Measurement of Surface Tension of Tantalum by a Dynamic Technique in a Microgravity Environment

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A dynamic technique has been used in a microgravity environment to measure the surface tension of tantalum at its melting point. The basic method involves resistively heating a tubular specimen from ambient temperature to temperatures above its melting point in about 1 s by passing an electrical current pulse through it, while simultaneously measuring the pertinent experimental quantities with millisecond resolution. A balance between the magnetic and the surface tension forces acting on the specimen is achieved by splitting the current after it passes through the specimen tube and returning a fraction of the current along the tube axis and the remaining fraction concentrically outside the specimen. Values for surface tension are determined from measurements of the equilibrium dimensions of the molten specimen tube and the magnitudes of the currents. Rapid melting experiments were performed during microgravity simulations with NASA's KC-135 aircraft and the results were analyzed, yielding a value of \(2.07 \pm 0.06 \text{ N}\cdot\text{m}^{-1}\) for the surface tension of tantalum at its melting point. Conditions for improving specimen stability during temperature excursions into the liquid phase are discussed.

**KEY WORDS:** dynamic technique; high temperature; melting point; microgravity; surface tension; tantalum.

1. INTRODUCTION

Since the early 1960s, the continuing development of millisecond-resolution dynamic techniques at the National Institute of Standards and Technology (NIST) has enabled the accurate measurement of selected thermophysical properties for a number of electrically conducting refractory solids at high temperatures, primarily in the range 1500 K up to their melting point [1].

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The techniques involve resistively heating the specimen from room temperature through the temperature range of interest in less than 1 s by passing a large electrical current pulse through it and simultaneously measuring the pertinent experimental quantities with millisecond resolution. Because of the short duration of the heating period (<1 s), the techniques minimize problems associated with specimen evaporation and contamination, large heat transfers, etc., which tend to limit the accuracy of more conventional steady-state techniques, particularly at temperatures above 2000 K. However, millisecond-resolution dynamic techniques are essentially “containerless,” and therefore, when used on ground, they are limited to measurements on solids only, since at the melting point, the specimen becomes unstable and collapses due in part to the influence of gravity.

A few years ago, a research effort was undertaken to develop millisecond-resolution dynamic techniques for use in a microgravity environment in order to extend the measurement of thermophysical properties of refractory metals to the liquid phase [2]. As a result of this work, a new dynamic technique for measuring surface tension of liquid metals at high temperatures was developed and its feasibility was successfully demonstrated by performing rapid melting experiments on copper during microgravity simulations with NASA’s KC-135 aircraft [3]. The value obtained in these experiments for the surface tension of copper at its melting point was found to be in good agreement with literature data.

The present paper briefly describes the above method for measuring surface tension of liquid metals in a microgravity environment and presents results for the surface tension of tantalum at its melting point, based on microgravity experiments performed during a recent KC-135 flight. In addition, conditions for improving specimen stability during temperature excursions into the liquid phase are discussed. Details regarding the construction and operation of the measurement system, designed for microgravity experiments aboard the KC-135 aircraft, have been given elsewhere [2].

2. METHOD

The basic method consists of resistively heating a tubular specimen in a microgravity environment from ambient temperature to temperatures above its melting point in about 1 s by passing an electrical current pulse through it and, simultaneously, measuring the radiance temperature of the specimen surface by means of a high-speed pyrometer, measuring

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3 The design of the high-speed pyrometer, which operates at a single wavelength of nominally 650 nm, is a modification of that used in the six-wavelength millisecond-resolution pyrometer [4] constructed at NIST.