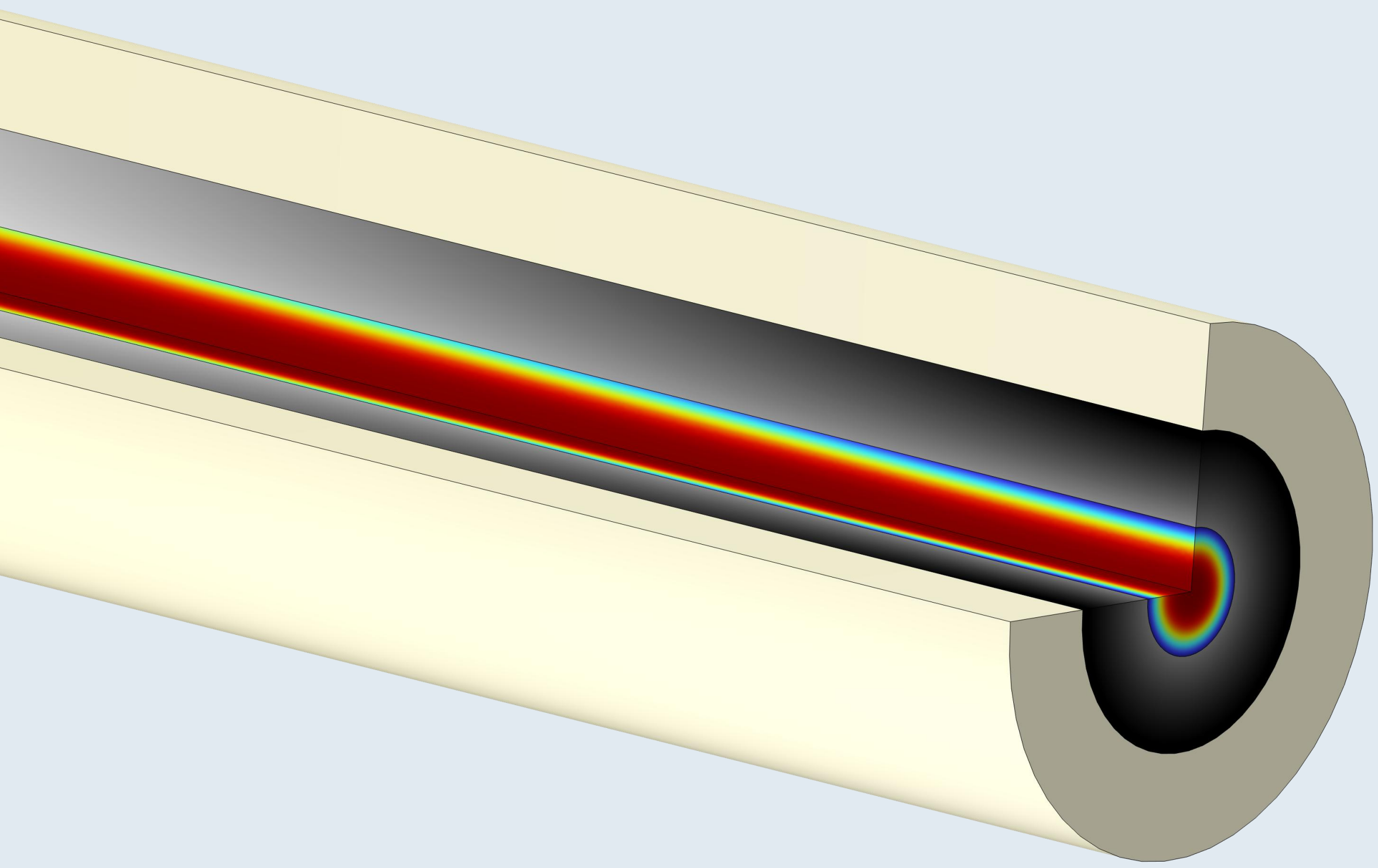




Vaporisation and vapour transport as a thermocouple drift mechanism

Gaining insight into the cause of temperature measurement and control errors in temperature sensors used for high value manufacturing processes

