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Metastable Metallic Hydrogen Glass

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Metastable Metallic Hydrogen Glass

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The quest for metallic hydrogen has been going on for over one hundred years. Before hydrogen was first condensed into a liquid in 1898, it was commonly thought that condensed hydrogen would be a metal, like the monatomic alkali metals below hydrogen in the first column of the Periodic Table. Instead, condensed hydrogen turned out to be transparent, like the diatomic insulating halogens in the seventh column of the Periodic Table. Wigner and Huntington predicted in 1935 that solid hydrogen at 0 K would undergo a first-order phase transition from a diatomic to a monatomic crystallographically ordered solid at ~ 25 GPa.[1] This first-order transition would be accompanied by an insulator-metal transition. Though searched for extensively, a first-order transition from an ordered diatomic insulator to a monatomic metal is yet to be observed at pressures up to 120 and 340 GPa using x-ray diffraction and visual inspection, respectively.[2,3]

On the other hand, hydrogen reaches the minimum electrical conductivity of a metal at 140 GPa, 0.6 g/cm^3, and 3000 K.[4,5] These conditions were achieved using a shock wave reverberating between two stiff sapphire anvils. The shock wave was generated with a two-stage light-gas gun. This temperature exceeds the calculated melting temperature at 140 GPa by a factor of ~2, indicating that this metal is in the disordered fluid phase. The disorder permits hydrogen to become metallic via a Mott transition in the liquid at a much smaller pressure than in the solid, which has an electronic bandgap to the highest pressures reached to date.[3] Thus, by using the finite temperature achieved with shock compression to achieve a disordered melt, metallic hydrogen can be achieved at a much lower pressure in a fluid than in a solid.

It is not known how, nor even whether, metallic hydrogen can be quenched from a fluid at high pressures to a disordered solid metallic glass at ambient pressure and temperature.[6] Because metallization occurs by simply pushing the molecules together sufficiently that an electron on one molecule can delocalize and move to an adjacent molecule, if the pressure is released the system will simply revert back to a diatomic insulator. Additives will probably be necessary to produce bonding which will inhibit the reverse transformation when pressure is released.[6]

One technique for rapidly quenching metallic fluid hydrogen is to use a thin micron-thick layer of condensed hydrogen contained between metal or diamond layers, which have a high thermal conductivity to quench shock temperature before pressure is released. An appropriate planar shock wave can probably be driven by a laser or small two-stage gun to achieve the necessary pressures, temperatures, and quench rates. In this way many experiments might be performed to find the appropriate combination of materials and shock-pressure history to achieve a shock-pressure-quenched metastable metallic hydrogen glass.

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