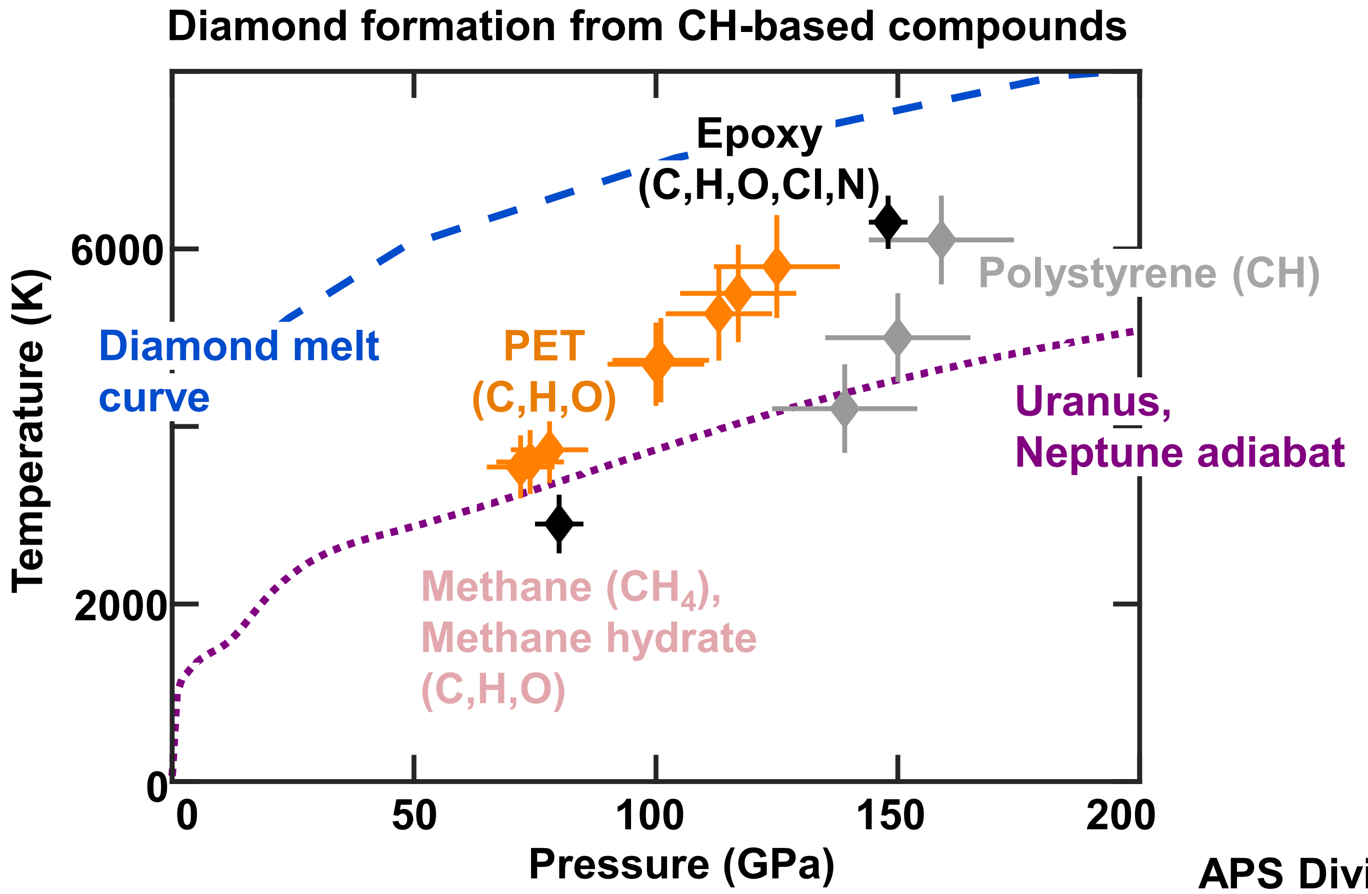
Diamond Formation in Reshocked Epoxy



Michelle Marshall
University of Rochester
Laboratory for Laser Energetics

APS Division of Plasma Physics
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Summary

Diamond formation at extreme conditions occurs for more materials and at more pressures and temperatures than previously known

- Diamond forms from Stycast 1266 epoxy (C:H:Cl:N:O ≈ 27:38:1:1:5) reshocked to 80 and 150 GPa
- The epoxy was compressed and heated using the Omega EP laser and the resulting diamond was probed *in situ* using x-ray diffraction
- These results support diamond precipitation in ice giant planets, which largely comprise C, H, N, and O
- This work* in combination with others on CH- and CHO-based materials** indicates that chemical composition, the thermodynamic compression path, and kinetics play an important role in diamond formation at extreme conditions

*M. C. Marshall *et al.*, J. Appl. Phys. 131, 085904 (2022).
**L. R. Benedetti et al., Science 286, 100 (1999).
H. Hirai et al., Phys. Earth Planet. Inter. 174, 242 (2009).
H. Kadobayashi et al., Sci. Rep. 11, 8165 (2021).
D. Kraus et al., Nat. Astron. 1, 606 (2017).
N. J. Hartley et al., Sci. Rep. 9, 4196 (2019).
Z. He et al., Sci. Adv. 8, eabo0617 (2022).

