Density and Surface Tension of Binary and Ternary Al-Ti-V Liquid Alloys and the Influence of Oxygen on the Surface Tension

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Density and surface tension of electromagnetically levitated liquid Al-Ti-V binary and ternary alloys are presented. Density is measured using a shadowgraph technique where the droplet is illuminated from one side by an expanded laser beam and the edge curve of the shadow picture is numerically integrated in order to obtain the volume of the sample.

Surface tension is obtained by analyzing the spectra of the droplet oscillations. To this end, pictures of the sample are recorded with a digital camera at a framerate of 400 fps.

Alloy samples are investigated with respect to temperature and composition. The entire compositional range is hereby covered, including the pure elements Al, Ti, and V.

In all cases, density and surface tension obey linear laws with respect to temperature whereas the slopes are negative. The Ti-V alloys exhibit ideal mixing behavior with respect to both density and surface tension. In contrast, Al-Ti and Al-V exhibit pronounced non-ideal behavior. The excess volumes are strongly negative and amount to about -10 %. The surface tensions significantly exceed those of the corresponding ideal solutions proving a pronounced attractive interaction.

In addition, the influence of oxygen on the surface tension of various compositions of Ti-V is investigated in detail. Defined amounts of TiO_2 and V_2O_5 are added to the liquid, so that atomic oxygen concentrations range from 0.01 at. % up to 26 at. %. At the same time, the oxygen partial pressure pO_2 is passively measured by an oxygen control sensor (OCS) based on Y_2O_3-stabilized-ZrO_2 (YSZ). The OCS is also used in order to actively adjust the pO_2 in the range between 10^{-12} bar to 10^{-4} bar.

The surface tension decays linearly with temperature under oxygen influence too. Its magnitude strongly depends on the amount of oxygen added, as well as on the adjusted oxygen partial pressure.

For constant temperature, and as a function of bulk oxygen concentration, the surface tension curves exhibit the typical shapes of Belton-type isotherms. There is a plateau at low oxygen mole fractions x_O, corresponding to virtually clean surfaces, and a nearly linear decay of the surface tension with $\log(x_O)$ when x_O exceeds a certain threshold. For the samples investigated, a comparatively large threshold of approximately 1.0 at. % is evident pointing towards an attractive interaction between oxygen and Ti or V. The data is discussed with respect to thermodynamic models based on the Butler, Langmuir and Gibbs equations. A relation between the oxygen partial pressure and the mole fraction is established.