# Implementation of M-C eutectics into mainstream metrology

## A series of proposals for consideration by CCT-WG2

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### 1.0 Introduction

There has been a long-standing requirement for high temperature fixed-points, above the copper point, in both radiometry and thermometry. With the advent of metal-carbon eutectics [1] it is now clear that this requirement can be met. It is clear that these fixed-points have huge metrological potential and it is the purpose of this document to indicate where implementation, even in their present stated of development, could lead to significant improvements in high temperature metrology.

### 2.0 Proposed recommendations to CCT-WG2

The following proposals are made to WG2 for the implementation of M-C eutectics into mainstream metrology.

The first two proposals (2.1, 2.2) suggest that the immediate use of selected M-C eutectics would significantly enhance the reliability of NMI's current realisation of ITS-90 above the silver point. The third proposal (2.3) is to include in any revision or replacement of the "approximations to the ITS-90" book explicit reference to the interpolation schemes elaborated in [2, and references therein] to ensure that these reliable schemes are adopted as the use of M-C eutectics becomes more widespread. Section 2.4 is of a more general nature and discusses the requirement for further investigations of other metal-carbon fixed-points to qualify them as secondary references. Proposals for consideration by CCT-WG2 are given in detail in sections 2.1 to 2.3 below and can be summarised as:

- Formal recognition by CCT-WG2 of selected M-C eutectic fixed-point temperatures as secondary reference values
- Use of at least one M-C eutectic fixed point as a means to confirm the integrity of an NMIs formal realisation of ITS-90 e.g. Re-C at 2475 °C
- Formal adoption of the interpolation scheme, as a secondary method for realising ITS-90 (using secondary reference fixed-points)

#### *2.1 M-C eutectic fixed-point temperatures as secondary reference values*

In a recent paper [3] it was clearly demonstrated that the performance of metal-carbon eutectics is far better than that of many currently recommended secondary reference points on the ITS-90. The paper gave an in depth analysis of the published temperature values both ITS-90 and thermodynamic temperature for the following four M-C eutectic blackbody fixed-points Co-C, Pd-C, Pt-C and Re-C, including a treatment of the uncertainties.

It is proposed to WG2 that:

A. **The values given in reference [3] be adopted, after the requisite tests for a secondary reference have been applied, as secondary reference values on the ITS-90**
B. **That WG2 examine the data on other M-C eutectics that were not treated in that paper to identify whether any of these are well enough understood to qualify as secondary reference points**

*2.2 Confirming scale integrity*

The formal realisation of ITS-90 above the silver point requires that a high performance pyrometer be maintained. Its linearity and reference radiance have to be well known and these quantities must be regularly re-assessed to ensure the lowest uncertainty realisation. Ideally any laboratory would have at least two high performance pyrometers in operation and these would be regularly compared to identify any possible drifts.

The introduction of just one M-C eutectic of known high temperature into the checking regime would greatly simplify scale maintenance. For instance if a fixed point of Re-C was used at 2475 °C then if the standard pyrometer was checked relatively frequently against this fixed-point any drifts would easily be detected. If the temperature indicated by the pyrometer had drifted by more than a set criterion then it would indicate that for e.g. maintenance/recalibration of the pyrometer had become necessary.

For laboratories operating at the highest levels it is proposed that CCT-WG2 consider:
**Where possible a M-C eutectic fixed-point of known high temperature be introduced into the routine checking of the integrity of any ITS-90 realisation**

*2.3 Interpolation method*

An interpolation scheme, for relating radiation thermometry/radiometer output with fixed-point temperature utilising M-C eutectics, has recently been elaborated [2]. This two-point interpolation method is sufficiently robust so that the errors do not significantly escalate even if used in extrapolation. See Figure 1. Here a 50 mK uncertainty at the Pt-C point only expands to about 300 mK at 3500 K, which is negligible for all practical purposes and is probably a factor 5-10 better than is achievable by the best current ITS-90 realisations.

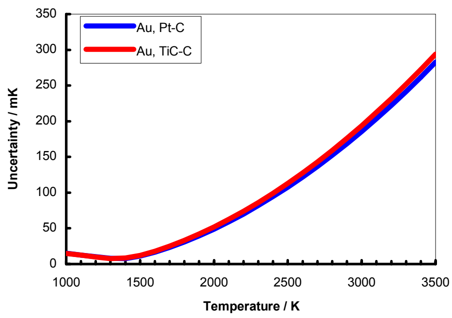


Figure 1: The two point interpolation scheme. The uncertainty of the TiC-C point is assumed to be four times that of Pt-C (50 mK).

Where fixed-point values are available (see 2.1) it is immediately possible to generate an approximation to the ITS-90 using this formalism[1].

It is proposed to WG2 that:
**The interpolation formalism as specified in reference [2], in conjunction with M-C eutectics, be adopted as a means of generating a secondary realisation of ITS-90**

*2.4 Other secondary references in the field of M-C eutectics*

Besides the well-studied M-C eutectic systems that have been recommended as secondary references [3] other systems are also of great interest. The Ru-C point (1953 °C) is of great

[1] As an interesting aside if a thermodynamic temperature scale is required, one could again use the thermodynamic temperatures listed in [3] or for a lower uncertainty realisation:
- Measure directly the thermodynamic temperatures of a series of metal-carbon eutectic cells [at least 2] using absolute radiometry
- Apply the formalism described in [2] to generate a thermodynamic temperature scale with low uncertainties

utility to the contact thermometry community as it is close to the upper temperature required to evaluate and calibrate W-Re type thermocouples. The TiC-C (2759 °C) point is of great interest to the radiometry community as its temperature is close to that of FEL lamps used in spectral irradiance measurements. In addition, although Re-C is probably a sufficiently high temperature for thermometry purposes, if the extrapolation method in [2] is used, even lower uncertainties would be attainable if a well-characterised TiC-C point was available.

Other higher temperature points such as ZrC-C are also of specialist interest to the radiometry community. Further research is required in the construction of TiC-C and Ru-C to qualify these fixed points as secondary reference points of the ITS-90, and in the case of TiC-C, as a potential candidate for the upper temperature in any new definition of a future high temperature scale. Further work is also required for the even higher temperature points to understand their utility as irradiance sources for the radiometry community.

## 3.0 Acknowledgements

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## 4.0 References

[1] Yamada Y., Sakate H., Sakuma F., Ono A., *Metrologia*, 1999, **36**, pp.207-209
[2] Saunders, P., Bloembergen, P., White, R., *Tempmeko 04,* To be published, 2005
[3] Sadli, M., Fischer, J., Yamada, Y., Sapritsky, V., Lowe, D., Machin, G., *Tempmeko 04,* To be published, 2005