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UHF RFID INDUSTRY HEAT RESISTANT TAG

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The use of UHF RFID heat resistant tags for monitoring heating industry processes is one of many prospective RFID applications. As a result of long-term development has been developed the UHF RFID heat resistant tag fabricated by printing silver antenna on a ceramic substrate. The novelty of this solution is in improving the endurance of UHF RFID heat resistant tags from 50-60 temperature cycles 260-300°C/1minute up to 3500 cycles 260-300°C/1minute. The endurance of new tag is prolonged by more than fifty times compare the solutions up to today.

Keywords: UHF RFID identification, UHF RFID heat resistant tag

Introduction

Industry heating processes are an area where it is both tempting and suitable to use RFID technology. The use of RFID technology has become the main focus of attention. There are a lot of RFID heat resistant tags – labels available on the market. Primarily the labels have one common denominator. This is a limited number of temperature cycles due to the temperature degradation of the materials which are used in the production of heat resistant tags.

Our research has shown that the main problem is not the UHF RFID chip itself, but the connection between chip and antenna and the material used. We have to understand that if we are speaking about the connection between chip and antenna, we are talking in terms of micro meters. As a result, the main problems are dilatation of the material, dilatation of the connection between chip and antenna and temperature-frequency characteristics.

This paper begins with an overview of thermal noise, calculation of thermal dilatation and examples of our testing of another version of the tag and a review of the results of ceramic UHF RFID heat resistant tags.

RF devices use air as a communication medium. A requirement for successful operation was that the power transmiting from the reader and the signal received and retransmitted from the tag be above the temperature noise floor (this is our main focus). Noise is the major limiting factor in the communications system performance.

The thermal noise can be calculated with the equation (1)

$$N = kTB, \tag{1}$$

where k is Boltzmann's constant 1.3803×10^{-23} J/K and T is the temperature in Kelvin (T = 273.16 + t (°C)).

In dBW, the equation (1) would look as follows:

$$N = -228.6 + 10logT + 10logB. \tag{2}$$

Table 1. Thermal noise with addition of -3dB receive noise factor [1]

Temperature [°C]	Thermal noise [dBm] for B=63MHz 865-928MHz	Thermal noise [dBm] for B=26MHz US ISM band	Thermal noise [dBm] for B=3MHz ETSI band
21	-92.9	-96.8	-106.1
100	-91.9	-95.7	-105.1
200	-90.9	-94.7	-104.0
300	-90.0	-93.9	-103.2
400	-89.3	-93.2	-102.5
500	-88.7	-92.6	-101.9

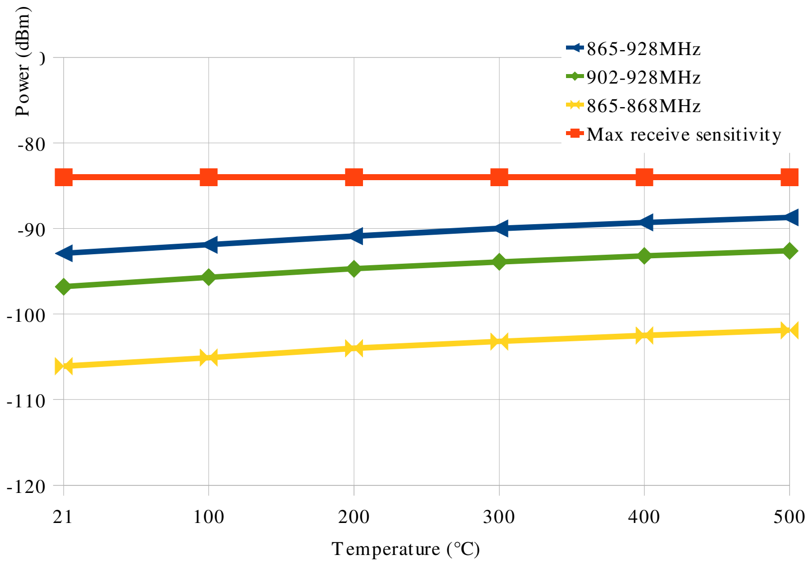

Figure 1. Thermal noise vs temperature

Fig. 1 shows the impact on thermal noise of increasing temperature. In all cases the thermal noise does not reach the maximal sensitivity value of the UHF RFID reader (-84dBm). Consequently, thermal noise is not a limiting parameter.

The next important paramenter is the linear coeficient of thermal expansion. RFID technology works with very small sizes (micrometers). Consequently, thermal expansion may have an influence on the reliability of the connection chip – antenna.

It is necessary to be aware that when heat is applied to most materials, the average amplitude of the atoms vibrating within the material increases. This increases the separation between the atoms, which in turn causes the material to expand. If the materiall does not go through a phase change, the expansion can be easily related to the temperature change. The linear coefficient of thermal expansion describes the relative change in length of a material per degree of temperature change [resource NDT Resource center]. The linear thermal expansion can be calculated using the equation (3)

$$L = \alpha \cdot L_1 \cdot (T_1 - T_2), \tag{3}$$

where α is a coefficient of linear expansion of the material, L_1 is an initial length of the material used, T_1 is an initial temperature and T_2 is a final temperature.

