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High-yield implosions using DT wetted foam for inertial fusion energy (IFE)*

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IFE applications require high repetition rates, and capsules utilizing DT wetted foams offer an advantage over those using a DT ice layer, as the foam does not require a prolonged duration for cryogenic layering. However, wetted foam can lead to significant yield degradation[1] due to several critical issues. (1) The C and O present in 3-D printed foams created by the 2PP process, or Si and O in chemically produced SiO_2 foams, absorb hard x-rays, which can penetrate conventional ablators, e.g., high-density carbon (HDC), Be, or CH. These x-rays preheat the foam, raise the adiabat, and reduce the areal density (ρR). The rate of preheating escalates with foam density. (2) There is additional radiation loss from the foam during the burn phase. (3) The inert mass of the foam in DT fuel reduces yield. (4) The turbulence created by shocks traversing the irregular foam structures can lead to under-compression.[2]

To evaluate the performance of DT wetted-foam implosions, we use an HDC capsule with an outer radius (OR) of 1189 μm, driven by an Au-lined DU hohlraum.[3] When the ice layer is replaced with a DT-wetted foam of 25 mg/cc density, the yield degradation is ~55% in 1D simulation due to the x-ray preheating of the wetted foam. However, this degradation can be mitigated by ~15% if an unlined-DU hohlraum is utilized to reduce the hard x-rays.[3] For a 50 mg/cc foam, ignition cannot be achieved. A larger Be capsule with an OR of 2340 μm absorbs 1.3 MJ of laser energy and achieves a 1D yield of 400 MJ. The extent of yield reduction varies between 20-80 %, depending on the O content, for a wetted foam at 25 mg/cc. Therefore, it is essential to develop methods to address the significant yield degradation.

The heavy ablator, known as the Pusher-Single Shell (PSS),[4,5] was designed with a high concentration of Mo to block hard x-rays effectively. It optimizes the trade-off between implosion velocity and ρR. The PSS features a Be ablator with a 20 at.% of Mo in the inner region. The concentration of Mo decreases toward the outer region to minimize the Rayleigh-Taylor instability. Calculations indicate that PSS has a high ignition margin, e.g., a 1500 μm OR PSS absorbing 490 kJ of laser energy has a yield of 40 MJ. The yield degradation associated with wetted foam is notably reduced — 15% (20%) for 25 mg/cc (50 mg/cc) foam density. The Mo blocks almost all the hard x-rays, resulting in minimal change to adiabat. For foam density less than 50 mg/cc, the under-compression caused by turbulence is likely negligible.[2]

References

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