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The 2024 MRE *HP Special Volume* selects papers on new theoretical and experimental developments in the use of static large-volume presses (LVPs)^{1–3} and dynamic compression^{4,5} for studies under extreme high-pressure and high-temperature (HPHT) conditions. It also continues the previous year's⁶ contemporary focus on superhydrides^{7–11} with extremely high superconducting temperatures T_c and addresses some controversial issues.^{12–14} In addition, it explores unconventional pressure-induced chemistry, particularly novel chemical stoichiometry and its impact on geochemistry and cosmochemistry in the deep interiors of Earth and other planets.^{18–21}

Ge *et al.*¹ review the Synergetic Extreme Condition User Facility at Jilin University, a versatile new platform serving the general high-pressure community. Its multiple LVPs include a liquid subsystem providing 1.8 GPa and 1000 K with *in situ* spectroscopic access, and a nonequilibrium subsystem reaching 10.2 GPa in 20 ms for dynamic experiments. The platform supports diverse research in geoscience, condensed matter physics, materials science, chemistry, and biology. Example applications demonstrate its broad capability and potential for advancing high-pressure science and technology. Feng *et al.*² introduce a three-dimensional finite element model as a virtual thermometer for ultrahigh-temperature–pressure experiments using boron-doped diamond (BDD) heaters in an LVP. Unlike previous models, it accounts for AC/DC heating, compressed cell dimensions, and heat dissipation effects. The model accurately reproduces experimental power–temperature relationships below

2600 K and provides reliable temperature estimates above 2600 K. It also reveals that BDD heaters offer more homogeneous temperature distributions (19–26 K/mm radially, <83 K/mm longitudinally) compared with conventional heaters. This virtual thermometer enhances temperature control and estimation in extreme-condition research in Earth and material sciences. Wu *et al.*³ introduce a low-cost, rapid-cooling experimental assembly for six-anvil cubic presses, achieving cooling rates of ~600 °C/s from 1900 °C—about ten times faster than traditional designs. The assembly maintains high heating efficiency and thermal insulation without requiring expensive materials or press modifications. It enables the formation of homogeneous, texture-free silicate glasses, eliminating quench textures that hinder analysis of volatile contents and melt properties. This advance significantly enhances the accuracy of high-pressure studies on silicate melts, facilitating better quantification of volatiles (e.g., H₂O, CO₂, and S) and element partitioning, with broad applications in Earth and planetary sciences.

Ramp loading using high-energy lasers has been the only way to achieve extremely high pressure (>1 TPa) in the solid phase. Shen and Kang⁴ revisit the validity of the Lagrangian analysis method commonly employed to determine stress–density states in compressed samples and present a new method for analyzing ramp loading experiments. By using large-scale molecular dynamics (MD) simulations, they demonstrate how the Lagrangian analysis misses phase transitions. This paper brings a huge improvement in the

field. Yang *et al.*⁵ introduce an innovative *in situ* X-ray diffraction (XRD) technique to investigate laser-driven dynamic fragmentation in tin. This method enables simultaneous determination of fragment phase and temperature. The findings challenge the isentropic release assumption, revealing temperatures over 100 K due to plastic-work-induced heating. MD simulations confirm strain energy conversion into heat during void nucleation and growth. This study offers new insights into material response under extreme conditions and highlights the critical role of plastic deformation in shock-release scenarios. This advance improves understanding of dynamic fragmentation and enhances temperature diagnostic methods for high-speed fragments.

Sun *et al.*¹² propose a novel method for determining the resistivity of compressed superconducting materials. Considering the standard resistance measurement geometry, they establish a relationship between resistance and the lattice constants and numbers of unit cells along the current flow direction and cross-section. Under continuous compression without structural phase transition, these unit cell numbers along crystal axes remain the same, although the lattice constants may change quite anisotropically. Combined with the lattice constants measured by XRD under high pressure, a precise relationship can be obtained between the measured resistance and the physical property of resistivity, which represents a technical advance for many applications, such as studies of superfluid density and quantum materials. Wang *et al.*¹³ rigorously challenge claims of near-room-temperature superconductivity in nitrogen-doped lutetium hydrides. Through careful synthesis and characterization, they identify the material in question as lutetium dihydride (LuH₂), rather than the proposed trihydride (LuH₃). Moreover, the observed resistance drop is clarified as being due to a pressure-induced metal-to-metal transition rather than superconductivity. The intrinsic properties of LuH₂ are elucidated, and nitrogen doping is shown to have a minimal impact on the transition. This work sets a critical benchmark and methodological standard for future high-pressure hydride superconductor research, highlighting the importance of rigorous validation in evaluating potential room-temperature superconductors. Liang *et al.*¹⁴ report an effective approach to the design of hydride superconductors stable at much lower pressures. Alloyed hydrides such as AlZrH₆ and AlHfH₆ retain a stable A15 structure, exhibiting thermodynamic/dynamic stability at far lower pressures than pure AlH₃. They have an enhanced Fermi-level electronic density of states, giving a higher T_c . Alloying Sc, Ti, Zr, or Hf with GaH₃ also lowers the stable pressure and gives a high T_c , advancing the development of low-pressure high- T_c hydride superconductors.

