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ENLARGEMENT OF GLASS AND PLASTIC SHELLS TO 2 mm IN DIAMETER BY REDROPPING THROUGH A SHORT HEATED TOWER

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ABSTRACT

Large glass shells (≥ 1200 μm diameter) made by the traditional very high temperature (1650°C) long drop tower are usually wrinkled. We have found that these shells soften at relatively low temperatures. We have enlarged these shells by filling them with a few atmospheres of helium and dropping them down a very short (few feet long) tower heated to 900 to 1100°C. The helium acts as a blowing agent as the shell goes through the heated zone and causes the shells to grow larger. We have been able to smooth out large wrinkled shells by this process, as well. Glass shells as large as 2 mm in diameter and less than 6 μm out-of-round that do not have any obvious wrinkles have been made. In addition, the same process can be applied to both poly-alpha-methylstyrene (PAMS) and glow discharge polymer (GDP) shells at lower tower temperatures. Roundness of the enlarged shells is very much dependent on the wall thickness uniformity of the initial mandrels.

I. INTRODUCTION

Currently, cryogenic DT layering experiments for the NIF are performed on plastic shells with attached fill tubes.[1] While this technique has provided a great deal of information on the layering process, the fill tubes invariably introduce undesired perturbations in the measurements. Therefore, it is highly desirable to perform these experiments using shells that are capable of holding the desired DT pressure without the necessity of a fill tube.

Traditionally, glass shells have proven to be excellent for this purpose, because of their high strength and low permeability to DT at room temperature. Glass shells are made using the traditional drop tower technique[2] which is currently incapable of making good quality shells greater than 1500 μm in diameter. However, for the National Ignition Facility (NIF), larger glass shells, that are close to 2 mm in diameter are needed.

In this paper we discuss a new technique we have developed that enables us to produce good quality glass shells up to 2 mm in diameter. Smaller (less than 1500 μm in diameter) glass shells made using the traditional drop tower technique are first filled with gas. They are then redropped through a short tower which has an approximately one foot hot zone heated to 950°C. The glass shells soften at that temperature and the increased internal gas pressure actually blows the shells larger. Because the heated zone is short, the enlarged glass shells exit the hot zone and freeze before the helium can permeate out of the shell.

We have also used the same technique to enlarge plastic shell. We used both PAMS shells and GDP shells made by the depolymerizable mandrel technique.[3] Enlargement of the plastic shells is done at much lower temperatures (≈ 200°C).

II. EXPERIMENTAL

For glass shell re-drops, the starting mandrels were glass shells made using the traditional drop tower technique. Their diameters ranged between 1100 and 1300 μm. The wall thicknesses were typically between 5 and 10 μm. These shells were filled with helium at 360°C to expedite the fill process. Using these conditions, the entire fill process typically took less than one hour. A similar deuterium fill would last over a day. A 3 in.

diameter three zone furnace was stood up on end and was used as the short drop tower. Typically only the middle zone of this furnace was heated to 900 to 1100°C. A five foot alumina tube was placed in the furnace and acted as the tower itself. Thermocouple gauges were placed in each zone to measure the temperatures of the zones. Shells were dropped one by one or as a batch. When shells were dropped as a batch, shards from exploding or imploding shells, contaminated the survivors. The enlarged shells were collected on a petri dish at the bottom of the tower.

For the plastic shell redrops, the ten foot tower used for making polystyrene shells[4] was used. This tower was heated by heater tapes wrapped around the stainless steel tube which served as the tower itself. PAMS shells made by the microencapsulation technique were used as the starting mandrels. These shells were filled with nitrogen since helium leaks out of these shells in seconds. The enlarged plastic shells were also collected on a petri dish.

III. RESULTS AND DISCUSSION

The redrops were first performed in the long drop tower (18 feet long) that is used for making the starting mandrels. The results of the drops through this tower are shown in Fig. 1. The shells expand as they go through the tower, but before they can exit the tower and freeze, the interior helium leaks out of the shells, resulting in the collapse of the shells. This indicated the need for a shorter tower.

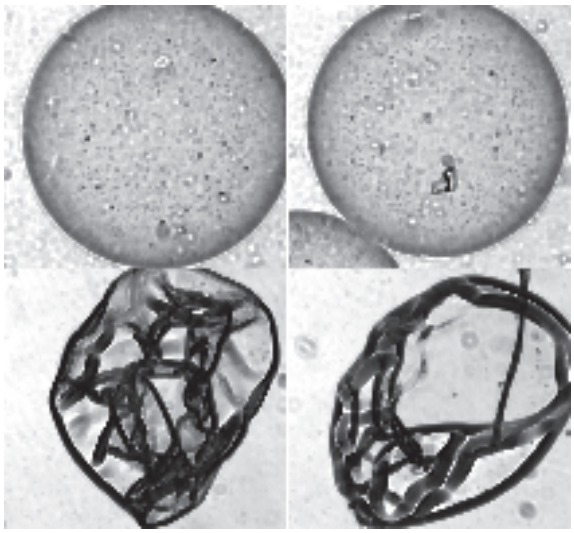

Fig. 1. Top- Starting glass shells ≈ 1200 μm in diameter filled with 1 atm of helium. Bottom- Same two shells after dropping down the long (18 foot) drop tower heated to 1100°C. These shells initially expanded, but because of the length of the tower, the helium leaked out of the shells while they were in the heated tower. They then collapsed due to the external ambient pressure.

