectric electrode as well, there is no need for a discharge electrode that conventional DBD solutions require. Charges collect on the surface of the dielectric material, where high electric fields are located and discharge within microseconds, leading to their reformation elsewhere on the surface. Similar to other electrical discharge methods, the plasma is sustained as long as the energy source provides sufficient ionization.

### Compact and safe

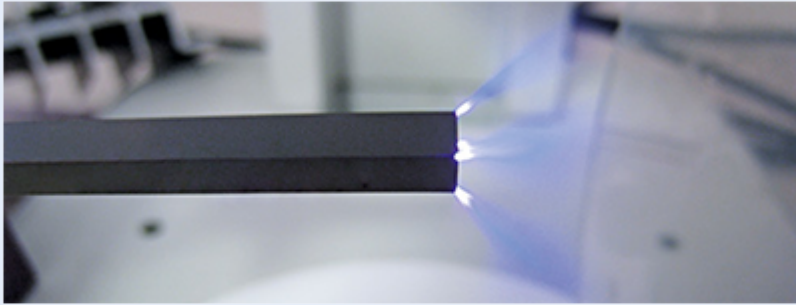
The CeraPlas is a component that features compact size, low weight, low power consumption, a low input voltage and a high output voltage. It can be integrated easily into different plasma source concepts without the need for special high voltage safety measures, thus giving it a high degree of application flexibility. All these beneficial properties are combined with an outstanding performance regarding plasma temperature and surface activation. In comparison with conventional plasma generation techniques, CeraPlas achieves a more effective surface activation at very low power (Figure 2).

Figure 2: Surface activation with plasma generated using CeraPlas



Voltages up to 20 kV can be reached at the output of the CeraPlas with a sinusoidal voltage of 12 to 24 V<sub>pp</sub>, which is high enough to generate a discharge in air and other industrial gases such as nitrogen or argon (Figure 3). The plasma itself has a temperature of below 50 °C and is therefore suitable for treating the surface of nearly all temperature sensitive materials.

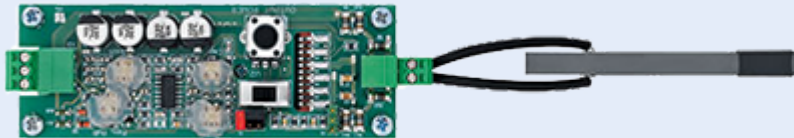
Figure 3: Air plasma generated by the CeraPlas



Cold atmospheric pressure plasma is ignited directly in air at the corners of the output side of the CeraPlas by driving the component with a sinusoidal voltage of 12 to 24 V<sub>pp</sub> at 50 kHz.

To enhance the efficiency of the CeraPlas component, a driver has been developed that is optimally matched to the requirements of the piezoelectric plasma generator. A piezoelectric transformer must be driven at its resonance frequency. For stable operation it is essential to immediately react to load and environmental changes. The prototype driving stage shown in Figure 4 with a CeraPlas plasma generator tunes the piezoelectric transformer and thus reduces potential stress to the component.

Figure 4: Driver for the CeraPlas



The driver developed for the CeraPlas component is optimally matched to the requirements of the piezoelectric plasma generator and thus enhances its efficiency. It ensures stable operation by immediately reacting to load and environmental changes and thus preventing hard switching.

Plasma sources based on CeraPlas exhibit outstanding performance in comparison to existing low-power plasma generators. The overall plasma generator concept is very elegant, requiring only a low-voltage power supply, the driver, CeraPlas and an optional gas supply. Thus, depending on the application requirements, CeraPlas can enable a wide range of designs for plasma generation units: from simple pen designs and handheld devices up to integrated modules for industrial applications.

### First commercial product using CeraPlas

The first product on the market based on CeraPlas is the piezobrush® PZ2, a wear-free cold atmospheric pressure plasma source that was developed by relyon plasma in close cooperation with TDK (Figure 5). The piezobrush PZ2 is

a compact handheld device that needs no external processing gas. The plasma is ignited by the CeraPlas component in the gas flow and features high activation efficiency. Due to its low plasma temperature of less than 50 °C, the piezobrush PZ2 can be used to activate temperature-sensitive materials. These features combined with its compact size show the high potential for implementation in handheld devices and industrial plasma applications.



#### **Superior reliability and outstanding power density**

The piezobrush PZ2 from relyon plasma, which is based on CeraPlas, is a compact, handheld, cold plasma source that features low power consumption and is both lightweight and quiet. COMPONENTS spoke with Dr. Stefan Nettesheim, Managing Director of relyon plasma, about the benefits of CeraPlas.

Why did relyon plasma select CeraPlas as the key component for its new products?

Dr. Stefan Nettesheim: Because it allows us to design slim, handheld tools such as the piezobrush PZ2, a plasma source that is easy to operate, safe to touch and cleanroom-compatible.

What features of the CeraPlas are the most impressive?

Dr. Stefan Nettesheim: The efficiency of the plasma generation process of CeraPlas is very high. In addition, CeraPlas technology offers superior reliability and outstanding power density.

What are the specific benefits of the component's high efficiency?

Dr. Stefan Nettesheim: In a nutshell, size and performance of our products. CeraPlas enables us to design a robust driving circuit and housing without any additional cooling. Our piezobrush PZ2 can withstand mechanical blows and thermal stress, making it suitable for extreme operating conditions. Thanks to the high intrinsic voltage ratio of CeraPlas, we could design the PZ2's power supply and driving circuit as a very compact module.

Samples of the CeraPlas are now available, and series production of the CeraPlas is currently in preparation based on the existing volume manufacturing technology for EPCOS multilayer piezoelectric components such as the successful piezo actuators for automotive fuel injection systems.

As the world's first combined transformer and plasma-generating component, Cera-Plas is suitable for use in a wide range of innovative applications such as surface treatment of car interior textiles and plastics, the sterilization of food processing machines and medical devices, or even the direct treatment of wounds.

Table: Key technical data for the CeraPlas



Operating voltage [V <sub>pp</sub> ]	12 to 24
Operating frequency [kHz]	~ 50
Output voltage [kV]	Up to 15 (depending on load)
Transferred power [W]	10 (max.)
Plasma temperature [°C]	<50
Processing gas	Air, industrial gases such as N <sub>2</sub> , Ar, He
Ozone generation rate [ppm] (at 8 W with customized measurement set up)	20
Dimensions [mm]	72 × 6 × 2.8
Material set	Hard PZT with co-fired copper electrodes
Assembly	Soldered mounts and connections at nodal points

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