Geng *et al.*¹⁵ use first-principles calculations to explore silver halides under pressure. They find that the downshift of Ag 4*d* orbitals under pressure fills antibonding states below the Fermi level, leading to the decomposition of AgCl, AgBr and AgI. While AgF remains stable owing to the presence of strong ionic bonds, the study reveals that orbital energy rather than electronegativity dominates the chemical behavior of ionic compounds under pressure. Xu *et al.*¹⁶ report first-principles calculations on Ae₅X₃ (Ae = Ca, Sr, Ba; X = As, Sb) electrides with Mn₅Si₃-type structure. Strong electron correlation between interstitial electrons induces spin splitting, leading to Mott-insulating behavior with indirect bandgaps (~0.30 eV). The half-filled antiferromagnetic configuration and weak orbital

hybridization localize magnetic centers. High pressure enhances correlation, widening the bandgap. These findings deepen understanding of Mott-insulating electrides and guide the search for new strongly correlated materials. Dong *et al.*¹⁷ demonstrate that the equiatomic CoCrNi medium-entropy alloy exhibits exceptional strength and plasticity under magnetically driven ramp wave compression. By combining in-depth multiscale characterization with a modified crystal plasticity model, they reveal how dislocation slip, stacking faults, nanotwins, and grain refinement cooperatively govern the alloy's dynamic response. Their model successfully captures both macro- and mesoscale behaviors, offering new insight into deformation mechanisms at extreme strain rates. These findings position CoCrNi as a promising candidate for advanced structural applications in extreme environments and provide a robust framework for designing next-generation high-performance alloys.

Terrestrial He/Xe abundance anomalies hint at deep-Earth reservoirs. Using advanced crystal structure searches and first-principles calculations, Zhang *et al.*¹⁸ predict Xe/He-bearing iron halides (Fe-F-He, Fe-F-Xe, Fe-Cl-Xe) under <60 GPa across a wide temperature range. These findings support early-Earth sequestration of He/Xe, suggest their broader present-Earth distribution, and offer insights into key mechanisms for elucidating major geological phenomena. Kong *et al.*¹⁹ challenge the conventional wisdom of calcium only existing as Ca²⁺ in ionic compounds, and theoretically predict the stability of several bulk monovalent calcium compounds, including CaCl, Ca₅Cl₆, and Ca₃Cl₄ under extreme pressures. They further validate these predictions by successfully synthesizing the body-centered cubic phase of CaCl at 30 GPa using laser heating. These findings demonstrate that under extreme pressures, calcium can exhibit multiple valence states (+1 or +2), thereby unlocking the potential for a new class of multivalent calcium-based materials and minerals. Oxygen is the most abundant terrestrial element, constituting 50 at. % of the Earth. New Raman spectroscopy studies by Dalladay-Simpson *et al.*²⁰ reveal that metallic oxygen (ζ -O₂) undergoes a significant structural change above 175 GPa. Below this pressure, ζ -O₂ has a monoclinic C_{2/m} structure (eight molecules per unit cell), retaining stable (O₂)₄ molecular clusters seen in lower-pressure phases. Above 175 GPa, however, vibrational signatures indicate dissociation of these clusters, favoring simpler structures (C_{2/c} or $\bar{C}i$, with two molecules per unit cell). This transition, supported by simulations, resolves longstanding ambiguities in oxygen's high-pressure behavior. The study also observes strong hysteresis and metastability between ζ -O₂ and its precursor (ϵ -O₂), suggesting a first-order phase transition. These insights are crucial for modeling oxygen-rich environments in planetary interiors and high-pressure chemistry.

Yang and Du²¹ study three minerals in lunar regolith samples returned by the Chang'e-5 mission. Two pivotal high-pressure silica polymorphs, seifertite coexisting with stishovite, document an impact's pressure history (~11 to 40 GPa). Formed via cristobalite-like phase transformation during "cold" compression, seifertite later partially converted to stishovite under aftershock heat. The novel mineral changesite-(Y), a phosphate containing rich yttrium and rare earth elements and found in basalt fragments, signals late-stage crystallization and silicate liquid immiscibility. These findings highlight the mission's value for decoding lunar HPHT impacts and magmatic processes.

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DATA AVAILABILITY

Data sharing is not applicable to this article as no new data were created or analyzed in this editorial.

