Comment on “Observation of the Wigner-Huntington transition to metallic hydrogen”

Dias and Silvera (Research Article, 17 February 2017, p. 715) claim the observation of the Wigner-Huntington transition to metallic hydrogen at 495 gigapascals. We show that neither the claims of the record pressure nor the phase transition to a metallic state are supported by data and that the data contradict the authors’ own unconfirmed previous results.

Dias and Silvera (1) present only one experimental run claiming a record pressure of 495 GPa. The paper presents two figures of the phase diagram, iPhone photos of the sample, and the deduced reflectivity of four wavelengths only at the highest pressure point. The supplementary materials provide processed and fitted infrared (IR) absorption spectra from 135 to 335 GPa, the pressure versus force curve assuming a linear dependence, and the Raman spectra of the stressed diamond from 1200 to 2200 cm⁻¹. The absence of data combined with the uncritical claims have led to the unprecedented three comments (2–4) written within a month of publication of (1).

In the past 5 years, we have conducted ~120 experiments on hydrogen reaching above 200 GPa (5–10). In ~30 runs out of 120, the pressure exceeded 300 GPa, and in only 5 out of 120, the pressure exceeded 350 GPa. The extensive statistics show that the diamond culet sizes of 30 µm diameter (used in (1)) could be used to reach maximum pressures of ~315 ± 10 GPa with the probability of 20%. To reach pressures close to 400 GPa, with lower probability of 10%, the culet sizes of 15 µm must be used with the sample contracting to 2 to 3 µm at the highest pressure. Our statistics are in excellent agreement with other groups working on hydrogen at high pressure (11–13). The authors of (1) had two experimental runs in the past year using culets of 30 µm diameter (1, 14) claiming the unsubstantiated pressures of 420 and 495 GPa.

Dias and Silvera (1) claim that a combination of annealing, fine polishing, and coating the culet with Al₂O₃ has led to an increase in the maximum pressure with larger culets (and samples), compared with previous studies (5–13). Those techniques would likely decrease the probability of the premature failure due to hydrogen diffusion, but there is no supportive evidence that these techniques would improve the mechanical stability of diamond. The record pressure of 600 GPa was recently achieved on metals using a novel double-stage approach, with the pressure-generating area having a diameter of 3 µm (15) [smaller by a factor of 100 than the area in (1)].

Figure 1 shows the pressure-versus-load curve from (1), (4), and our own data. Dias and Silvera (1) use three different, nonoverlapping calibration methods at ~100 and ~300 GPa. Measuring pressure by estimating the load is not a direct method, as it does not probe the sample and/or calibrant in situ. The loading curve is unique for each experimental run and depends on the size of the culets, angles of the bevels, and compressibility of the gasket and sample. The dependency cannot be linear, as shown in (1), but always consists of three distinct regimes, each of which is sublinear with differing gradients: (i) plastic deformation of the gasket, (ii) sharp rise of pressure beyond the plastic deformation, followed by (iii) the much slower pressure increase due to the bending of the diamonds.

To make the dependence linear, Dias and Silvera (1) take a point from a different experiment (16), rescaling it from 420 to 400 GPa, and plot four additional meaningless points of “visual observation.” Pressures of 495 and 420 GPa were deduced from a single Raman spectrum, which does not cover a wide energy range showing the signal from hydrogen and/or pressure-induced fluorescence. This rules out any critical assessment.

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Fig. 1. Pressure versus load. (A) Our data and data from (4). (B) Data from Dias and Silvera (1). (C) Some raw IR absorption spectra provided but not plotted in (1) (in color). The black curves are normalized spectra taken from figure S1 in (1). We note that the intensity and frequency of the raw spectra at 338 GPa do not match those displayed in figure S1 in (1).
that the sample did not diffuse out and that the peak assigned to the stressed diamond is not due to any other factors.

The IR absorption data are consistent with the loss of the sample and contradict the authors’ own previous claims (14). In Fig. 1, we plot the raw data provided by but not plotted in (I), together with the normalized spectra. The sample was clearly diffusing out between the claimed pressures of 314 and 338 GPa and ultimately was completely lost above this. The lack of IR transmission above 338 GPa and the fact that the authors claimed to be transparent (see figure 3S in (14)), which the authors claimed to be transparent (see figure 3S in (14)).

Furthermore, (I) cites one of the authors’ own publications on the melting curve but, without any explanation, plots the smooth melting curve (see Fig. 1), contradictory to the authors’ earlier claim about the existence of the sharp peak at 60 GPa.

REFERENCES AND NOTES


ACKNOWLEDGMENTS

The authors are grateful to P. Loubeyre for providing his data.

10.1126/science.aat2986
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Science 357 (6353), eaan2286.
DOI: 10.1126/science.aan2286