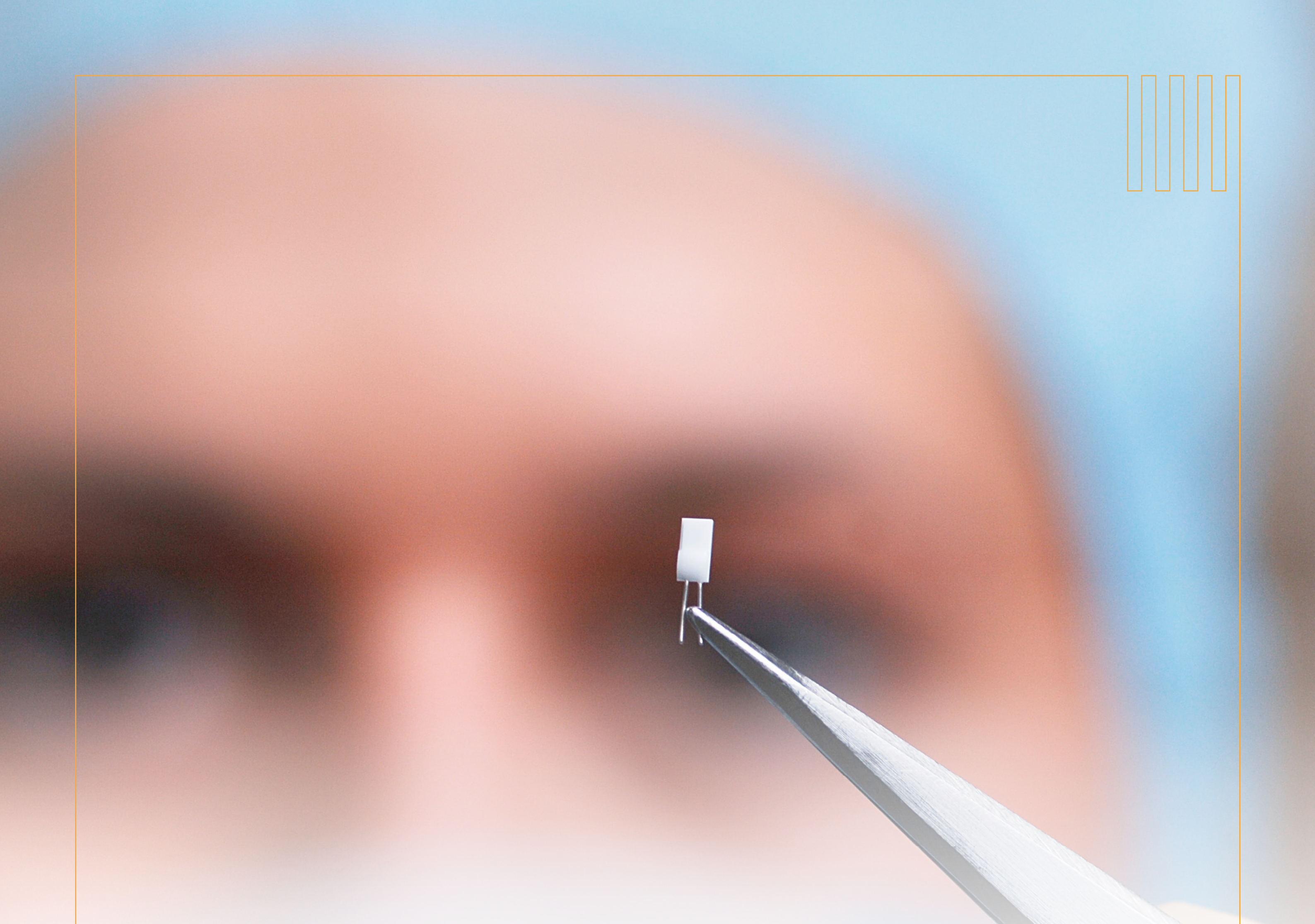


New Pt Thin Film Sensors for Exhaust Gas Treatment Systems in Gasoline-Fueled Vehicles

YAGEO Nexensos pushes the application range of Pt-RTDs to 1000 °C by improving the thermo-mechanical stability with new material combinations

Introduction

Modern diesel exhaust gas treatment systems must deal with temperatures of +800 °C and more. In gasoline cars the temperatures are even higher and can reach +1000 °C. While NTCs and Pt elements are the sensing technologies of choice for diesel cars, they have lifetime and drift limitations at +1000 °C. To add temperature safety margins, OEMs therefore use thermocouples in several applications and platforms.
Unfortunately, thermocouples require specific electronic interfaces and often increase the overall complexity and costs, especially when only a few temperature sensors are being employed in the exhaust gas system.