Collaborators

D. N. Polsin, M. K. Ginnane, G. W. Collins, and J. R. Rygg

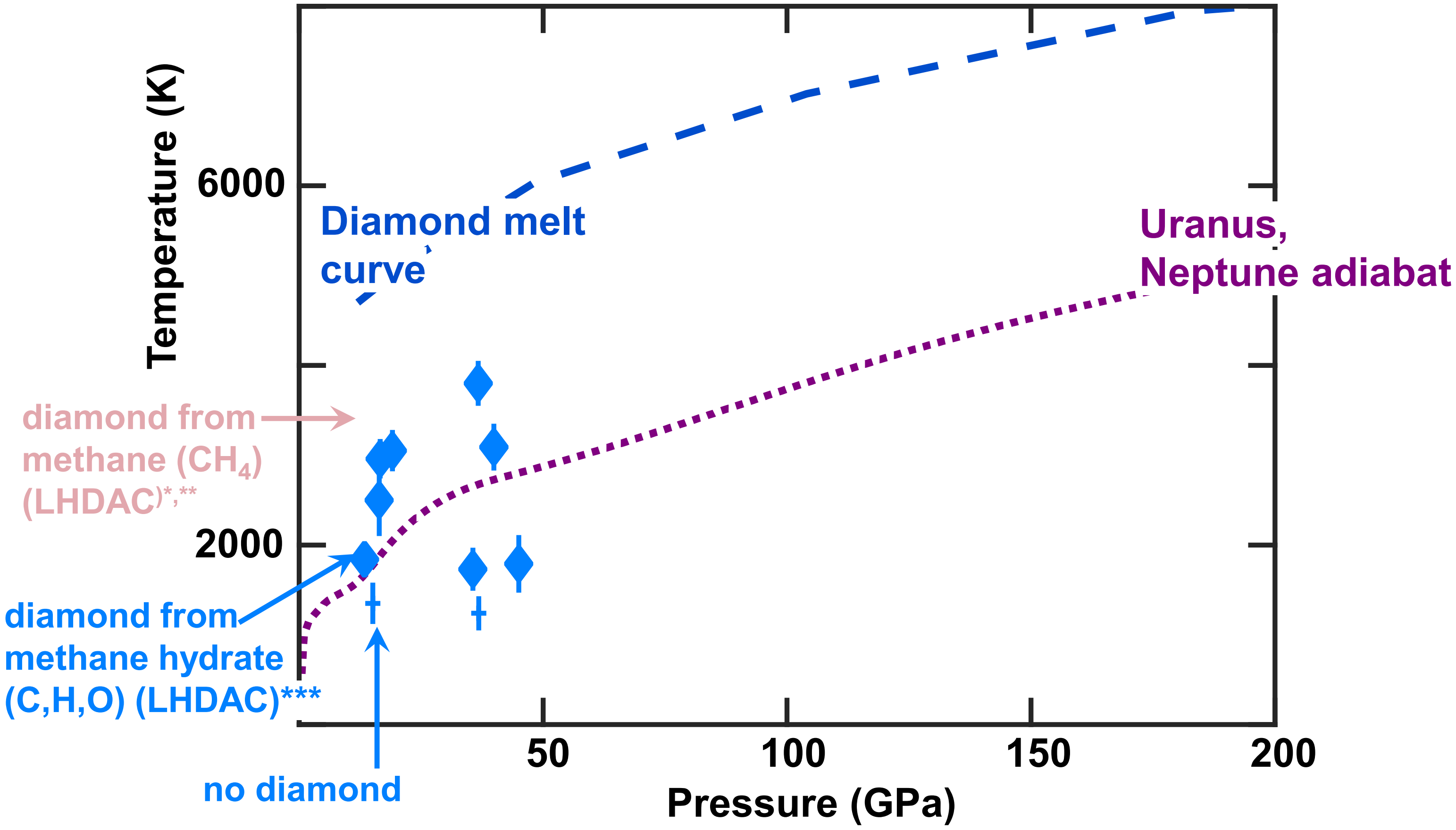
University of Rochester
Laboratory for Laser Energetics

M. G. Gorman, J. H. Eggert, and L. D. Leininger

Lawrence Livermore National Laboratory

Background

Diamond forms at ice giant conditions from compressed methane and methane hydrate in laser-heated diamond anvil cell (LHDAC) experiments

