The Relation between Deuterium Content and Melting Range of the Tripe Point of e-Hydrogen

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Some comments will be given concerning the relation between the melting range of the triple point of equilibrium hydrogen and the isotopic fractionation. The data have were published in

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by H. Sakurai

and were also presented at the

International Workshop, at IMGC (Torino 2003)
by O. Tamura

This article is the summary of isotopic effect shown in those reports.

As already pointed out in CCT/05-06(WG1) and CCT/05-15(WG3), the melting temperatures of the triple point of equilibrium hydrogen depend on the isotopic content of deuterium in hydrogen. At the same time, there is a possibility that *isotopic fractionation manifests itself as a difference between the liquidus point and the solidus point at the triple point of equilibrium hydrogen*, as it is pointed out that the temperature of the triple point of water is dependent on the isotopic fractionation between water and ice(*see WG3 draft report*[1]). It is because the isotopic content will be fractionated by increasing the fraction of melt during measurement.

Experimental results obtained by an open cell system at NMIJ/AIST are indicating such isotopic fractionation as shown in **Fig.1**[1]. The melting curves in Fig.1 were measured using three different hydrogen sources and a small amount of ferric oxy-hydroxide as a catalyst for equilibration of ortho- and para-hydrogen isomers. By adjusting the amount of the catalyst, the heat capacity anomaly by the catalyst was small enough compared with the experimental uncertainties of the heat capacity measurement.

In Fig.1, the melting curves are plotted against the inverse of the fraction of melt,$1/F$ and have a linear relation in the range below $1/F = 15$. The melting curves are separated into two groups. It is because of the different deuterium contents. The sample with the lowest melting temperature, A, contains about 33 ppm of deuterium in hydrogen and the samples, B and C, contain about 101 ppm. The values at $1/F = 1$ are consistent with the dependency of

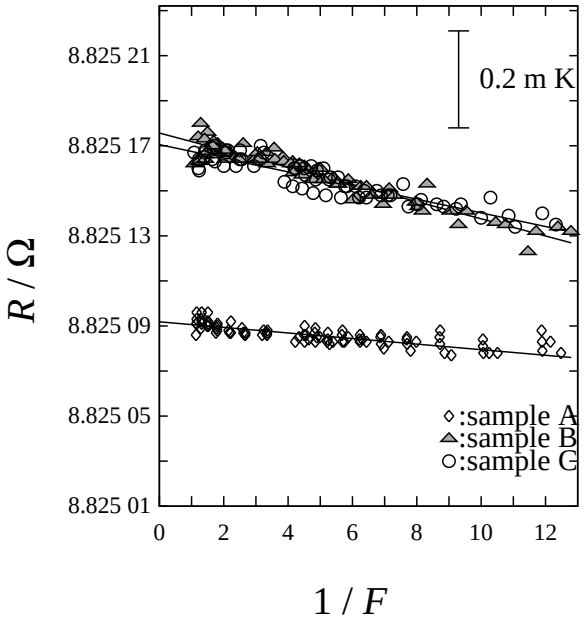

Fig. 1: The relation between the melting curves and $1/F$ by three different hydrogen samples. The sample A contains about 33 ppm of deuterium in hydrogen and the samples B and C contains about 101 ppm, cited from [1]

[1]Uncertainties in the Realization of the SPRT Sub-range of the ITS-90

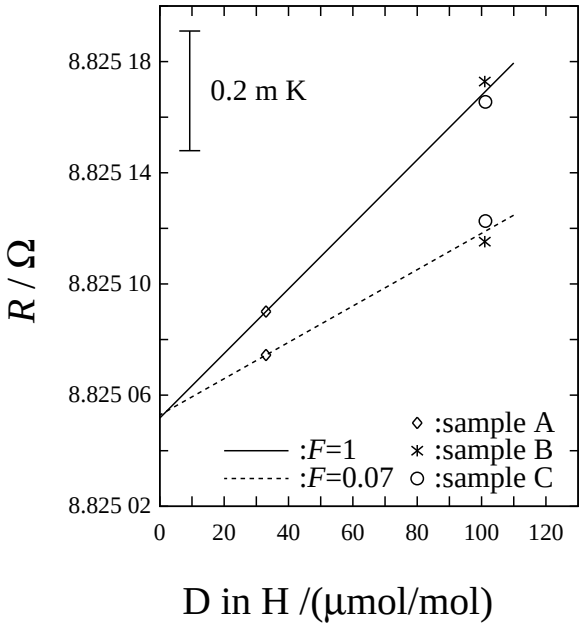

Fig. 2: The relation between the melting range of the triple point of e-hydrogen and the fraction of deuterium content in hydrogen cited from [2]

the triple point temperatures of equilibrium hydrogen on the deuterium content reported in CCT/05-06 within the experimental uncertainties.

The melting ranges, or the slope of the melting curves plotted by $1/F$, are also apparently different between two groups, although the nominal purities of the samples A, B and C, are better than 99.9999 %. And the same amount and the same kind of a catalyst were used throughout the measurements. The melting ranges of sample B and C are about 0.2 mK between at $1/F = 1$ and at $1/F = 15$. The latter is close to the solidus point. The value of $1/F = 15$ has no physical meaning but the melting curves were measured from this point. On the other hand, the melting range of sample A is less than 0.1 mK. The difference between melting ranges among these samples is thought to be caused by isotopic fractionation.

Fig.2 shows more clearly the relation between the melting range and the deuterium content[2]. In this figure, the data at $1/F = 1$ are the liquidus point and those at $1/F = 15$ are close to the solidus point. The slope of the melting curves, or the melting range, depends also on the impurities in the sample, but they are ignored in this article, as the samples used in this experiment are purer than 99.9999%. But the impurity effect may be systematically included in the data of Fig.2.

The data available now are limited concerning the relation between the melting range of the triple point equilibrium hydrogen and deuterium content. More data by hydrogen samples with higher deuterium content and different impurity level will be needed for precise discussion.

References

[1] H. Sakurai: *Temperature, Its Measurement and Control in Science and Industry* **Vol.8** 969-974 (2003)

[2] O. Tamura, T. Nakano and H. Sakruai: In *International Workshop, Problems in the Use of Gases and Isotopic Substances in Metrology and for a Knowledge-Based Society*, CD-ROM (CNR, Istituto di Metrologia "G. Colonnetti" Turin 2003).