SPUTTERED TYPE S THERMOCOUPLES ON QUARTZ GLASS SUBSTRATES

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1. Introduction

The work deals with the development of thin film thermocouples and their practical use. The principle of measuring planar thin film thermocouples is the same as for conventional thermocouples and is based on the thermoelectric effect, which named after its discoverer, Seebeck. In 1821 appeared i.e. Seebeck [1] called "Thermoelectric Voltage at the junction of two dissimilar metals. Seebeck effect is direct conversion of temperature differences to electric voltage. In different applications it is necessary to use temperature sensors with high spatial resolution (with the placement of several measured points on the segment of length 1 mm) and short response time. For this application are currently used planar thermocouples with important advantage in production price and reproducible production. The disadvantage of some methods of preparation of thin films, chemical methods such as exclusion from vapour deposition (CVD), but the productivity of small (low deposition rate) and the risk of entrainment of various contaminants (e.g. gases) into the coating [2].

2. Origin of interest

Literature devoted to the subject's own development and manufacturing of thin film thermocouples is quite poor and, moreover, rather than dealing with other types of Pt / Pt-Rh,

e.g. types of NiCr / NiSi, and Sb_2Te_3 Bi_2Te_3. It is obvious that although various thin layers such as in recent years the focus of research and development, thin film thermocouples have been - and notably the "classic" Thermocouple Pt / PtRh - in the last ten to twenty years in the world, the focus of intense interest.

3. Experimental

To get an idea of how thick the layers are actually planar thermocouples and other purposes of deposit, in the literature were searched for specific values of thickness. It was found that the reported values of layer thicknesses range from less than 35 nm [3] to 5 mm [4], while in the junctions, there were also thicker, up to 50 micron. The size of junction is 30-50 micron or, conversely, only 1.6 micron or "a few micron" [5].

The absolute values of Seebeck's coefficients of metals in the group (Au, Pd, Pt, Rh and Ir) depicts Fig. 1. Any group of metals Au, Rh and Ir, whose coefficients are similar, can be used on practically usable thermocouple in combination with either Pd or Pt. Similarly, it is possible to link the Pt and Pd. These combinations provide usable, sufficiently high values of the coefficients - about 6 μK^{-1} at 0 °C and 20 μK^{-1} at 1000 °C - in addition to a combination of Au, Rh or Ir with Pt, where the coefficient was approximately doubled.

4. Discussion

So far, the findings showed that the temperature of 1100 ° C, the thin film thermocouples behave like a traditional wired. Have a good life after a period of at least 10 hours (for measurement of melt temperature is longer intervals or no sense to consider). There were, they both positives and negatives that require further attention:

Advantages:

- Up to 1200 ° C sputtered thermocouple has the same features as the standard thermocouple;
- Thermoelectric properties of thermocouples are identical to each other;
- Repeated long-term measurements (24 h) didn't change their thermoelectric properties.

Disadvantages:

- No adhesive layer under suitable outlets can provide reliable connection terminals;
- Solution design and pin fixation is needed further testing and adjustment.

On the bases of these experimental results has been prepared a new series of sputtered thermocouples for determination the thickness and different types of adhesive layers on

corundum and quartz substrate, including the sample using a thermocouple sputtered layer on quartz tube diameter of 10 mm for operational verification.