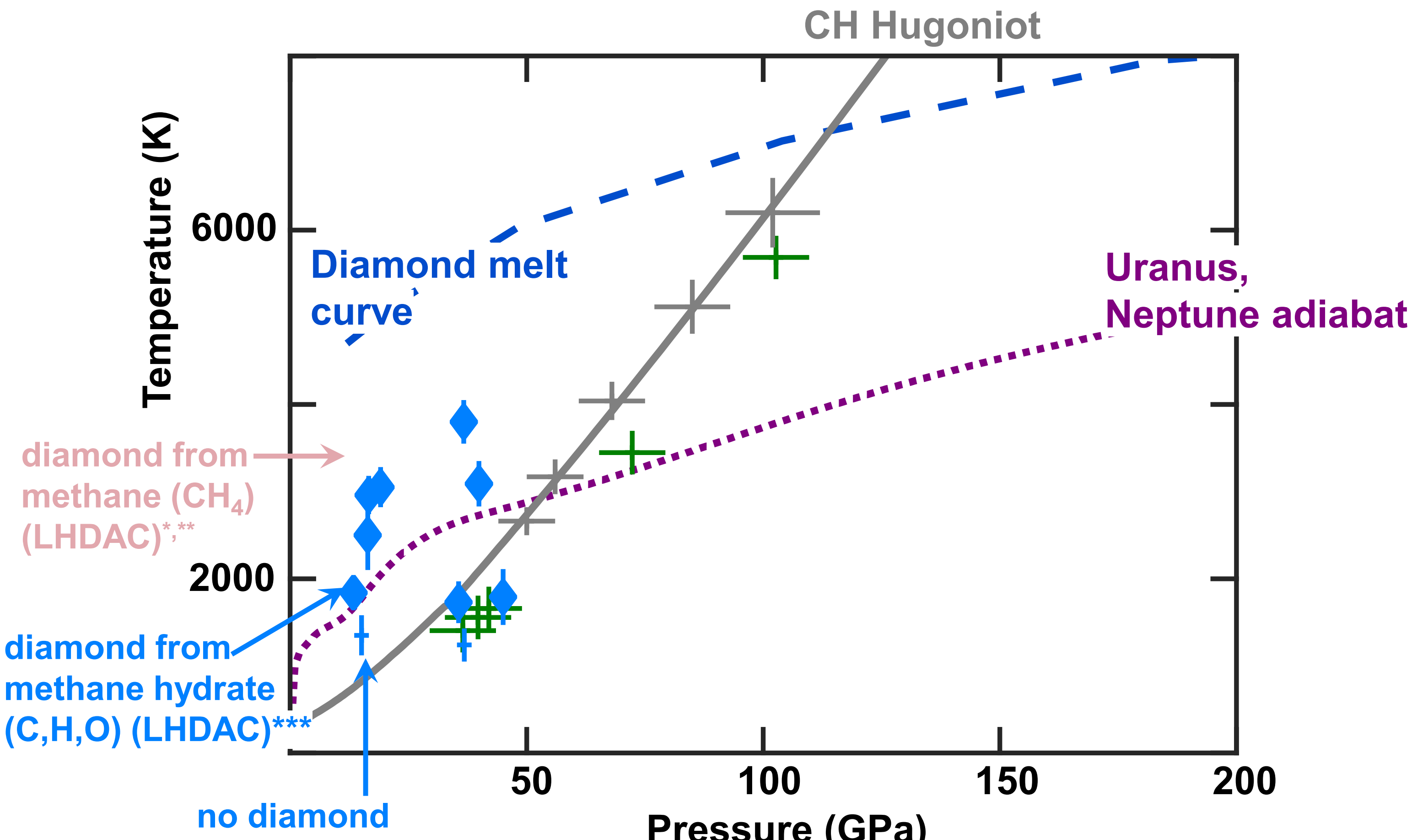


- Diamond forms from compressed and heated methane (CH_4)
- The addition of O in methane hydrate results in diamond formation at lower temperature

Chemical composition plays a role

* L. R. Benedetti et al., Science 286, 100 (1999).
** H. Hirai et al., Phys. Earth Planet. Inter. 174, 242 (2009).
*** H. Kadobayashi et al., Sci. Rep. 11, 8165 (2021).
Melt curve: X. Wang et al., Phys. Rev. Lett. 95, 185701 (2005).
Adiabat: T. Guillot, Annu. Rev. Earth Planet. Sci. 33, 493 (2005).

Diamond formation is not observed in shock experiments over the same conditions



Laser shock experiments

Diamond	No Diamond	Initial material	Ref.
	1 shock (green cross)	Polyethylene CH_2	Hartley 2019
	1 shock (gray cross)	Polystyrene CH	Kraus 2017

Kinetics or the thermodynamic compression path play a role

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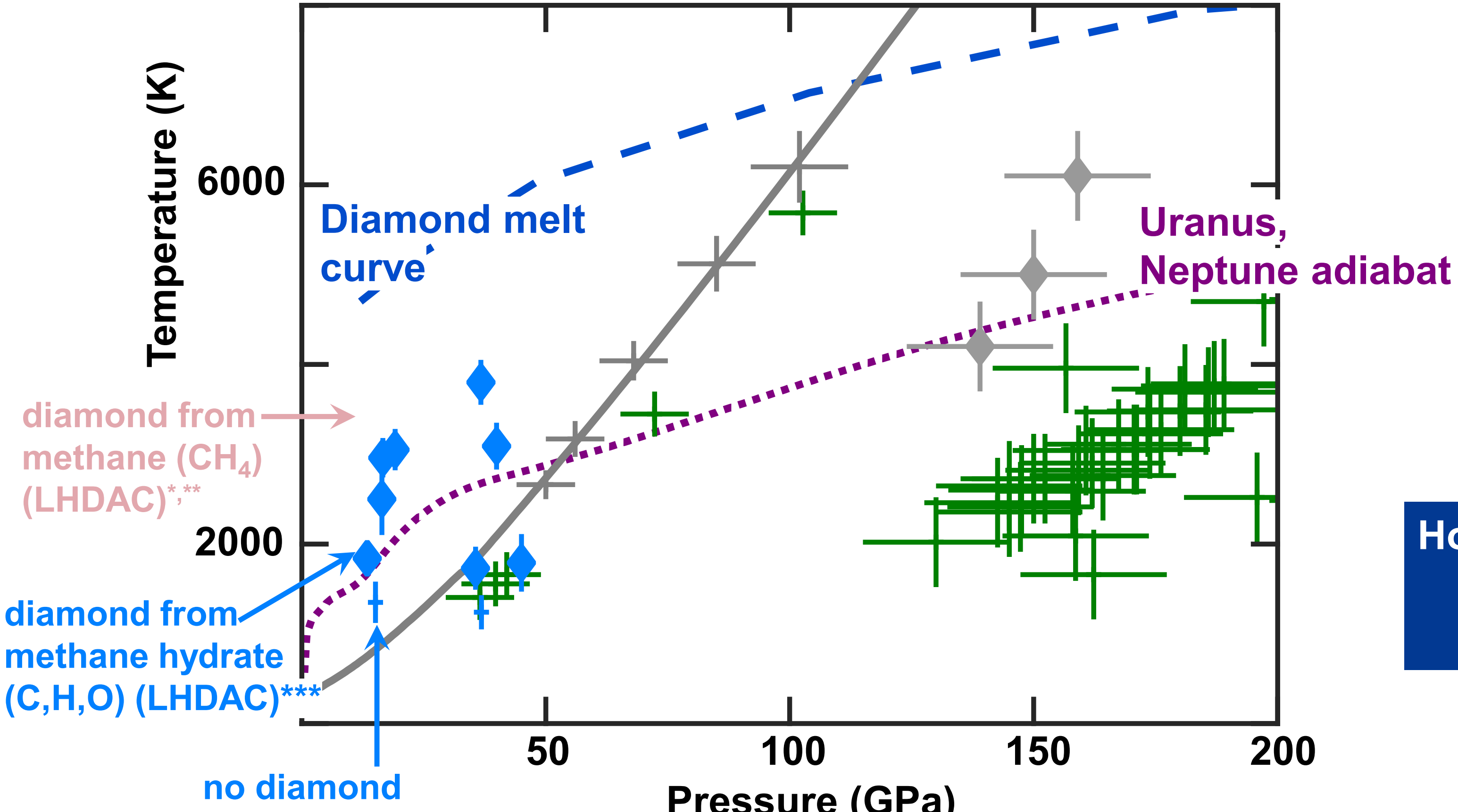
Diamond forms from double shocked CH but not CH_2