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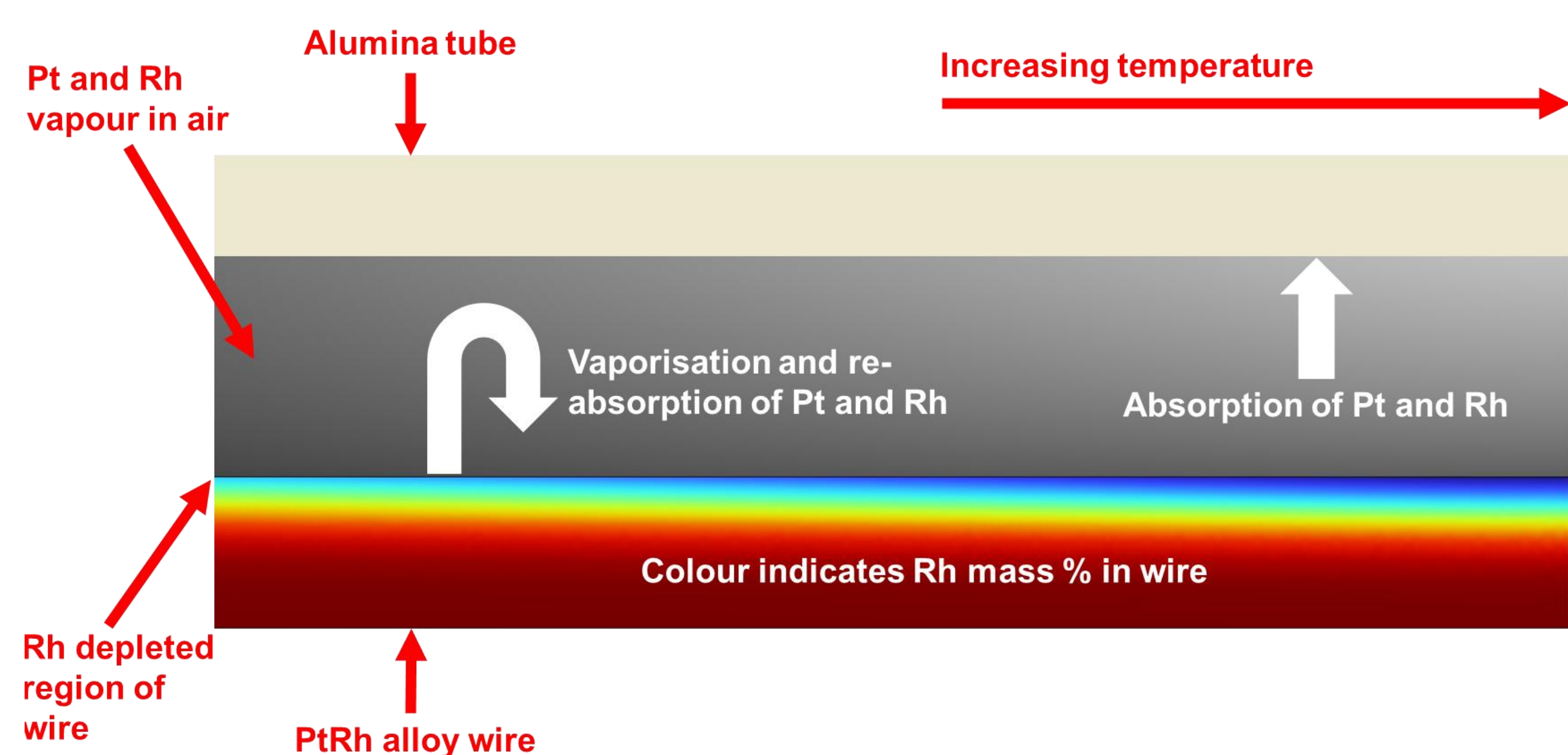
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Abstract

Thermocouples based on platinum and rhodium alloys are widely used in industry for process temperature measurement and control. However, they are subject to calibration drift. A key mechanism is the vaporization of platinum and rhodium at a rate determined by their respective vapour pressures¹. This causes a change of composition of the wire, which in turn causes

thermoelectric drift, i.e. a progressively increasing temperature measurement error.

The findings offer greater insight into the drift mechanism, and enable mitigation strategies to be investigated, such as modifying the thermocouple geometry and wire composition².



Schematic diagram of the thermocouple wire assembly and the vaporisation and absorption process.

Methodology

The axisymmetric model comprises Pt-Rh wire in air, inside an outer Al_2O_3 protective tube. The model includes non-isothermal flow (air/vapour), heat transfer in solids and fluids (all domains), transport in solids (wire), transport of diluted species (air).

Hertz-Knudsen vaporization for Pt and Rh oxide is driven by the pressure difference between the amount of vapour and the saturation vapour pressure, modelled as a flux J_{HK} out of the wire and into the air and vice versa:

$$J_{HK} = \frac{P_{vap} - cRT}{\sqrt{2\pi MRT}}$$

where P_{vap} is the saturated vapour pressure, c is the concentration, R is the molar gas constant, T is the temperature and M is the molar mass.