To enable OEMs to use the proven RTD technology with existing and efficient electronic interfaces, YAGEO Nexensos has taken up requests from the market and developed a new type of Pt thin film element. The element needs to withstand temperatures up to +1000 °C including thousands of fast thermal cycles down to the ambient.
To reach this goal the thermo-mechanical stability of the RTD had to be improved with new material combinations. The characterizations shown in this paper demonstrate the high potential of such a product for applications in gasoline particle filters.

HDA and a challenge of thermal cycling

The HDA chip was the first platinum thin-film RTD introduced by YAGEO Nexensos, which is suitable for temperatures above +800 °C. HDA is on the market since the 90's and became the benchmark for applications up to +900 °C. The design of such sensor is shown schematically in Fig. 1. HDA 420 platinum temperature sensors are characterized by long-term stability, precision over a broad temperature range and interchangeability. They are widely used in diesel engines and can withstand the long-term exposure to temperatures up to +900 °C without a noticeable drift (Fig. 2).

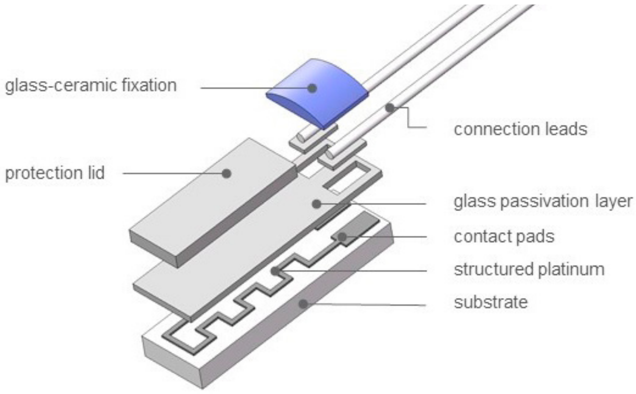


Fig. 1: Design of high-temperature sensor HDA.

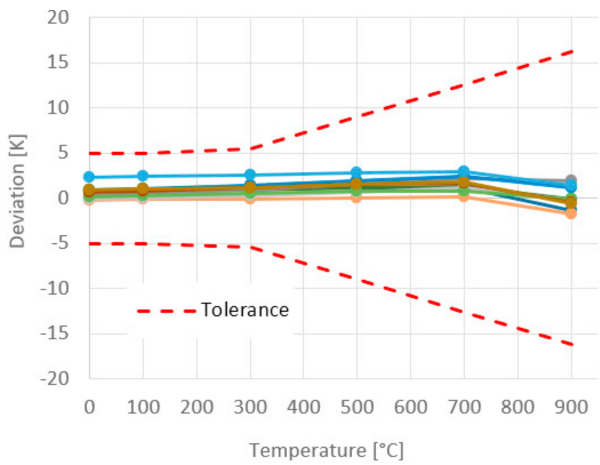


Fig. 2: Results of isothermal test for HDA 420: Deviation after 500 hours at +900 °C, powered with 5V, pullup resistor 1000 Ω.

A challenge for all platinum thin-film sensors for high temperatures which are available on the market so far is the stability under fast thermal cycles. For example, a maximum of 500 cycles (ambient to +900 °C) is specified for HDA 420. The limitation is of physical nature and due to the plastic deformation of Pt on Al_2O_3-substrate as a result of the large difference in thermal expansion. This is always the case when the sensor is rapidly cooled down from high temperature (> +850 °C) to below +300 °C at a gradient of 100 K/s or more. Each cycle induces stress in the Pt-layer, which cannot be relaxed within a short time.

To visualize this effect a sensor was subjected 10000 times to fast heating and cooling in the model experiment. SEM of the uncovered Pt-structure on Al_2O_3-substrate shows a displacement of the platinum after thermal cycling (Fig. 3) that causes a drift in resistance.