Laser shock experiments

Diamond	No Diamond	Initial material	Ref.
	1,2 shock	Polyethylene CH_2	Hartley 2019
2 shock	1 shock	Polystyrene CH	Kraus 2017

How does the addition of other elements affect diamond formation at high pressure over nanosecond time scales?

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Diamond formation in reshocked Stycast 1266 epoxy (C:H:O:Cl:N ≈ 27:38:5:1:1) was probed *in situ* using x-ray diffraction at the Omega EP laser facility

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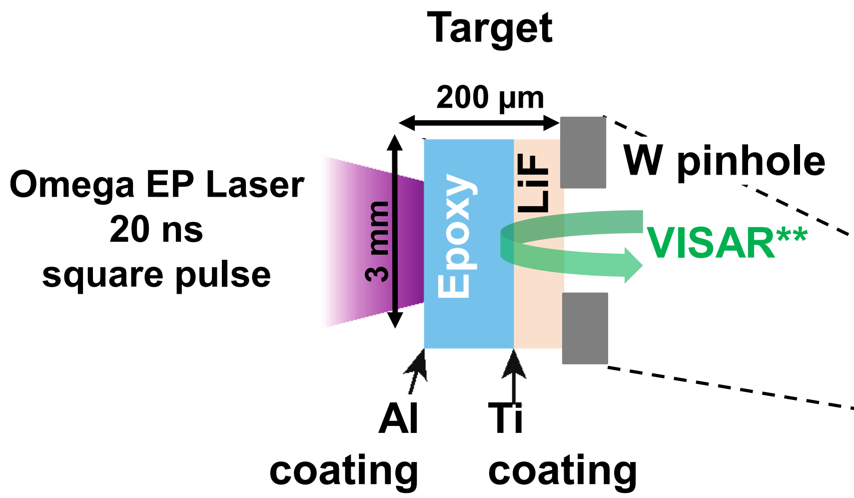
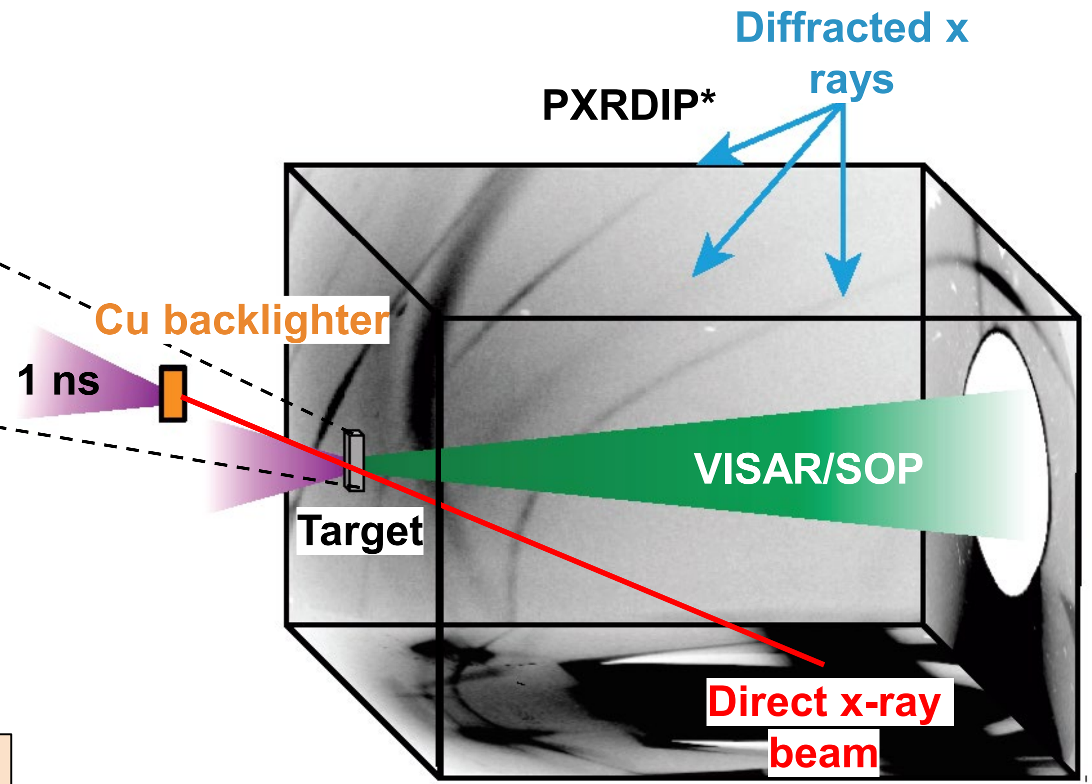
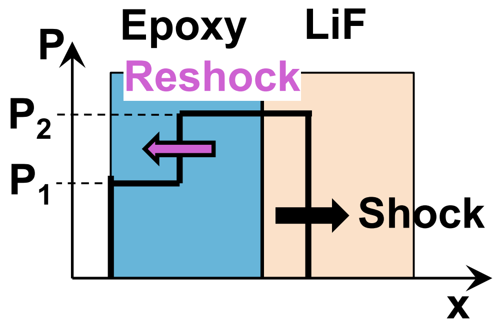