In our prototype there have been used three basic materials: ceramic, silver and copper.

The coefficient of linear expansion of these materials is as follows:

Table 2. Coefficient of Linear Expansion

Silver	19.5×10^{-6}m/mK
Ceramic	6.5×10^{-6}m/mK
Cooper	16.6×10^{-6}m/mK

The most critical material is silver, which is used for both the contact material of the chip and the antenna. As a result our next focus is on this material.

Table 3. Silver Linear Thermal Expansion

Temperature [°C]	LTE [10^{-6} m]
100	0,39
200	0,87
300	1,37
400	1,85
500	2,34

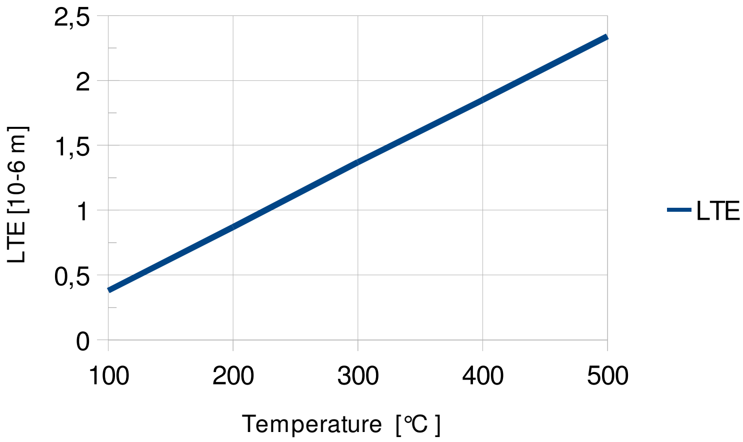

Figure 2. Siver – Linear thermal expansion

Table 3 shows the result of the calculation of the linear thermal expansion of silver between two contacts of the chip. The result of the calculation in Table 13 indicates that the temperature expansion of silver at the temperature level of 300°C has the value 1,37x10^{-6} m. This is 0.5% of the size of the contact place of the chip. At the same time, other materials with lower linear thermal expansions, such as ceramic and copper, will also be dilated. As a result, the final dilatation of the critical point between chip and antenna will be 0.3%. From this it can be concluded that the expansion of silver will not cause disconnection of the chip-antenna.

Experimental Results/Examples

The pictures below show the details of three ways of connecting the chip to the antenna. Fig. 3 shows the connection strap – antenna, Fig. 4 shows the solution of direct connection of the chip to the antenna and Fig.5 shows our solution of direct connection chip – antenna using silver.

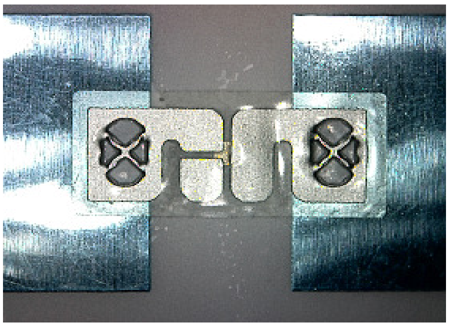

Figure 3(a). Inlay strap – antenna (21°C)

Figure 3(b). Inlay strap – influence of the temperature 200°C/1minute, the chip is disconnected

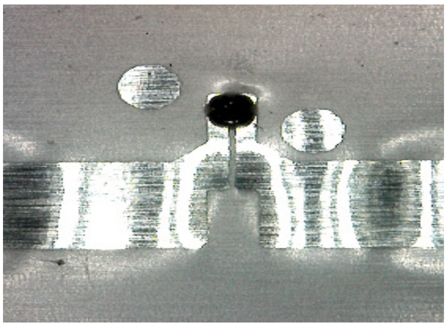

Figure 4(a). Inlay – direct connection chip – antenna (21°C)

Figure 4(b). Inlay – influence of the temperature 200°C/1minute, the chip is disconnected

In both cases Fig.3(b) and Fig.4(b), following exposure to a temperature 200°C/1minute, the material is deformed and the chip is disconnected. The chip is not damaged and continues to work after reconnection to the antenna. This confirmed our conclusion that our main focus should be on a reliable connection between chip and antenna.