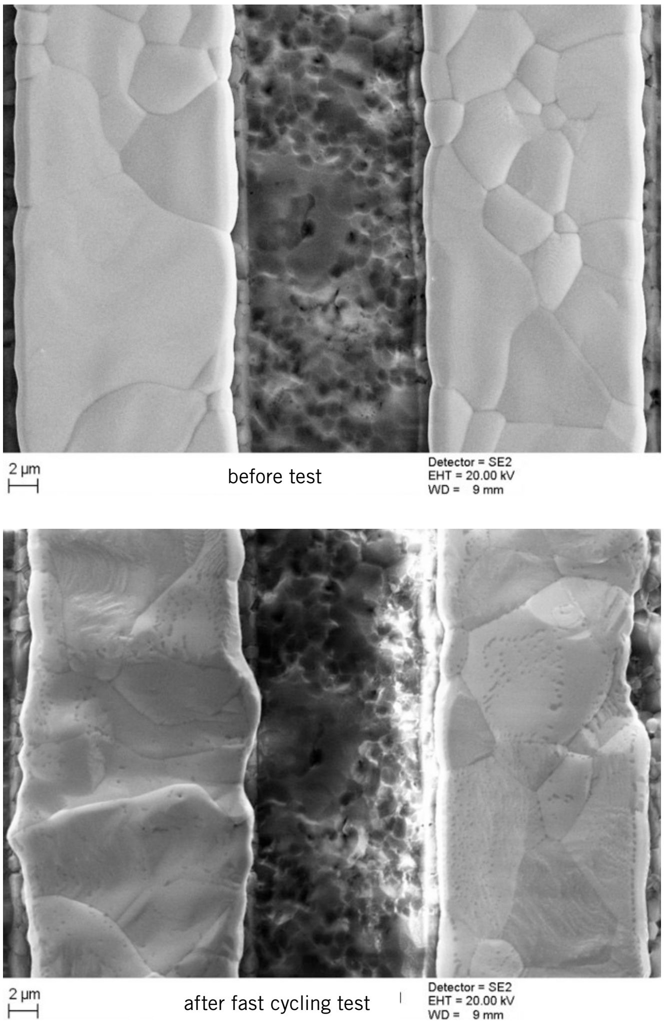


Fig. 3. SEM micrographs of uncovered Pt tracks on alumina substrate before and after fast cycling test (+250 °C to +910 °C, full cycle within 1 minute). Pictures taken at the same position of the sensor.

The current HDA performance is meeting the requirements in modern diesel cars. Modern gasoline type engines however are designed to work with many rapid thermal cycles at higher temperatures up to +1000 °C to achieve the desired efficiency. In many gasoline cleaning systems this means significantly higher requirements and more demanding specifications for temperature sensors, e.g. they have to withstand 5000 temperature cycles instead of 500, as depicted in the Table 1.

In order to meet these higher standards in combination with additionally improved accuracy, the new sensor type HDZ has been developed at YAGEO Nexensos.

Table 1: Technical specifications of high-temperature sensors HDA 420 and HDZ 420

Specification	HDA 420	HDZ 420
Temperature range	-40 °C to +900 °C Short-term up to +950 °C	-40 °C to +1000 °C Short-term up to +1100 °C
Nominal resistance @ 0 °C	200 Ω	200 Ω
Temperature coefficient (TCR)	3770 ppm/K	3850 ppm/K
Long-term stability	500 hours at +900 °C (5V, pullup resistor 1000 Ω)	1000 hours at +1000 °C (5V, pullup resistor 1000 Ω)
Specified number of thermal cycles (ambient to T_{max})	500	5000
Tolerance new	± 2.5 K (-40 °C to +280 °C) ± 0.9 % of temperature (> +280 °C)	± 2.5 K (-40 °C to +280 °C) ± 0.9 % of temperature (> +280 °C)
Tolerance aged	± 5 K (-40 °C to +280 °C) ± 1.8 % of temperature (> +280 °C) (± 16.2 K (+900 °C))	± 5 K (-40 °C to +280 °C) ± 13 K (+1000 °C)

Results

To overcome the limitations posed by thermal cycling, the thermal expansion of substrate and Pt-layer needs to match. This is accomplished by depositing the Pt-layer on a zirconia-based substrate instead of alumina. Simulations show that by using the optimized substrate, the stress on the Pt-layer is reduced by more than factor 20 (Fig. 4).

As a result, HDZ exhibits excellent high-temperature long-term stability in validation tests as shown in Figs. 5 and 6. The tolerance band for aged HDZ is tighter than that for aged HDA, and still the maximum deviation after isothermal and cycling tests is using only about 10 % of the tolerance band.
The specifications for HDA 420 and HDZ 420 are compared in Table 1.