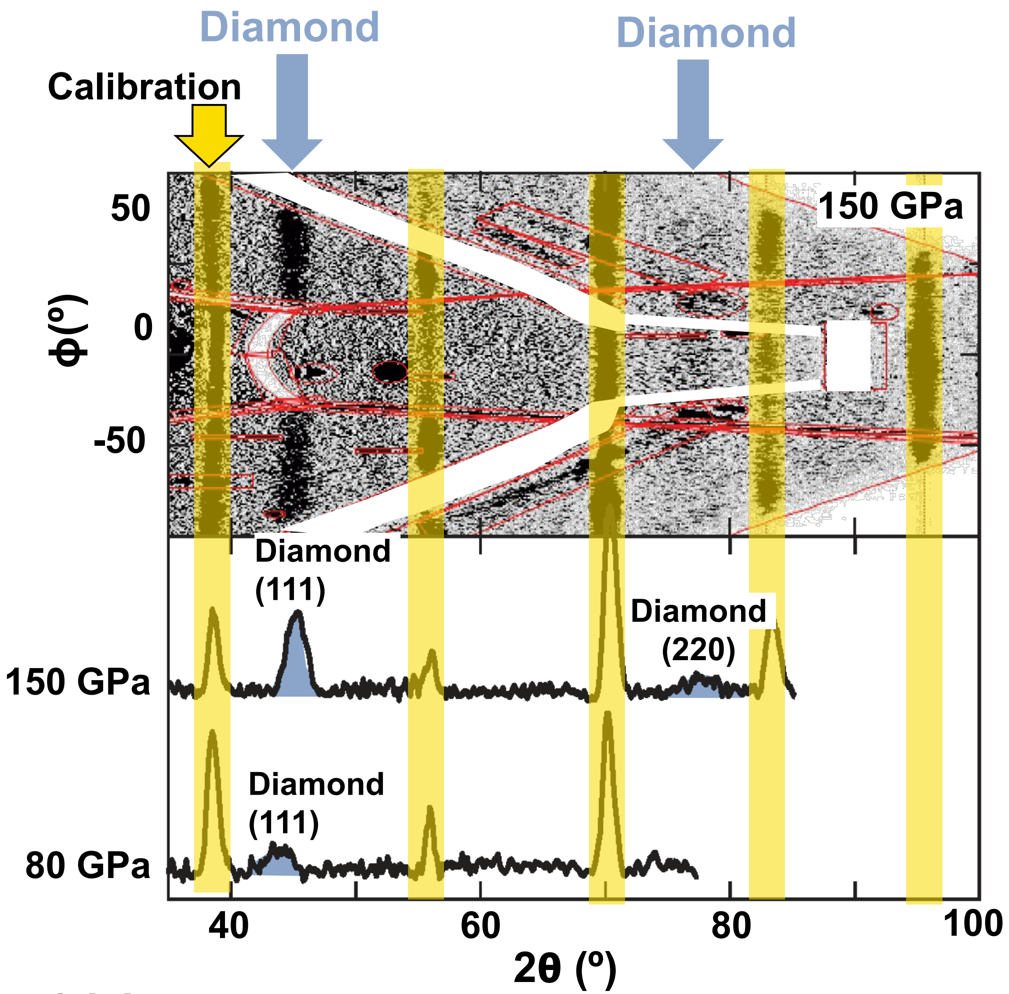


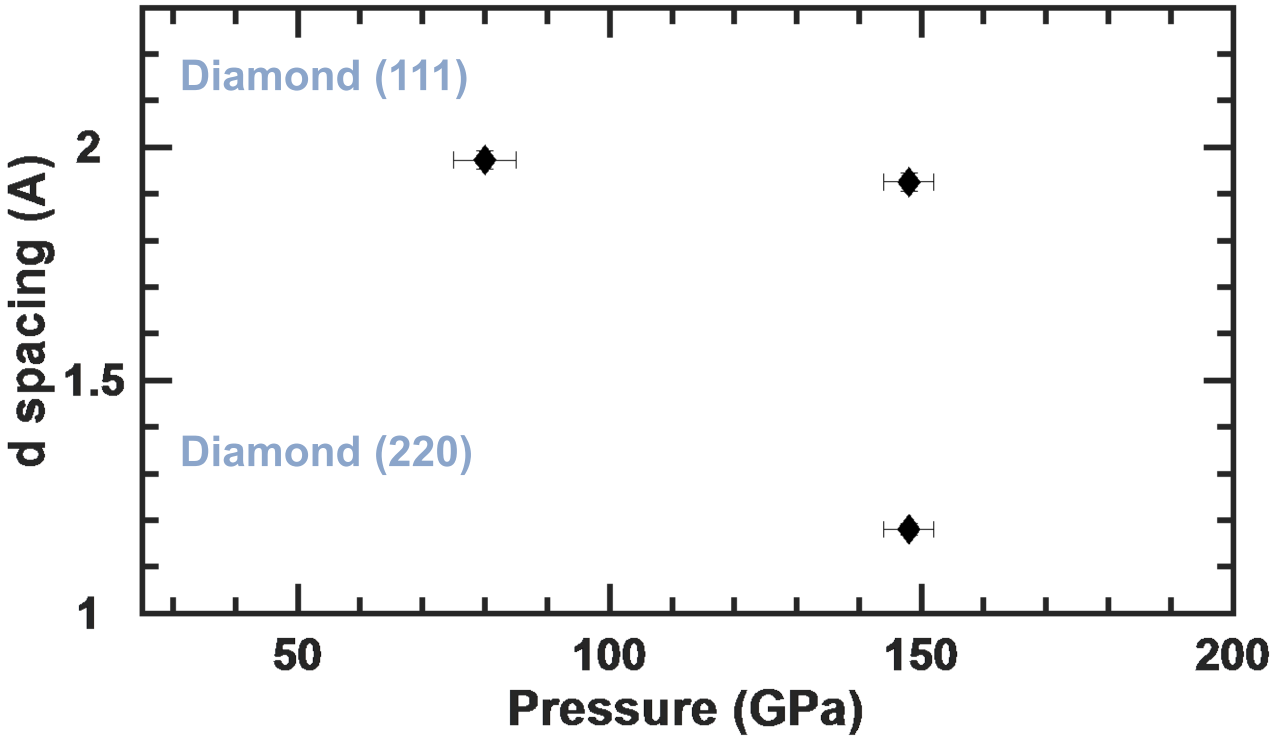
Target probed with x rays when epoxy is reshocked



* PXRDIP: Powder x-ray diffraction image plate
**VISAR: Velocity interferometer system for any reflector

