Platinum Thinfilm Sensors for Space

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INTRODUCTION

Resistance Temperature Device (RTD) uses the temperature dependence of resistivity of metals to convert temperature into an electrical signal. Platinum is the most accurate material due to its linearity and low hysteresis. In contrast to thermocouples, RTD's measure directly temperature and not temperature difference. Another advantage is, that thermoelectric Electromotive Force (EMF) is cancelled out and with special measurement principles even completely removed.
From design, RTD's are very robust and insensitive to many conditions found in space environment. This motivates the wide usage in those applications.

Wire Wound RTD

To gain higher base resistances, it is required to have a long but thin platinum conductor. The most common implementation is to wrap the wire on a coil. Critical for accurate sensors is to minimize mechanical stress on the wire, because this will influence the resistance as well.

The major drawbacks of this technology are the limited base resistance range, which is typically limited to 100 Ohm and sensitivity to vibrations, besides of the very high material and manufacturing costs.

Thinfilm RTD

With this technology a thin layer of platinum on a ceramic substrate is deposited. Due to the thickness in the range of a few hundred nanometres and very fine structuring capabilities, very high base resistances are possible. For the same reason, very small sensors can be manufactured. The platinum layer is protected with glass and is therefore well protected form harsh environment. Sensors can be manufactured with either bonding pads or lead wires. In the later case, the welding point is also covered with glass, protecting this very sensitive area. The technique is well controlled and guarantees excellent wire pull off strength.

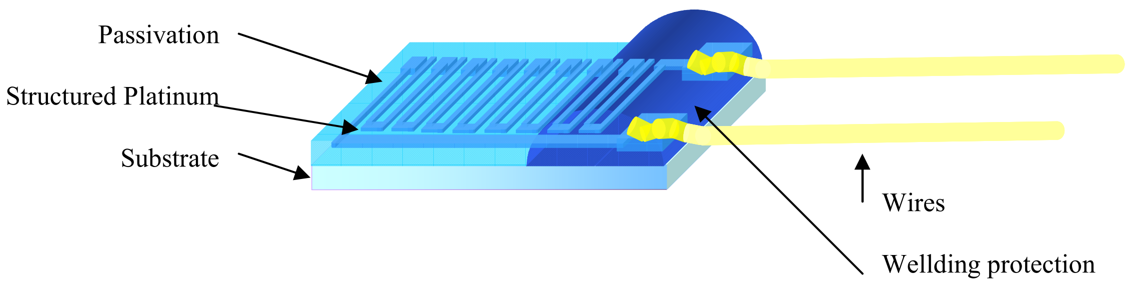

Fig 1: Schematic view of a thinfilm temperature sensor

Due to a significantly different volume to surface ratio of the conductor and a different thermal expansion coefficient of the carrier material, thinfilm RTD's have a slightly different temperature-resistance characteristic than wire wound sensors.

Measurement Performance

Overall measurement errors can be categorized in noise, drift and systematic errors. Noise is manly influenced by the sensor sensitivity because this influences the signal to noise ration (SNR) of the temperature readout. Drift is influenced by mechanical stress from thermal cycles (hysteresis) and other influences which degrade the material (e.g. certain chemicals). Systematic errors are e.g. non-linearity of the material, different thermal expansion of used material or fabrication tolerances.
Non-linearities are compensated with a polynomial model and error correction has to be applied from the customer, if highest accuracy is required. The Callendar-van-Dusen equation is used for this purpose and its coefficients are standardized in DIN EN 60751:

$$R(T) = R_0 \cdot \left[1 + A \cdot T + B \cdot T^2 + C \cdot T^3 \cdot (T - 100)\right]$$, where $C = 0\, for T > 0°C$

R_0 is adjusted with trimming during manufacturing whereas A, B and C are material and manufacturing process dependant. Especially the thickness of the conductor has an influence, where very thin layer show a difference to bulk material properties.

The Coefficients A, B and C are defined to
$A = 3.9083 \cdot 10^{-3} °C^{-2}$
$B = -5.775 \cdot 10^{-7} °C^{-2}$
$C = -4.183 \cdot 10^{-12} °C^{-4}$
according above norm.