By using a one foot tower heated to 950°C we were able to obtain the desired results. Figure 2 shows optical and interferometric images of shells expanded to over 1700 and 2000 μm. The starting shells were about 1200 μm in diameter. The outward pressure of the gas as the shells expand appears to smooth out any wrinkling in the shells. The smooth interferometric image in Fig. 2(b) is a good indicator of this effect. To investigate this further, we used this technique on shells that had severe dents as in Fig. 3. The reblowing process actually repaired the dent in the shell as can be seen in the figure.

We decided to use the same method on plastic shells. Initially GDP shells were used in the same short tower that was used for glass shells. However, the heated zone was at only 400°C for these experiments. The GDP shells did indeed expand despite the crosslinked structure of GDP.[5] Because of the relative unavailability of the GDP shells, we decided to perform experiments involving plastic shells by using PAMS shells. These shells are made in large batches and are readily available. We found that PAMS shells could also be enlarged. For these shells, depending on the batch used, we had to heat the tower to between 150°C and 220°C. Since the permeation rate of the fill gas (nitrogen) in this case is the same as the ambient air, the tower could be as long as desired. In fact, the roundness of the final shells may be better if a longer tower is used. We found we could make PAMS shells that were over 2 mm in diameter and had a maximum oblateness of only 2 μm in radius. This is comparable to the best shells made by microencapsulation technique at this size.[6]

While this method is very simple, it does require starting shells which have to satisfy some stringent requirements. In particular, the starting shells must be thick walled and have very good wall concentricity. The thick walls are required because as the shells expand, they also become thinner. For an expansion factor ß, the aspect ratio of the enlarged shell is increased by $ß^3$. Since the buckle strength of a shell is proportional to the square of the aspect ratio, the buckle strength of the enlarged shells is $ß^6$ lower than that of the starting shells. Therefore, since the final shell will have to withstand a 1 atm external pressure, the starting shell needs to have a buckle strength of $ß^6$ atmospheres. For ß = 2, this translates into 64 atm, requiring thick walls for the starting shells as mentioned before. The increased aspect ratio leads to buckling of many of the enlarged shells if the starting shells are too thin. In addition, starting shells with non-uniform walls will enlarge asymmetrically leading to oblate enlarged shells which cannot be used for layering experiments. This effect is shown in Fig. 4 for PAMS shells that were very round but had poor wall uniformity. The enlarged shells are grossly oblate (Fig. 4).

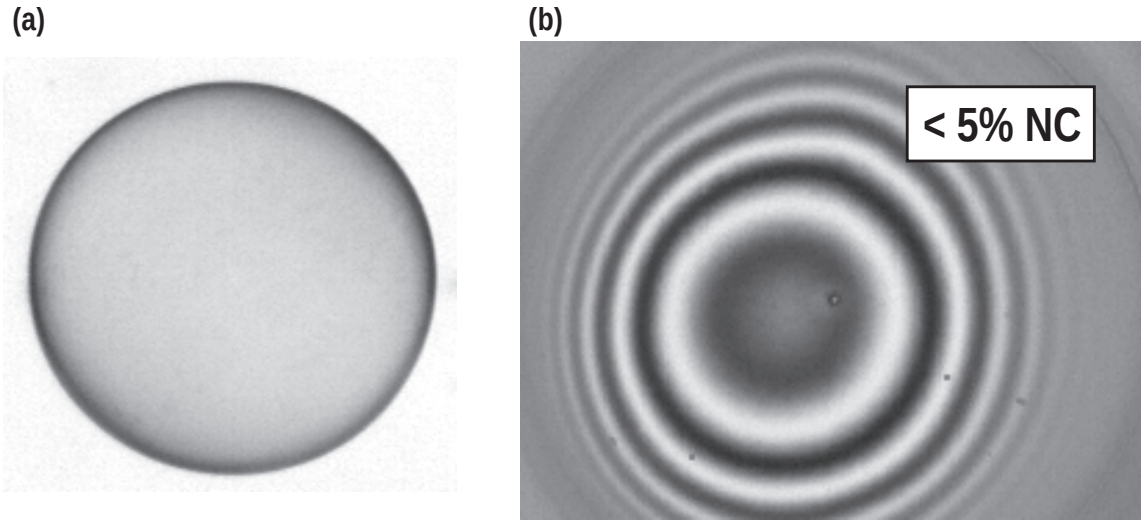

Fig. 2. Images of enlarged glass shells. (a) Optical microscope image of a 1740 μm glass shell expanded from a 1200 μm starting mandrel. Note the absence of any wrinkles or dents. (b) Interferomatric image of a 2002 μm glass shell made from a ≈ 1300 μm starting mandrel. The smooth fringe pattern indicates absence of wrinkling or major wall thickness variations in the shell. The wall thickness non-concentricity is less than 5 %.