Cubic diamond was detected in the reshocked epoxy





nλ = 2dsinθ

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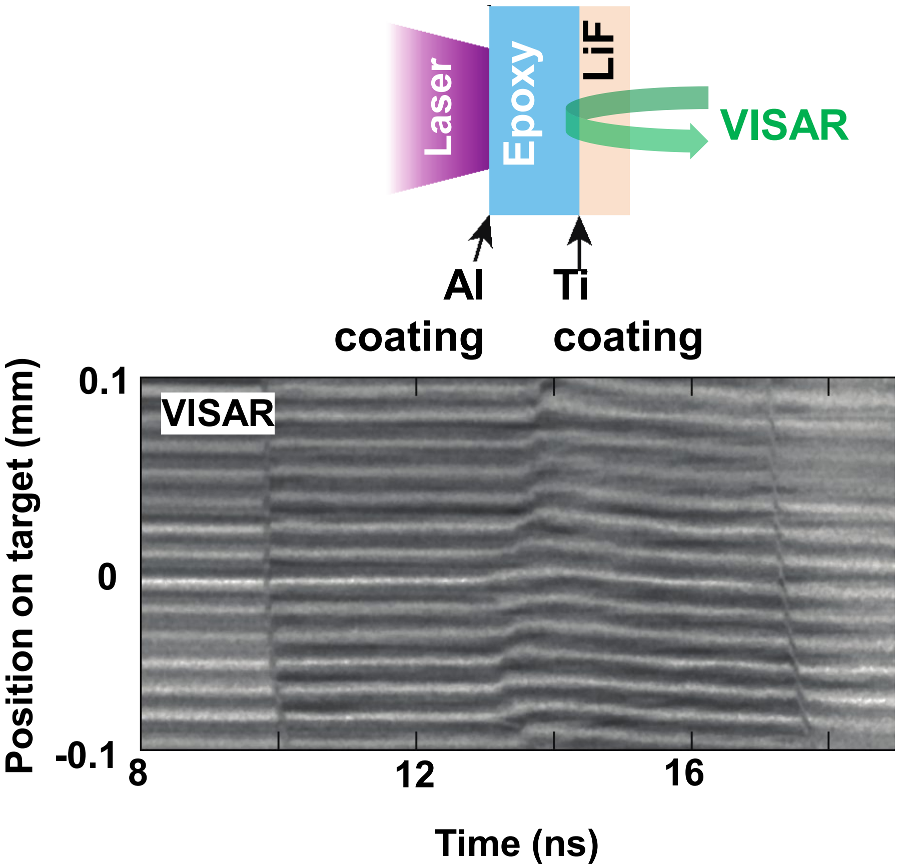
