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# Proving carbon under ultra-high pressure with sound velocity measurements
# 音速計測による炭素の超高圧相の観測

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Sound velocity is one of the important parameters on the phases at ultrahigh pressure. We measured the sound velocities at several pressures around the melt (0.5-2.0 TPa). A clear discontinuity is observed around the pressure (~0.7 - ~0.9 TPa) due to melting. First principle calculations suggests the difference in sound velocity between diamond and BC8 phases, which is not seen in the experimental results, showing that there is no BC8 phase on principal Hugoniot.

## 1. Introduction

Diamond is of great interest for many filelds in industries and sciences. High power laser can create post-diamond phase of carbon at multi-TPa regime. Recent experimental and theoretical studies suggest that the diamond starts to melt at around 700 GPa on the principal Hugoniot, then complete the melting at around 1 TPa [1-4]. There exists two complex phases in between, “diamond and liquid carbon” and “BC8 carbon and liquid carbon”. Recent experiments with ramp compression up to 5 TPa suggests that there is no clear phase transition from diamond to BC8 at around the pressure of 1 TPa from the sound velocity data [5]. Since sound velocity is a function of phase of material, it is very important to discuss on the basis of the sound velocity data. In this paper, we discuss the phase transition around the melt on Hugnoit curve with experimental data and with the first principle calculations.

## 2. Experiment

We have measured the sound velocity of the diamond foils at around the melting pressures (500 – 2000 GPa). Experiments were done on GEKKO-XII glass laser system with HIPER irradiation facility. Schematic view of the experimental setup is shown in Fig. 1. Single crystal diamond foils (Ia) of 20~30 μm thickness were irradiated at intensities of 0.2 – 2.0 × $10^{14}$ W/$cm^2$. We measured the sound velocity by side-on x-ray backlighting technique [6-8]. Trajectories of foil surfaces were observed by x-ray streak camera.

We also measured the shock velocity by two VISARs (velocity interferometer system for any

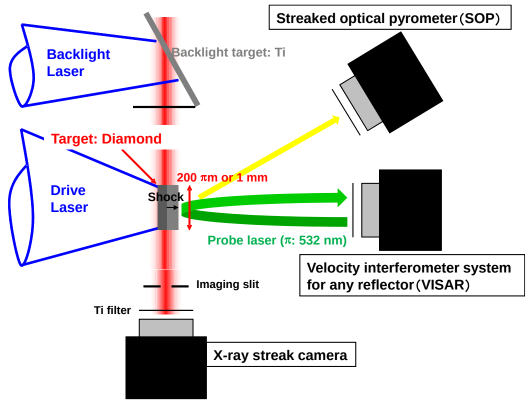


Fig. 1 Schematic view of the experimental setup

reflector), and shocked temperature by an SSOP (streaked spectral optical pyrometer) [9] in order to determine the pressure and the temperature at around the melting.

## 3. Results and Discussion

Figure 2 shows an example raw streaked data on the sound velocity measurement. We analyzed the sound velocity and other parameters (shock velocity, particle velocity, pressure and density) [6].

The measured sound velocity as a function of time as shown in Fig. 3. The sound velocity increases with pressure below 600 GPa, then rapidly drops to minimize value at around 900 GPa. Abobe 900 GPa, the sound velocity gradually increases again as a function of pressure. The rapid drop is mainly due to melting, which is also predicted in the first principle calculation. Curves in Fig.3 are the calculated sound velocity for diamond, BC8, and liquid. Large difference between solid and liquid carbons is also obtained from the calculations. It should be noted that there is also difference in sound velocity between diamond and BC8. However, our measured data shows no clear discontinuity around the melt, and seems no BC8 phase at around 1 TPa because the melting completes at around 900 GPa. The absence of the BC8 phase is also seen in recent NIF experiments [5].

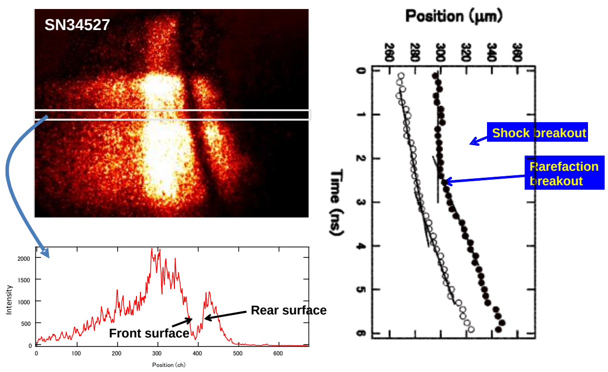


Fig.2 Raw streaked image of the sound velocity measurement and its scheme of data deduction

## 4. Conclusion

We have measured the sound velocity of diamond around the melting temperature at ultrahigh pressures. The sound velocity starts to decrease at ~700 GPa, then completes 900 GPa. The decrease of the sound velocity agrees qualitatively with the first principle calculations. This also indicates that there is no complex phase of BC8 and liquid, which is in agreement with the NIF experiments.

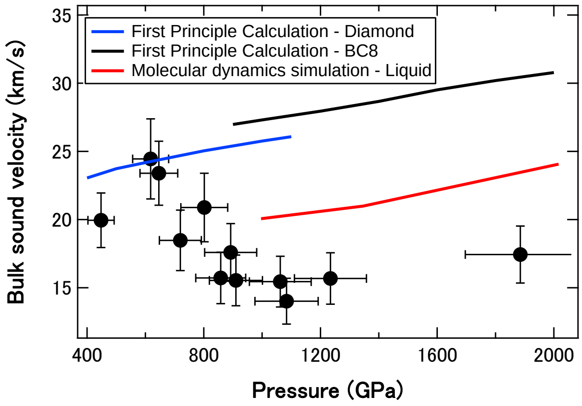


Fig.3 Measured sound velocity (circles) and calculated sound velocity with the first principle calculation for diamond (blue), BC8 (black) and liquid carbon (red).

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