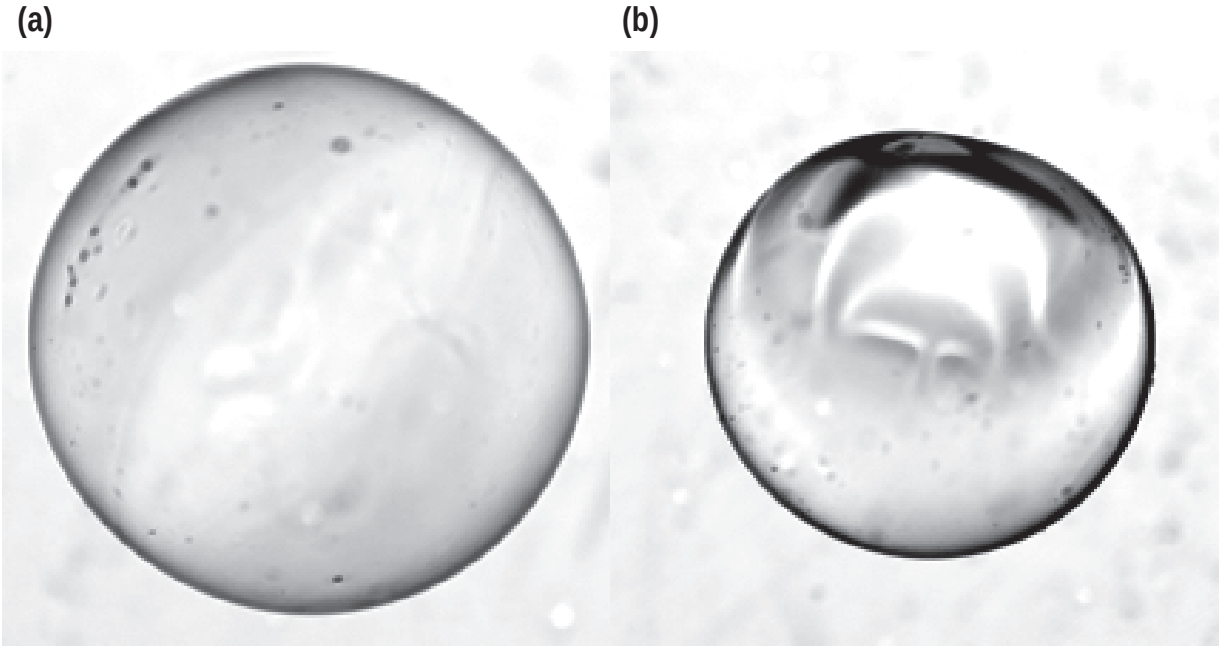

Fig. 3. (a) Optical microscope image of a 1600 μm diameter shell that was repaired by the reblowing technique. (b) Image of the shell in (a) in its original puckered state before reblowing.

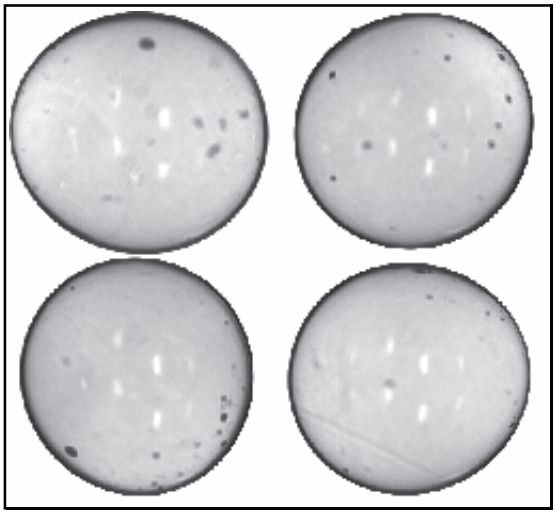

Fig. 4. Optical image of a sample of enlarged PAMS shell ≈ 2050 μm in diameter. The starting mandrels were 1450 μm in diameter and out-of-round by only 1.7 μm, but had very poor wall thickness uniformity (Δ wall/wall ≈ 20%). The enlarged shells are obviously oblate with an out-of-roundness of 47 μm in diameter. Wall thickness uniformity of the starting shells is essential for obtaining round final shells.

IV. CONCLUSION

We have been able to enlarge glass or plastic shells by redropping gas filled smaller shells through a heated tower. Using this technique high quality glass shells up to 2 mm in diameter were made. The roundness of the final shells is determined by the wall thickness uniformity of the initial shells. Because of the increased aspect ratio of the enlarged shells thick starting mandrels must be used to ensure survival of the final shells. With the current starting shells available, the final shells are 1500–2000 μm in diameter and 2-3 μm thick. These shells are very fragile because of their very high aspect ratio. We are currently pursuing several ways of strengthening these shells to render them suitable for the layering experiments which will require pressures greater than 100 atm.

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