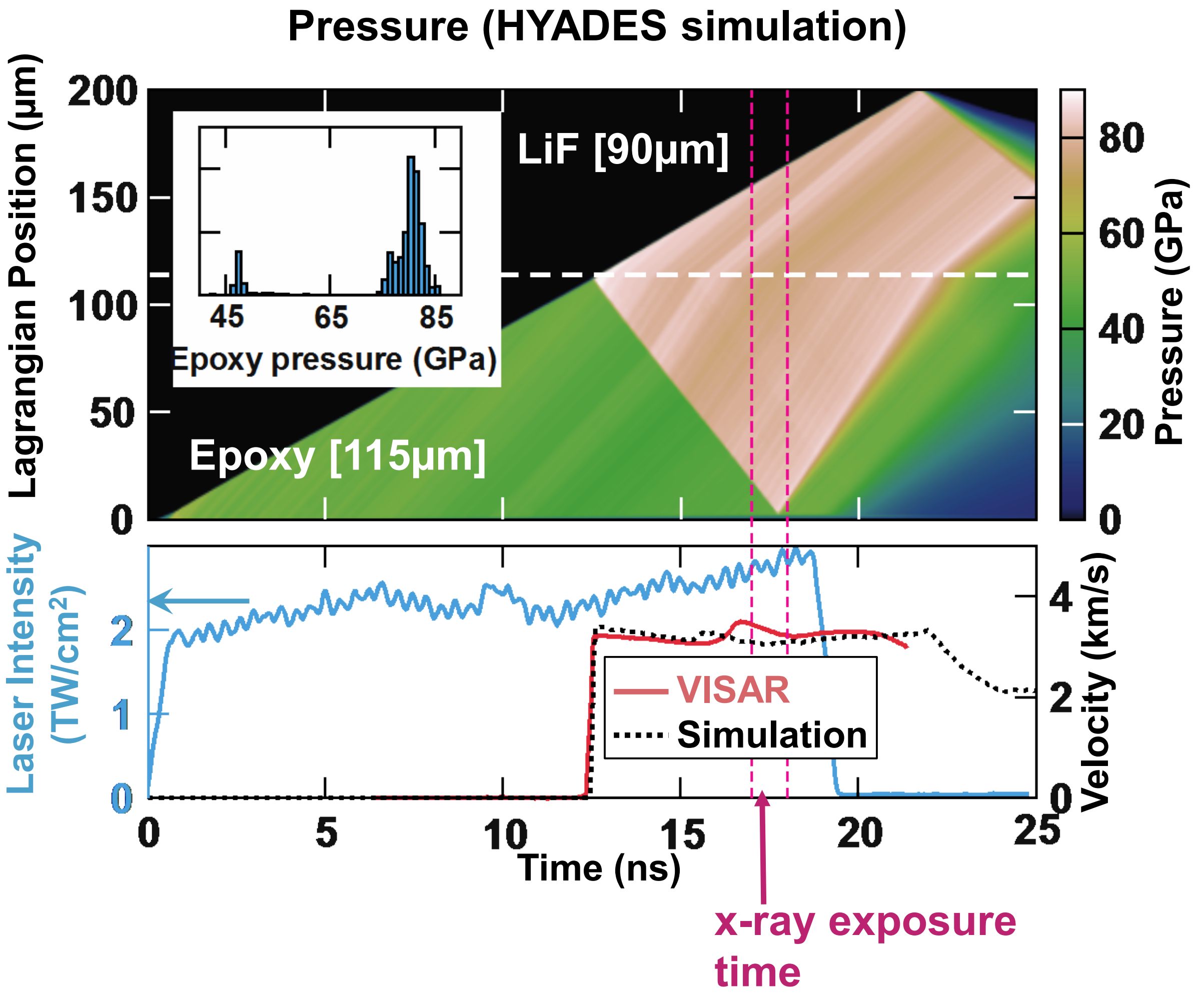
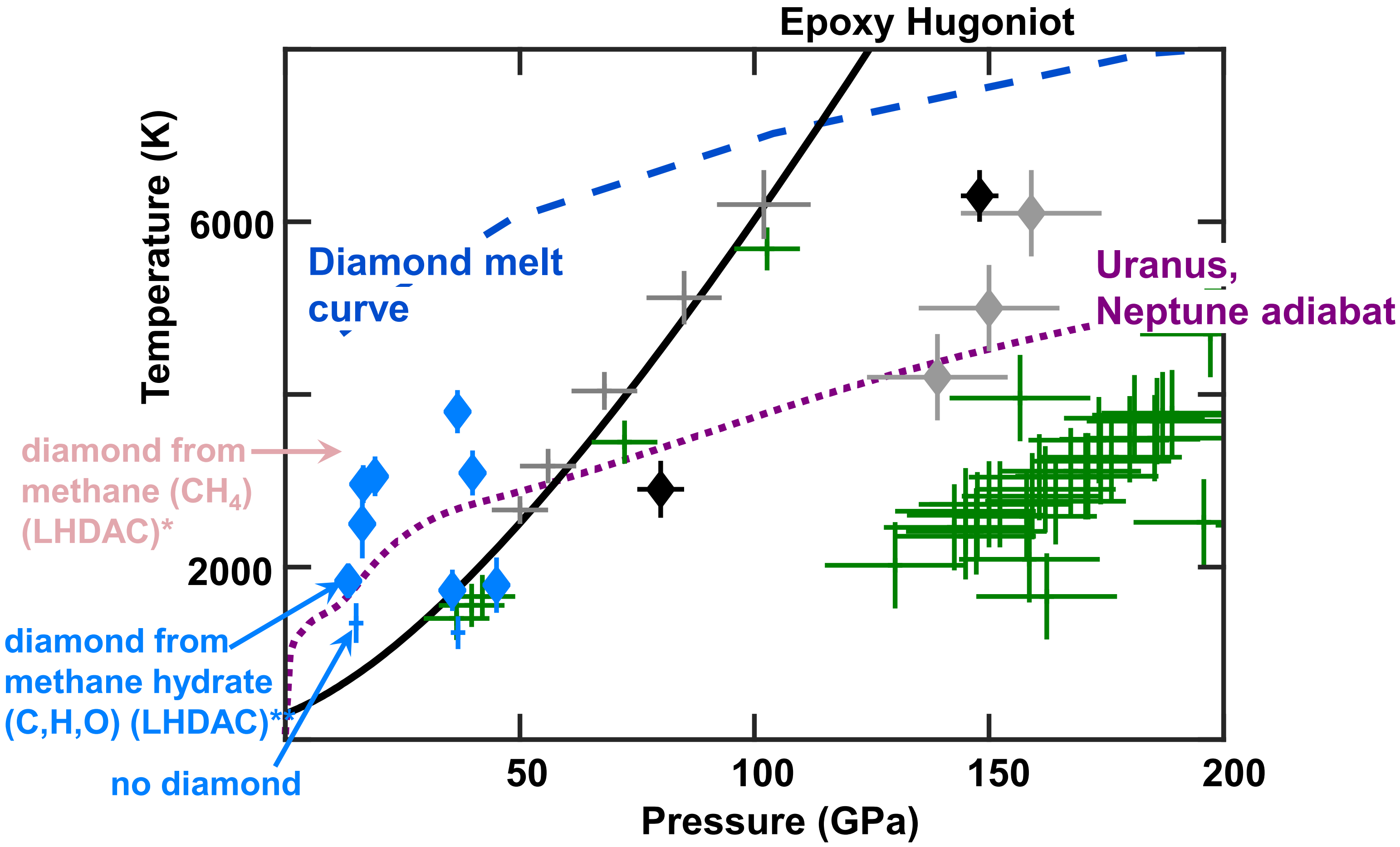
Pressure was determined using the VISAR data (velocity interferometer for any reflector) and HYADES simulations