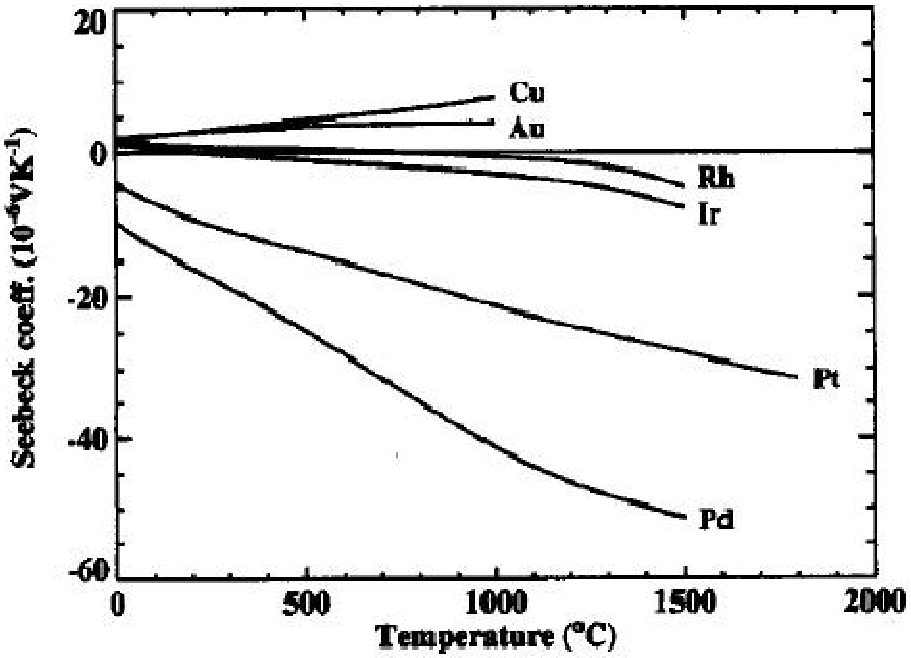

Fig. 1 - *Seebeck coefficients of different elements derived from the relative rates of Pt, data EMS / and the absolute temperature coefficient for Pt.*

It was found excellent agreement of simulation of thermoelectric voltage on the thermocouple corundum Al_2O_3 standard instrument to temperatures up to 1100 ° C. Overall, it is possible for the simulation thermocouples state:

1st very good reproducibility of independent measurements,

2nd satisfactory repeatability for same thermocouples (tested up to 3 times in a row),

3rd very good accuracy.

Besides the thin-film thermocouples are made of so-called thermocouple simulation, which was used in thin layers, but wired functional branches, but in the corresponding flat construction design development of thin film thermocouples with thermocouple wires sandwiched between plane-parallel development substrates.

Thin-film thermocouples have been manufactured in several series with the following results:

- Thermocouple junction Pt-PtRh was functional even after reducing the contact area,
- Deposited layer of Pt-CuNi, PtRh10-Cu showed excellent contact resistance and the perfect connection.

At present are carried out repeated measurements of the samples and the production of next batch. In the next stage of technology development will be further investigated and will be carried out measurements of thin film thermocouples to the planned operating temperature. The solution is primarily trying to save precious metals. We expect to widen the methodology of measurement for other variants of thermocouples.

5. Conclusions

The innovative potential of thin-film thermocouples are to be found mainly in:
1st use of technology in thin layers, unlike the already mature technologies applied in the production of conventional thermocouple probes are capable of further improvement with the usage of new substrate materials, modified methods for creating electrical contacts to the new thermocouple configuration and adhesive and protective layers,
2nd in saving precious and rare metals,
3rd decreasing the thickness of the layers and reducing the overall size of thermo probe.
Measuring the temperature of molten steel, leading to a general loss of strength and the subsequent destruction of the probe. Here exhibited the highest resistance of quartz plates used in thin film substrates thermocouples.

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References

[1] L.V. Körtvélyessy: Thermospannung. Thermoelement Praxis, Vulkan-Verlag, Essen Germany (1987).

[2] J.R. Vargas Garcia, T. Goto: *Materials Transactions*, **44**, 1717 (2003).

[3] D. Kojima, K. Makihara, J. Shi, M. Hashimoto: *Applied Surface Science*, **169**, 320 (2001).

[4] Takashi Ota, Masashi Fukuyama, Hitoshi Hasegawa, Kazutoshi Tohyama: *US patent No. US6354111*, 14. Dec 1998, publ. 2002

[5] Q. Zeng, B. Sun, J. Xu, X. Deng, J. Xu, Y. Jia: *Journal of Manufacturing Science and Engineering*, **128**, 175 (2006).