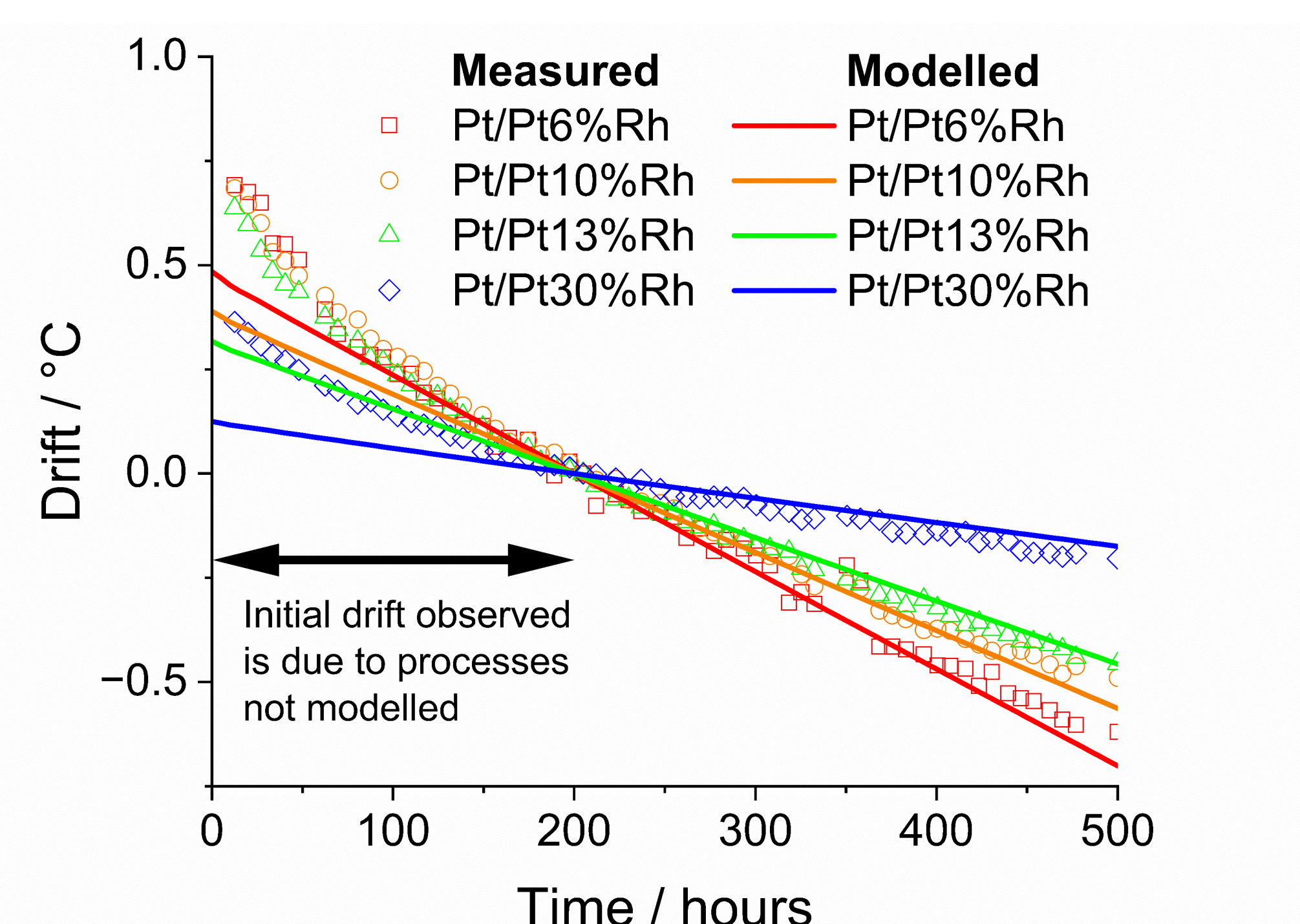
Results

The thermoelectric drift can be determined from the change in composition. For a high temperature exposure duration beyond 200 hours, the COMSOL model produces results which are in qualitative and quantitative agreement with measurements of thermoelectric drift of Pt-Rh thermocouples, without the application of any arbitrary factors.

This suggests that the essential underlying physics are captured:

- non-isothermal flow (air/vapour)
- heat transfer in solids and fluids (all domains)
- transport in solids (wire)
- transport of diluted species (air)

Hence the model is useful for investigating drift mitigation approaches.



Measured (points) and COMSOL model (lines) drift of four Pt/PtRh thermocouples. The drift axis is shifted to represent the drift regime beyond 200 hours' exposure caused by vaporisation.

REFERENCES

1. A validated physical model of the thermoelectric drift of Pt-Rh thermocouples above 1200 °C, J.V. Pearce, Metrologia 57 025009 (2020) <https://doi.org/10.1088/1681-7575/ab71b3>
2. The project (23IND11 ThermoSI) has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.