Fabrication of Millimeter-sized Glass Shells for High Pressure Gas Targets

Xiao-bo Qi [#], Cong Gao, Zhan-wen Zhang, Su-fen Chen, Bo Li, Sheng Wei

Research Center of Laser Fusion, China Academy of Engineering Physics, Mianyang, Sichuan 621900, China

Tel: 86-816-248-5264; Email: xbqi@caep.cn

Glass shells have been widely used in inertial confinement fusion (ICF) targets as fusion fuel containers due to their excellent spherical symmetry, high surface finish and strength, low permeability to deuterium-tritium (DT) fuel gas, and easy doping with diagnostic atoms. As laser drivers become more powerful, ICF physical experiments need glass shells with high aspect ratios (=outer radius/wall thickness) as the DT fuel containers to study mixing[1]. Such high aspect ratio glass shells need to be both large in diameter (800-1200 μm) and thin in wall thickness (0.8-1.5 μm).

The glass shells produced by the dried gel method can meet the requirements of ICF targets in a wide range, such as diameters, wall thicknesses, glass compositions, strengths, permeability and doping of high-Z elements[2]. In the transformation process from dried-gel particles to glass shells in the drop-tower furnace, choosing proper initial glass-froming compositions, optimizing the gel particle sizes, and regulating the heat and mass transfer rates between the gel particles and the furnace atmosphere are the keys to producing millimeter-sized glass shells with target quality.

This work focused on the production and characterization of millimeter-sized glass shells for ICF targets by the dried gel method. To this end, the effects of the initial glass-froming compositions and dried gel particle sizes, the refining zone temperatures and lengths, the furnace gas pressures and compositions on glass shell diameters, quality and yields was studied intensively by both experimental investigation and numerical simulation.

The experimental and simulation results show:

(1) The addition of water in the gel particles favors increasing the diameter of the resulting glass shells, but the effectiveness is limited.

(2) Although the more massive gel particles result in the larger glass shells, with gel particles larger than 400μm, the sphericity and wall uniformity of the resulting glass shells decreases rapidly.

(3) The displacement of argon gas with helium gas in furnace gas leads to a rapid increase in the glass shell diameter. However, the proper addition of argon gas in the furnace ambience can reduce dramatically the fragmentation of the gel particles and the ripples and collapse on the shell surface.

(4) Although lowering the furnace atmosphere pressure can increase the glass shell diameter, the percent of Class A shells in the batches decreases rapidly. Particularly, the furnace atmosphere pressures less than 0.04 MPa contribute to severe ripples and collapse on the surface of the resulting glass shells.

(5) The glass shell diameters increase slightly with the furnace temperatures and the percents of Class A shells in the batches increase notably with the furnace length. However, the quality and yield of the large glass shells with diameter greater than 800 μm decrease remarkably with the increase in the glass shell size.

---

[1] Smalyuk, V.A., Betti, R., Delettrez, J.A., et al. Implosion experiments using glass ablators for direct-drive inertial confinement fusion. Phys. Rev. Lett., 104, 165002, 2010.

[2] Downs, R.L., Ebner, M.A., Miller, W.J. Hollow glass microsphere by sol-gel technology, in: Klein, L.C. (Eds.), Sol-gel technology for thin films, fibers, preforms, electronic, and specialty shapes. Noyes Publications, Park Ridge, pp. 334-364, 1988.