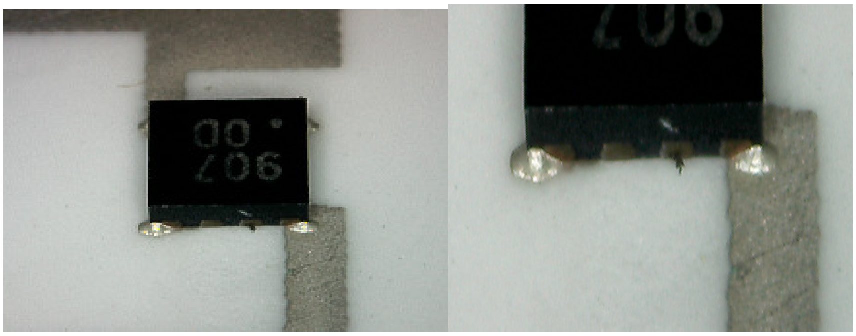

Figure 5(a). Chip – antenna connection by silver on a ceramic substrate (21°C)

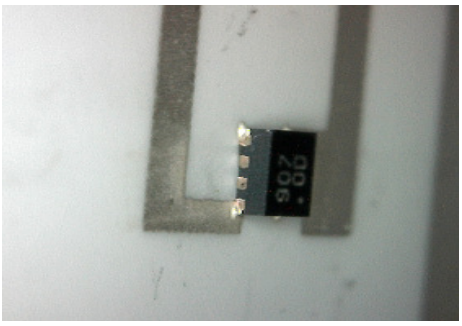

Figure 5(b). Chip – influence of the temperature 300°C/60minute, the chip is connected

Fig.5(b) shows that the temperature cycle 300°C/60minutes has no influence on the disconection of chip –antenna. Endurance is dependent solely on the life time of the chip.

Figure 6. Final solution UHF RFID tag on ceramic substrate

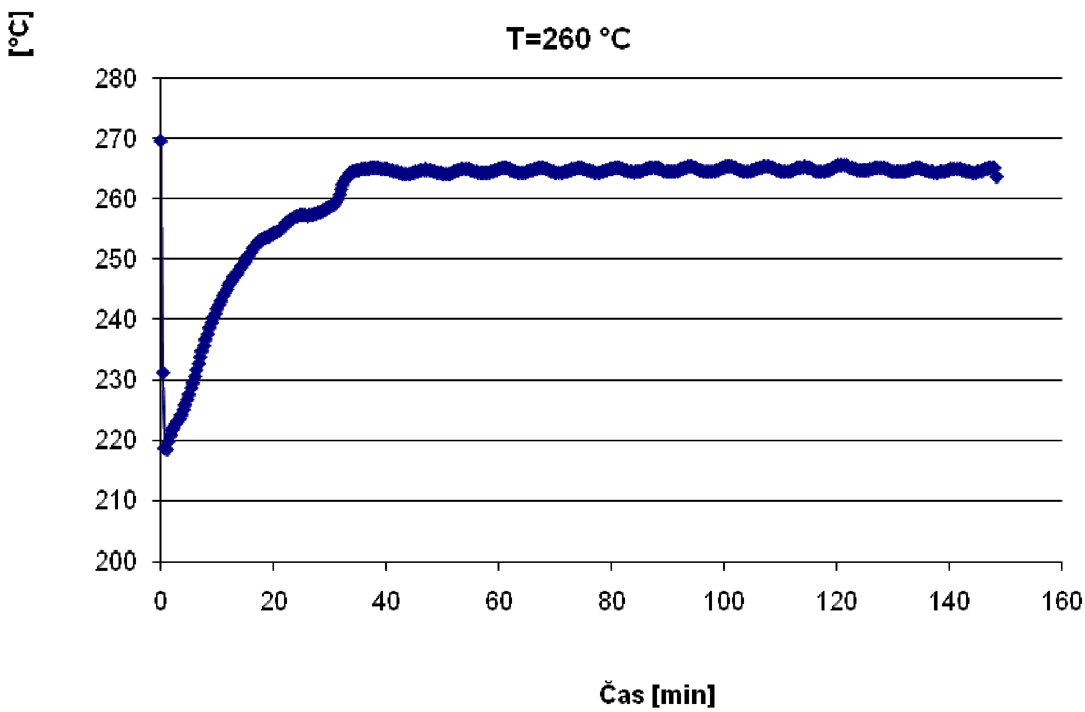

Figure 6. Life test – 37cycles 260°C/120minutes

Conclusion

The tests have shown the importance of the correct choice of materials in the area of heating application for use in RFID technology. Our samples UHF RFID tag on ceramic substrate have been able to pass a temperature of 300°C without any mechanical change to the connections. During long-term testing of 10 samples, the tags were able to pass 3700 temperature cycles 260°C/1minute. If this result is compared to the results of UHF RFID labels, which are able to only pass 20-30 cycles 205°C/30minutes, it is clear that the ceramic solution is the most economic one.

The factor of dilatation must be taken into account when designing heat resistant tags. This is one example which gives a clear indication that RFID is not only about the propagation of electromagnetic waves, but it also crosses a range of different technnologies.

This paper does not cover all questions regarding UHF RFID heat resistant tags. Further questions include the relationship of the radiation pattern of RFID tags versus temperature and the relationship of the resistance of the connection chip – antenna versus temperature.

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