SPACE REQUIREMENTS

Thinfilm RTD's have many advantages for space applications:

From a mechanical point of view, they are small, lightweight and very insensitive to mechanical vibrations. Due to the availability of bonding pads, they can be directly integrated with electronics and do not require additional wiring. The mechanical design makes them also very insensitive for high number of thermo cycles.

Due to the possibility of high base resistances, very low power measurement electronic is possible, which helps also to improve measurement accuracy to lower self heating.

For temperature stabilisation applications, a heater can be implemented with the same technology. If required, the sensor and heater can be combined on the same die.

IST has more the 20 years experience with thin film RTD's in industrial applications and several years in the space market. Therefore, highest reliability is proven and qualification according ESCC 4006 is availabble.

PW TECHNOLOGY

State of the art thinfilm technology has the drawback of a slightly different transfer characteristic compared to wire wound sensors. (see figure 1) This has been solved with PW technology alongside with a significant improvement on hysteresis and long term drift performance.

Fig 3 compares a traditional wire wound sensor with a PW sensor, which is cycled form -196°C to 600°C. Whereas the wire wound sensor has comparably high drift and hysteresis, PW does not show this effect.

Figure 4 shows long term drift behaviour. Exposition to high temperature, thermal cycles and high humidity will cause only minimal drift.

