LETTERS
PUBLISHED ONLINE: 8 NOVEMBER 2009 | DOI: 10.1038/NPHYS1438

nature physics

Melting temperature of diamond at ultrahigh pressure

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Since Ross proposed that there might be 'diamonds in the sky' in 1981 (ref. 1), the idea of significant quantities of pure carbon existing in giant planets such as Uranus and Neptune has gained both experimental[2] and theoretical[3] support. It is now accepted that the high-pressure, high-temperature behaviour of carbon is essential to predicting the evolution and structure of such planets[4]. Still, one of the most defining of thermal properties for diamond, the melting temperature, has never been directly measured. This is perhaps understandable, given that diamond is thermodynamically unstable, converting to graphite before melting at ambient pressure, and tightly bonded, being the strongest bulk material known[5,6]. Shock-compression experiments on diamond reported here reveal the melting temperature of carbon at pressures of 0.6–1.1 TPa (6–11 Mbar), and show that crystalline diamond can be stable deep inside giant planets such as Uranus and Neptune[1–4,7]. The data indicate that diamond melts to a denser, metallic fluid—with the melting curve showing a negative Clapeyron slope—between 0.60 and 1.05 TPa, in good agreement with predictions of first-principles calculations[8]. Temperature data at still higher pressures suggest diamond melts to a complex fluid state, which dissociates at shock pressures between 1.1 and 2.5 TPa (11–25 Mbar) as the temperatures increase above 50,000 K.

As a result of the importance of high-pressure carbon in both planetary science and inertial confinement fusion (for which high-density carbon is a candidate ablator material for ignition target designs), there are many theoretical calculations of the high-pressure melting curve of diamond, with some predicting a maximum in temperature at 500 GPa (5 Mbar; refs 8–11). Direct temperature measurements are challenging for both static and dynamic high-pressure experiments, so confirmation of melt-curve predictions have been only by inference, never by direct measurement. Under static conditions, equation-of-state data relevant to diamond melting do not extend to pressures much above 50 GPa, and are interpreted as indicating a positive Clapeyron slope, $(\partial T/\partial P)_{\mathrm{melt}} > 0$, for diamond up to 60 GPa (refs 5, 6, 12, 13). Dynamic shock experiments on graphite, which is thought to convert to diamond under dynamic loading, suggest a positive melting slope to at least 140 GPa (refs 14–16). Finally, recent shock experiments on diamond show an increase in density near 600 GPa, suggesting that shocked diamond might potentially melt with a negative melt curve near 600 GPa (refs 17–20).

Here we report the first temperature measurements for shock-compressed diamond at conditions of 0.6–4 TPa (6–40 Mbar) and 8,000–100,000 K. These data reveal the melting curve for carbon up to 1.1 TPa and a complex fluid state between 1.2 and 2.5 TPa.

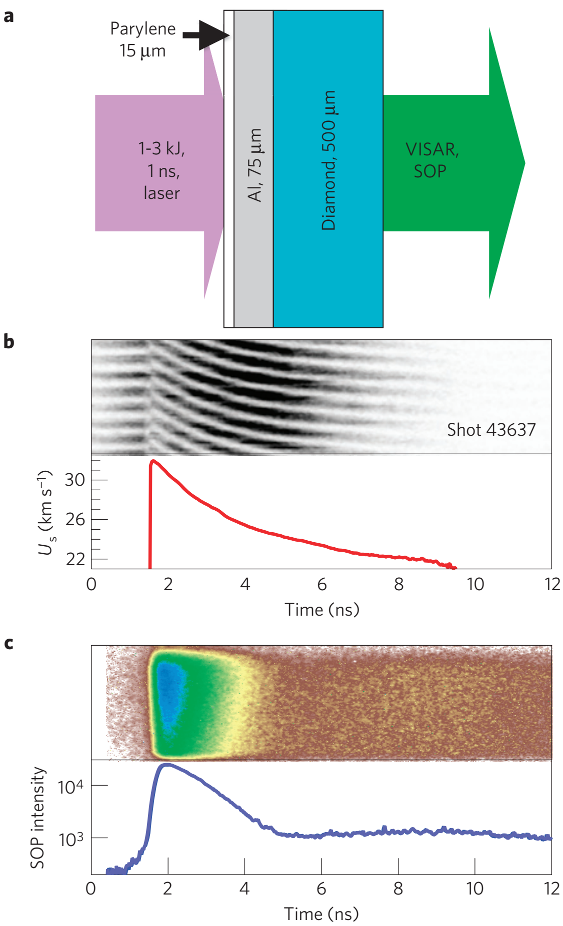

Figure 1 | Experimental configuration and data collected to determine the melting temperature of diamond. a, Diamond melt target. **b**, Velocity interferometry (VISAR) data for polycrystalline diamond, showing raw fringe data and velocity (U_s) lineout. The pressure falls continuously and smoothly with time as U_s decreases. **c**, SOP data, showing raw data and intensity lineout. The SOP intensity plateaus and rises even as U_s decreases smoothly.

Shock experiments traditionally study a steady-shock Hugoniot characterized by the shock velocity U_s, particle velocity U_p, pressure P, specific volume V, (=1/density) and internal energy E of the shocked material. These five variables are related by the three Rankine–Hugoniot relations, so that the state of the sample under

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