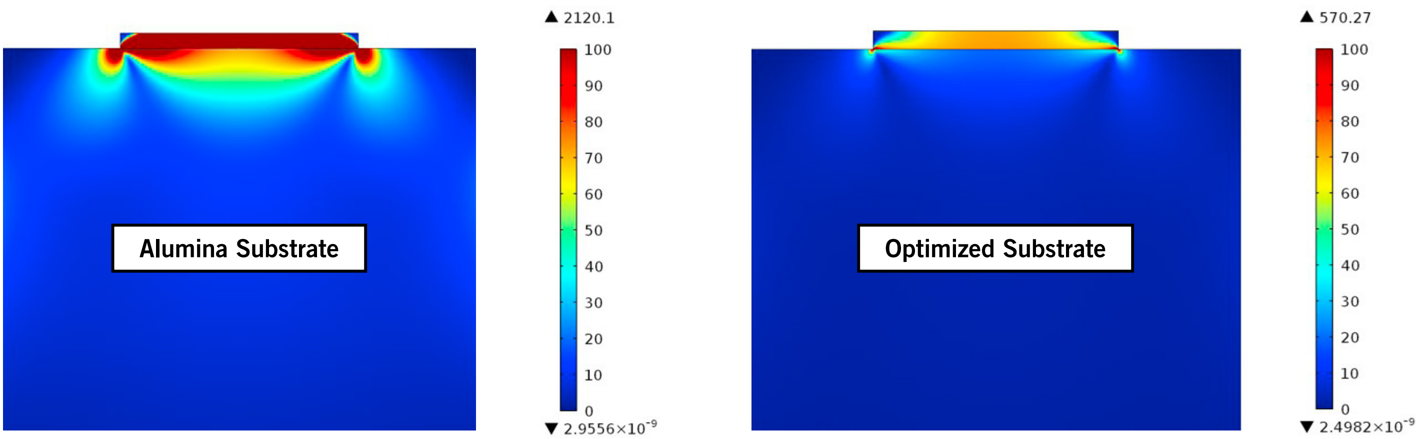
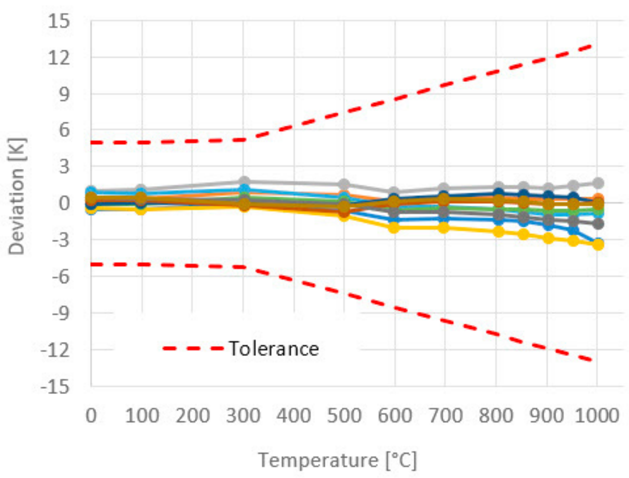


Fig. 4. Results of FEM simulation showing the stress [MPa] after cooling from +900 °C down to ambient temperature.



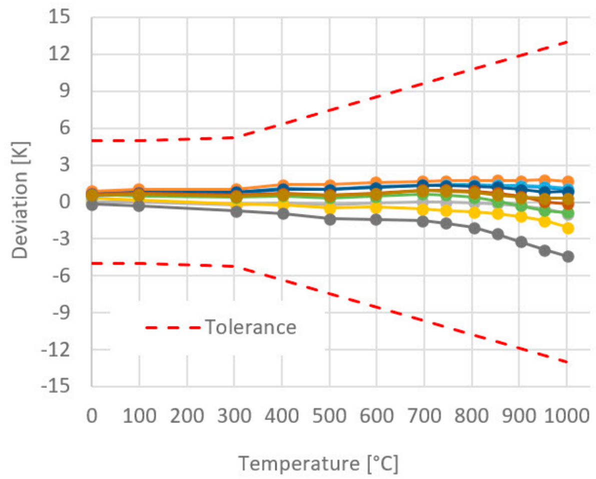


Fig. 5: Results of isothermal test for HDZ 420: Deviation after 1000 hours storage at +1000 °C, powered with 5V, pullup resistor 1000 Ω.

Fig. 6: Results of temperature cycling test for HDZ 420: Deviation after 5000 cycles between ambient and +1000 °C, well time 5 minutes each phase, poweredwith 5V, pullup resistor 1000 Ω.

Conclusion

To provide a Pt-RTD for the use in modern gasoline particle filters and cleaning systems, YAGEO Nexensos has developed a new thin film Pt-RTD with increased thermo-mechanical stability. One of the key factors is the use of a zirconia-based substrate, which is better thermally matched to the Pt layer. The new HDZ sensor operates in the range of -40 °C to +1000 °C, can withstand thousands of thermal cycles and is characterized by an improved accuracy compared to today's standard high temperature elements. The drift is less than 1K @ 0 °C, which enables HDZ to precisely control temperature up to +1000 °C degrees.

Moreover, it allows OEMs and Tier 1 suppliers to use the proven RTD technology with existing signal interfaces and electronics and helps to limit system complexity and total cost.

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