REFERENCES

- ¹Y. Ge, S. Ma, C. You, K. Hu, C. Liu *et al.*, “A distinctive HPHT platform with different types of large-volume press subsystems at SECUF,” *Matter Radiat. Extremes* **9**, 063801 (2024).
- ²B. Feng, L. Xie, X. Hou, S. Liu, L. Chen *et al.*, “A virtual thermometer for ultrahigh-temperature–pressure experiments in a large-volume press,” *Matter Radiat. Extremes* **9**, 047401 (2024).
- ³P. Wu, Y. Xu, and Y. Lin, “A novel rapid cooling assembly design in a high-pressure cubic press apparatus,” *Matter Radiat. Extremes* **9**, 027402 (2024).
- ⁴J. Shen and W. Kang, “Fundamental influence of irreversible stress–strain properties in solids on the validity of the ramp loading method,” *Matter Radiat. Extremes* **9**, 067801 (2024).
- ⁵J. Yang, X. Wang, L. Xu, Q. Wang, Y. Sun *et al.*, “Direct visualization of laser-driven dynamic fragmentation in tin by *in situ* x-ray diffraction,” *Matter Radiat. Extremes* **9**, 057803 (2024).
- ⁶H.-K. Mao, B. Chen, H. Gou, K. Li, J. Liu *et al.*, “2023 HP special volume: Synergistic progress of high-pressure physics and chemistry,” *Matter Radiat. Extremes* **9**, 063001 (2024).
- ⁷T. Meier, D. Laniel, and F. Trybel, “Direct hydrogen quantification in high-pressure metal hydrides,” *Matter Radiat. Extremes* **8**, 018401 (2023).
- ⁸N. Dasenbrock-Gammon, E. Snider, R. McBride, H. Pasan, D. Durkee *et al.*, “RETRACTED ARTICLE: Evidence of near-ambient superconductivity in a N-doped lutetium hydride,” *Nature* **615**, 244 (2023).
- ⁹S. Cai, J. Guo, H. Shu, L. Yang, P. Wang *et al.*, “No evidence of superconductivity in a compressed sample prepared from lutetium foil and H₂/N₂ gas mixture,” *Matter Radiat. Extremes* **8**, 048001 (2023).
- ¹⁰D. Peng, Q. Zeng, F. Lan, Z. Xing, Y. Ding *et al.*, “The near-room-temperature upsurge of electrical resistivity in Lu-H-N is not superconductivity, but a metal-to-poor-conductor transition,” *Matter Radiat. Extremes* **8**, 058401 (2023).
- ¹¹Z. Huo, D. Duan, T. Ma, Z. Zhang, Q. Jiang *et al.*, “First-principles study on the conventional superconductivity of N-doped *fcc*-LuH₃,” *Matter Radiat. Extremes* **8**, 038402 (2023).
- ¹²L. Sun, Q. Wu, S. Cai, Y. Ding, and H.-k. Mao, “A novel method for determining the resistivity of compressed superconducting materials,” *Matter Radiat. Extremes* **9**, 043001 (2024).
- ¹³D. Wang, N. Wang, C. Zhang, C. Xia, W. Guo *et al.*, “Unveiling a novel metal-to-metal transition in LuH₂: Critically challenging superconductivity claims in lutetium hydrides,” *Matter Radiat. Extremes* **9**, 037401 (2024).
- ¹⁴X. Liang, X. Wei, E. Zurek, A. Bergara, P. Li *et al.*, “Design of high-temperature superconductors at moderate pressures by alloying AlH₃ or GaH₃,” *Matter Radiat. Extremes* **9**, 018401 (2024).
- ¹⁵Y. Geng, J. Li, Z. Zhang, Y. Lv, M. Lu *et al.*, “Downshift of *d*-states and the decomposition of silver halides,” *Matter Radiat. Extremes* **9**, 067804 (2024).
- ¹⁶Y. Xu, L. Zheng, Y. Zhang, Z. Zhang, Q. Wang *et al.*, “Strong electron correlation-induced Mott-insulating electrides of Ae₂X₃ (Ae = Ca, Sr, and Ba; X = As and Sb),” *Matter Radiat. Extremes* **9**, 037402 (2024).
- ¹⁷J. Dong, X. Zhang, G. Wang, X. Wu, B. Luo *et al.*, “Mechanical responses and crystal plasticity model of CoCrNi medium-entropy alloy under ramp wave compression,” *Matter Radiat. Extremes* **9**, 057802 (2024).
- ¹⁸J. Zhang, H. Liu, C. Chen, and Y. Ma, “Sequestration of helium and xenon via iron-halide compounds in early Earth,” *Matter Radiat. Extremes* **9**, 037403 (2024).
- ¹⁹J. Kong, K. Shi, A. R. Oganov, J. Zhang, L. Su *et al.*, “Exotic compounds of monovalent calcium synthesized at high pressure,” *Matter Radiat. Extremes* **9**, 067803 (2024).
- ²⁰P. Dalladay-Simpson, B. Monserrat, L. Zhang, and F. Gorelli, “Distinct vibrational signatures and complex phase behavior in metallic oxygen,” *Matter Radiat. Extremes* **9**, 028401 (2024).
- ²¹J. Yang and W. Du, “High-pressure minerals and new lunar mineral changesite-(Y) in Chang’e-5 regolith,” *Matter Radiat. Extremes* **9**, 027401 (2024).