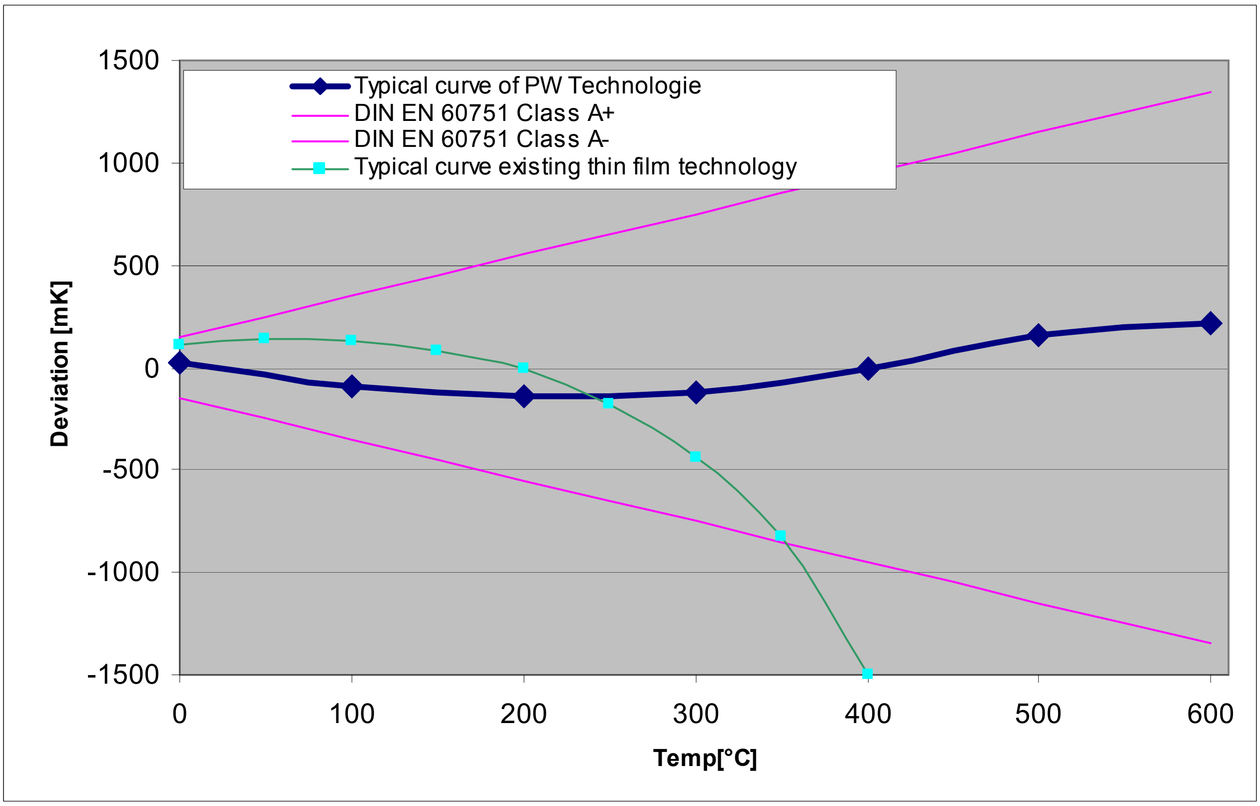

Figure 2: Systematic deviation of traditional thinfilm sensors and PW. The zero-line is the perfect standardized wire wound sensor

