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LOW PRESSURE GAS FILLING OF LASER FUSION MICROSPHERES*

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In our laser fusion microsphere production, large thin gel-microspheres are formed before the chemicals are fused into glass. In this transient stage, the gel-microspheres are found to be highly permeable to argon and many other inert gases. When the gel transforms to glass, the argon gas, for example, is trapped within to form argon filled, fusion target quality, glass microspheres. On the average, the partial pressure of the argon fills attained in this process is around 2×10^6 Pa at room temperature.

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1. INTRODUCTION

An important parameter in the laser fusion experiments is the peak DT fuel density attained in the inertial confinement process. In order to measure this density, it is generally necessary to include a diagnostic gas, such as argon, with the DT fuel inside the glass microsphere targets. Unfortunately, the permeability of argon gas for normal glasses is about six orders of magnitude smaller than hydrogen under the similar circumstances.⁽¹⁾ Thus, to introduce such a gas into the glass microspheres by the normal permeation method, one has to first develop glass microspheres with a high silicon composition, and then subject them to high temperature and pressure for a prolonged period. Often these processes cause various failures in the structure of the glass microspheres. Such failures include the devitrification of the glass, the surface roughening due to alkali precipitation and the distortion of the glass structure due to stress. It is quite difficult, therefore, to produce argon filled, laser fusion target quality, glass microspheres by any permeation method.

In our previous studies of the physical processes in the glass microsphere productions by either the Liquid Droplet method⁽²⁾ or the Dried Gel technique,⁽³⁾ we learned that as the droplets of the

aqueous solutions in the Liquid Droplet method or the granules of the dried gels in the other technique are passing through the low temperature dehydration region of the vertical drop ovens (as shown in Figure 1), it is possible to form large, thin gel-microspheres before the glass forming chemicals fuse into glass in the high temperature fusion region below. Since a large amount of water (90 wt% in the Liquid Droplet method and about 50 wt% in the Dried Gel technique) has to be evaporated through these thin membranes of the gel-microspheres during this dehydration process, it seems likely that we should be able to permeate argon or any other inert gas into these gel-microspheres. The wall thicknesses of the spherical gel-microspheres are around 1000 Å. Because of their large size and low density, they float in air and are trapped in a temperature zone about 700°C - 900°C between the low temperature dehydration region and the high temperature glass fusion region by the turbulent air flow in the order of tens of seconds. All of these conditions encourages gas permeation through these thin membranes of the gel-microspheres. As gel transforms into glass, both the density of the material and the value of the surface tension increase. From theoretical calculation,⁽⁴⁾ it shows that it is possible to form a stable state by trapping interior gas in the center to form a concentric microsphere, provided that the membrane is poreless and the

size of the microsphere is sufficiently small. It is quite obvious that both conditions -- the high gas permeation of the gel-microspheres and the ability to trap the argon gas in the glass transformation process -- are necessary to produce argon filled, laser fusion target quality, glass microspheres.

2. EXPERIMENTAL

Argon (or Kr, Xe, Ne) gas is fed into the vertical drop oven (VDO) through a small opening at the top as shown in Figure 1. The flow rate is controlled by a valve and flow meter system. The oven is first flushed with the inert gas by pumping the residual gas out at the bottom of the VDO. Then, the gas flow rate is reduced to allow only a small amount of the inert gas flow through the VDO to serve as a particle carrier during the glass production. The chemical compositions for the two production processes (the droplet generator technique and the dry gel method) are listed in Table I. The average temperature for the dehydration region of the VDO used in the case of the droplet generator technique is about 200°C, and it is about 600°C for the dry gel process. The temperature of the glass fusion region of the VDO is set at 1500°C. The glass microspheres produced in either of these processes are collected at the bottom of the VDO.

Table 1. Chemical Composition

	Droplet Generator*	Dry Gel
Na-silica (J.M.)**	91 wt%	-
H.S. 40 Ludox**	-	53 wt%
Boric Acid	4.8 wt%	15 wt%
KOH	3.9 wt%	26 wt%
LiOH	0.3 wt%	-
NaOH	-	6 wt%

* For a moderate density solution, there is about 360 g of chemicals per liter of water.

** Du Pont products.

In the case of argon fill, the amount of argon gas trapped inside each glass microsphere is measured separately using a mass spectrometer.⁽⁵⁾ From their measured masses, and volumes, the partial pressures of argon gas are calculated. Some of the experimental results are listed in Table II.

Table II. Argon Measurement

	Outside diameter	WALL thickness	PRESSURE of Argon
NO	μm	μm	pascal $\times 10^5$
200	164	3,6	0,21
201	140	6,6	0,10
202	134	2,9	0,17
203	139	5,1	0,26
204	134	2,3	0,08
205	129	3,4	0,12
206	136	3,3	0,11

The average value for the partial pressure of argon is around 2×10^4 Pa at room temperature. Partial pressures of argon are about 1/2 to 1/3 of the total pressure inside the glass microspheres (the average value for the total gas pressure inside the microspheres is about 6×10^4 Pa at room temperature).⁽⁵⁾ It is interesting to note that at the glass fusion process, the interior pressure of the microspheres is higher than the atmosphere pressure.

For other inert gases, i.e., He, Kr and Xe, we have used the same mass spectrometer technique to analyze the gases contained in those glass microspheres produced in the similar process. The results clearly verify that this method can be used to fill the glass microspheres with any kind of inert gases at low pressure.

Scanning electron microscope (SEM) pictures of a gel-microsphere with different magnifications are shown in Figure 2. Most of these gel microspheres are broken due to handling. The important aspect is that even up to the maximum magnification, no porelike structure is observed. It is quite obvious that this structure is responsible for trapping of the high gas pressure during the fusion process.

3. CONCLUSION

In these experiments, we have not only demonstrated that it is rather easy to produce argon filled, laser fusion target quality, glass microspheres using our unique production processes, but also verified that the gel-microspheres are highly permeable. The gas

compositions inside the gel-microspheres may well reach equilibrium with the oven atmosphere during the transient period. During the transition from the highly permeable gel-microsphere state to the low permeable glass microsphere state, the residual gases inside the microspheres are trapped and, thus, the glass microspheres may be filled with any of a variety of gases to which normal glass microspheres are impermeable.

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NOTES

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FIGURE 1. A schematic diagram of the vertical drop furnace.

A

300 μm

B

300 μm

Scanning electron microscope views of a gel-microsphere (A) at 3×100 magnification and (B) at $3 \times 10,000$ magnification.