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ABSTRACT

Hugoniot measurements on vanadium have been made using the LLNL two-stage light-gas gun. The direct collision method with electrical pins and a tantalum flyer accelerated to 6.28 km/s was used. Alt'shuler, et al,[1] have reported Hugoniot measurements in vanadium using explosives and the impedance match method. They reported a kink in the $U_s - U_p$ relationship at 183 GPa, and attribute it to electronic transitions. The upper portion of their curve is based on a single point at 339 GPa. The present work was performed to further investigate the equation-of-state in the high-pressure range.

1.0 INTRODUCTION

Alt'shuler, et al, have reported Hugoniot measurements in 17 metals including vanadium, using the impedance match method with aluminum, copper, and iron as standard materials. Shock velocities were measured using the standard electrical shorting pin methods and high explosive driven flyers. A kink was observed in the U_s-U_p curve for all but three of the metals. They attribute it to the transition of s level electrons, which find themselves above the Fermi level to a d-band at the higher pressures.

McQueen, et al,[2,3] have also made measurements on vanadium with the impedance match method and high explosive drivers. In their earlier work they used a brass standard, whose properties were determined by measuring shock velocity and free surface velocity. An iterative technique was used to deduce the corresponding particle velocity by means of calculated isentropes, until a self-consistent result was obtained. In the later work, 2024 Al was used as a standard for the lower pressure experiments, and a high leaded brass was used for the highest pressure.

In the earlier work,[2] a linear weighted least-square fit was made to the U_s-U_p data assigning a weight of 1 to the lower velocity results and a weight of 0.5 to the higher velocity data.

For the later work,[3] a weighted least-square fit was made to data which included a sound speed at zero particle velocity derived from Bridgeman's isothermal bulk modulus. Their result was given as:

$$U_s = 5.077 + 1.201\ U_p \qquad (1)$$

where the velocities are in km/s. This result is produced if one assigns a weight of 1 to the sound speed result and the data using the aluminum standard, and a weight of 0.5 to the results using the brass standard.

In order to investigate the high pressure region further, we have made Hugoniot measurements on vanadium with the LLNL two-stage light-gas gun using tantalum impactors with the direct collision method and electrical pins.[4,5]

We have made a weighted least-square fit incorporating all of the data from Refs. 2 and 3, along with our own. A weight of 1 was assigned to our results and the aluminum standard results of Ref. 3. A weight of 0.5 was assigned to the brass standard results of Ref. 3 and the lower velocity results of Ref. 2. A weight of 0.25 was assigned to the higher velocity measurements in Ref. 2. The lower weight assigned to the earliest data was chosen simply because of its age.

The result of the fit is:

$$U_s = 5.060 + 1.229\ U_p \qquad (2)$$

Figure 1 shows the results along with the fits of Alt'shuler, et al. The RMS scatter of the values of U_s from Refs. 2 and 3, and this work from the fit above is 0.83%. The curve also passes within the error bounds of our results.

2.0 CONCLUSIONS

The data of these measurements do not support the existence of a phase change in vanadium at 183 GPa. It appears that the point at U_s = 8.95 km/s from Alt'shuler, et al, is likely in error. We are planning experiments at still higher pressures to further investigate the reported slope changes in the U_s-U_p relation of vanadium.

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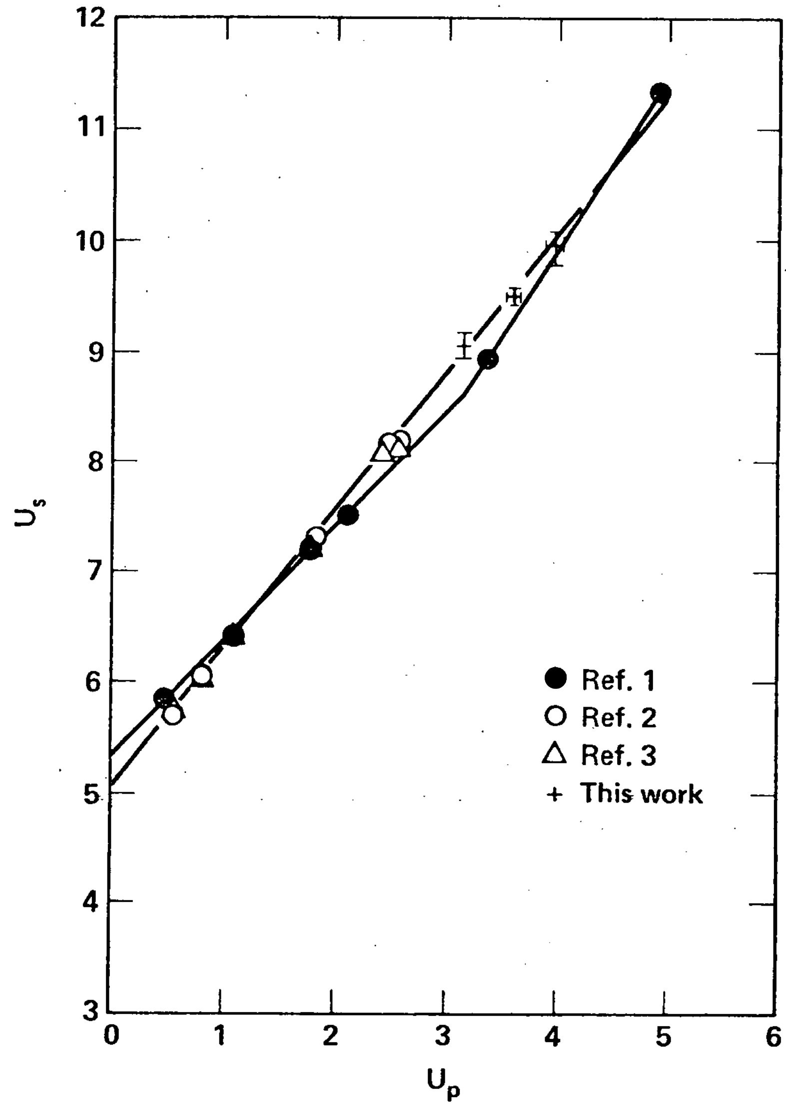

Fig. 1. Hugoinot data for vanadium.
The dashed curve represents the U_s-U_p curve for the fit of equation (2). The two segmented solid curve represents the fit of Alt'shuler, et al.

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