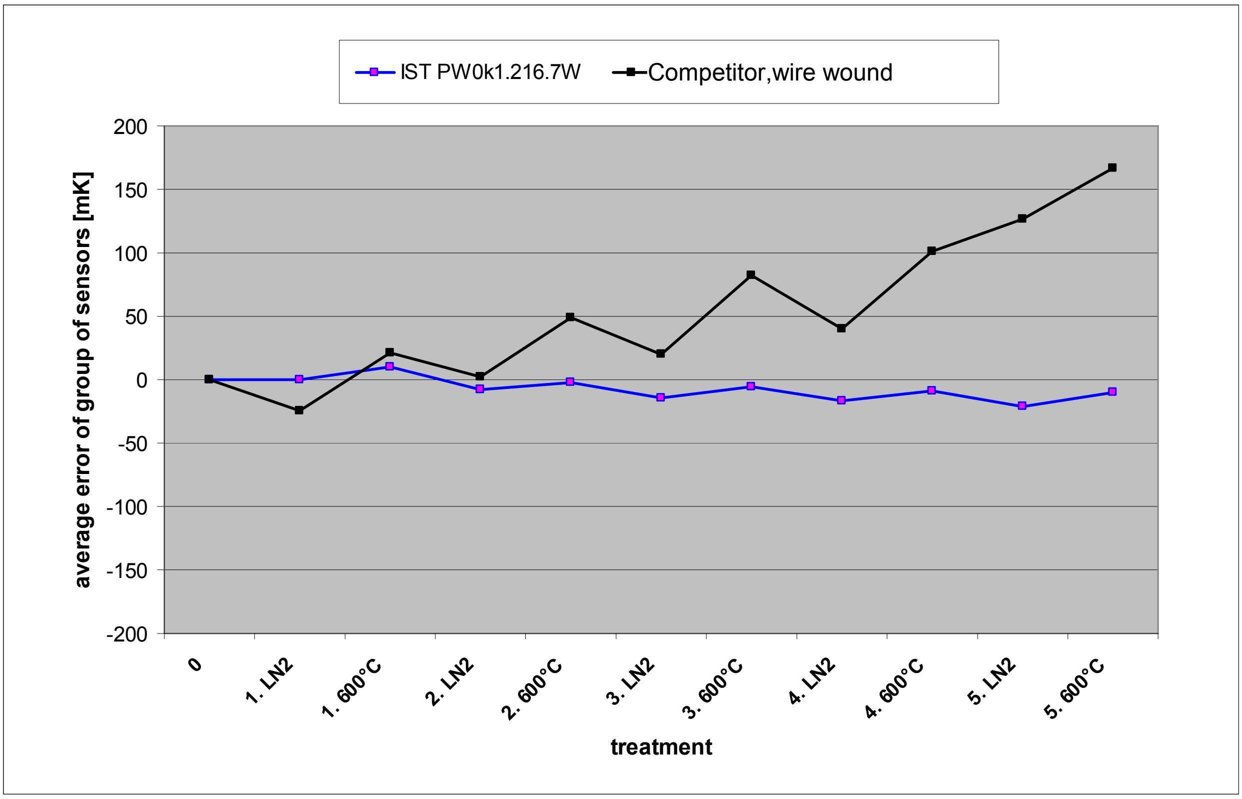

Fig 3: Hysteresis plot comparing traditional wire wound sensor and PW sensor

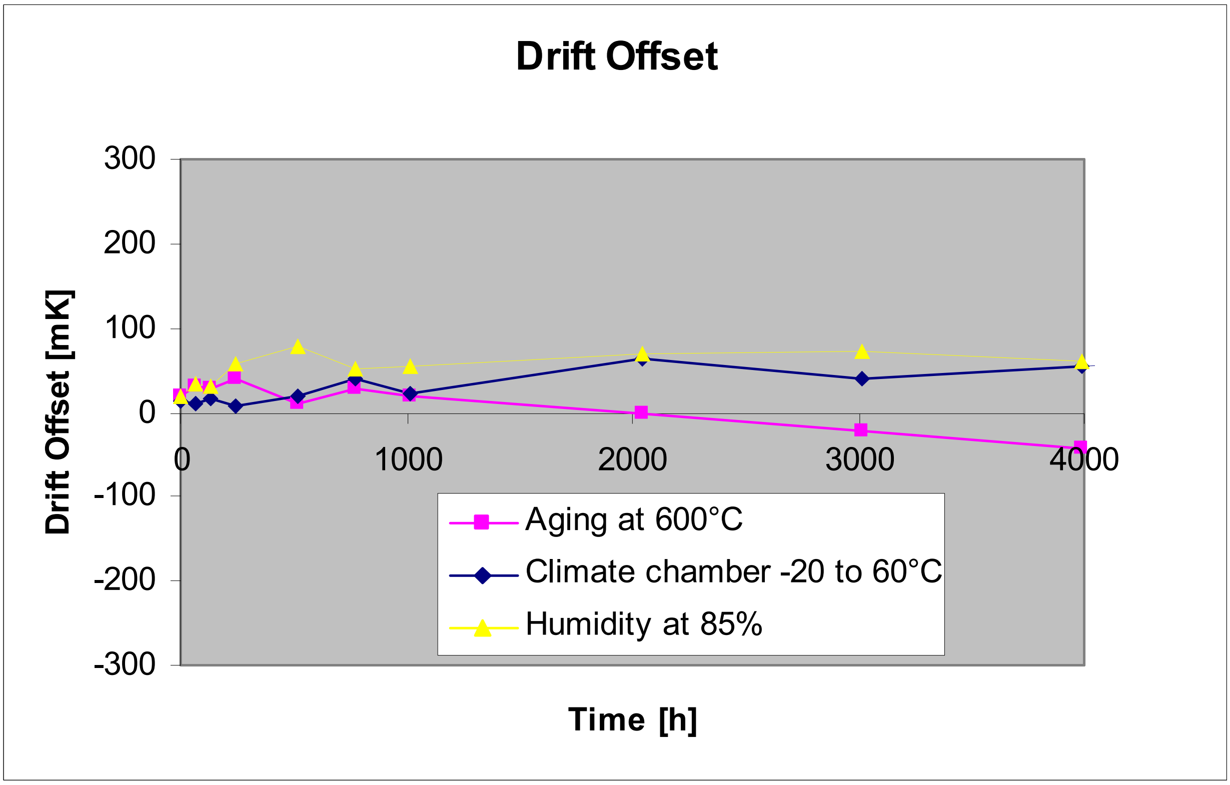

Fig 4: Drift behavior of PW sensor

This improvement is archived with some small but important changes:
The substrate material is changed, so that the thermal expansion of platinum is matched. Therefore mechanical stress of the platinum is almost completely removed. This results in a very good performance regarding thermal cycle and hysteresis.

To further enhance the transfer characteristic, the platinum material is doped with certain materials. A passivation layer below and on top of the platinum protects the platinum optimally form environment influences and reduces stress because of symmetry.

CONCLUSION

Thin film technology is matured over the past twenty years and is ready for high reliability applications. Many of the features give lots of benefits to space applications, including small size and light weight, robustness regarding mechanical vibration and thermal stress. All used materials are out gassing free and withstand cosmic radiation.
If high accuracy and backward compatibility to wire wound sensors is required, PW technology is optimally suited to the equalized transfer characteristic.