Diamond forms from twice shocked epoxy at high pressures



Laser shock experiments

Diamond	No Diamond	Initial material	Ref.
	1,2 shock	Polyethylene CH_2	Hartley 2019
2 shock	1 shock	Polystyrene CH	Kraus 2017
2 shock		Epoxy C,H,O,Cl,N	Marshall 2022

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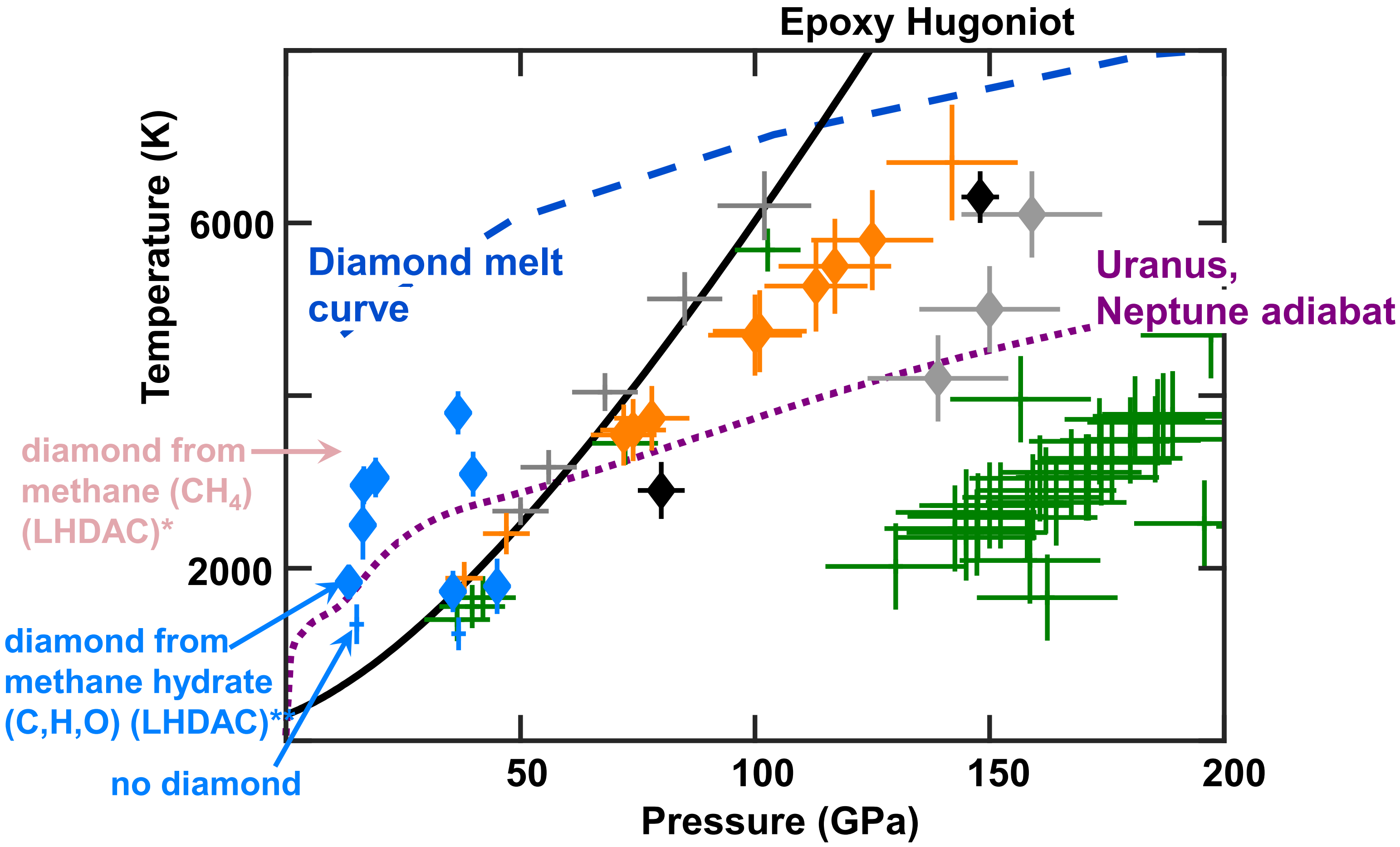
Oxygen may facilitate CH separation and diamond formation at extreme pressures



Laser shock experiments

Diamond	No Diamond	Initial material	Ref.
	1,2 shock	Polyethylene CH_2	Hartley 2019
2 shock	1 shock	Polystyrene CH	Kraus 2017
2 shock		Epoxy C,H,O,Cl,N	Marshall 2022
1 shock	1 shock	PET C,H,O	He 2022

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