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ABSTRACT

Plasma polymer coating of larger (1 mm or greater in diameter) Inertial Confinement Fusion (ICF) targets in a piezo electric based bounce pan results in surfaces which contain numerous domes of various sizes for coating thicknesses greater than about 3 µm. The density of domes increases with the size of the shells, number of shells coated at once, the strength of bouncing, and the coating thickness. The same problem is encountered when bounce coating large numbers of smaller Nova shells as well. The domes appear to grow from seeds produced by chips of the brittle plasma polymer coating itself produced in shell-to-shell collisions. A tilted spinning pan has been shown to produce smooth dome free coating while providing sufficient agitation to obtain uniform coatings.

I. INTRODUCTION

ICF target shells generally contain an ablator layer which is mainly a glow discharge polymer (GDP) film deposited by plasma polymeriazation.[1] The surface finish of the finished ICF targets must satisfy demanding specifications. Such specifications are normally provided by an ideal modal power spectrum.[2] For uniform deposition of the GDP layer, the spherical targets must be agitated during coating. A piezo electric driven bounce pan has been used extensively and with great success for this purpose on Nova size (440 µm diameter) shells.[1,3] In the our laboratory's production environment, coating a large number of shells at the same time is required in order to provide timely turn around on the requested targets. We have encountered a problem in using the piezo bouncing system when coating large numbers of various types of shells. Frequent collisions between the shells during the coating results in dome filled surface finishes for the shells and production of small beads during the coating. We report here on the correlation between the density of domes on the GDP surfaces and the number, size and agitation strength of shells in the piezo bouncing scheme. We also show that a tilted spinning pan is superior to the piezo bouncer for large scale production GDP coatings. This agitation scheme reduces the collisions between the shells and results in the improved surfaces for the finished targets. The origin of domes is also discussed.

II. EXPERIMENTAL

All mandrels used for the experiments were PAMS mandrels made by the droplet generator technique.[4] The plasma polymerization system based on a helical resonator and the piezo bouncer have been described elsewhere by other authors.[1,5] Our coaters are clones of such a system. These systems are routinely used for deposition of ablator layers for experiments at various ICF laboratories.[6] For the rotating pan agitation, a small DC motor capable of being operated in vacuum and in a plasma was fitted with a gear reduction head and was used to spin the coating pan at 0.2 to 3 Hz. The spinning pan was mounted with approximately a 15° tilt to vertical on a rod through a vacuum feedthrough to allow tapping the pan to dislodge stuck shells. The surface finish of the shells was examined optically and by Scanning Electron Microscopy SEM) and spheremapper atomic force microscope (AFM).

III. RESULTS

We have found very dome filled surfaces after GDP coating of pristine OMEGA size PAMS mandrels [Fig. 1(a)] when the shells are vigorously bounced in a piezo based bouncer. Coatings of 3 µm or less exhibit very

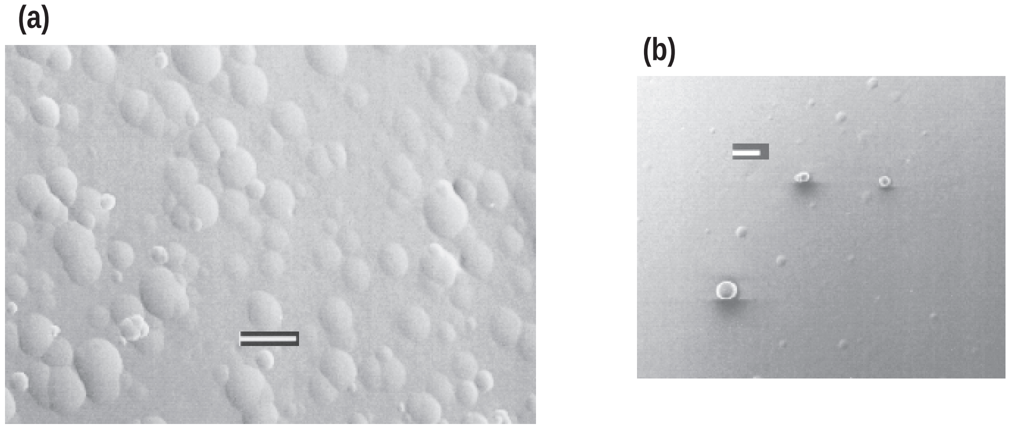

Fig. 1. (a) Scanning electrom microscope (SEM) image of the surface of a 12 µm coating of GDP on an OMEGA (900 µm) size PAMs mandrel. The surface contains numerous domes. This shell is one of 120 shells bounced coated together at once. The bouncing action was very vigorous in order to obtain a uniform GDP coating on the non-uniform PAMs mandrel. A bead can be seen near the lower right hand side of the image. (b) A side view of the surface of another shell exhibiting many domes on the surface. The presence of beads along with the domes is clearly seen in this view. The scale bars are 10 µm.The beads in (b) are about 10 µm tall.

few domes, while once the thickness is above 4 µm the surface becomes filled with domes. The density of domes increases as the thickness increases. In addition, spherical beads of about 10 µm diameter are usually seen attached to the shells [Fig. 1(b)]. The beads can be washed or knocked off the shells and are therefore not integrated into the coating. The background surface finish , however, is the usual 1 or less nm RMS.[5] The domes result in power increase in the modal spectrum of the shell as examined by the spheremapper AFM (Fig. 2). While the main contribution of the domes is to modes greater than 100, there is a significant increase in the power in modes 10–100. In particular, mode 100 power is almost one order of magnitude higher on the GDP coated shells. This enhancement of middle modes power can be very important for larger, 2 mm, National Ignition Facility (NIF) targets, and is believed to be critical for NIF target performance.

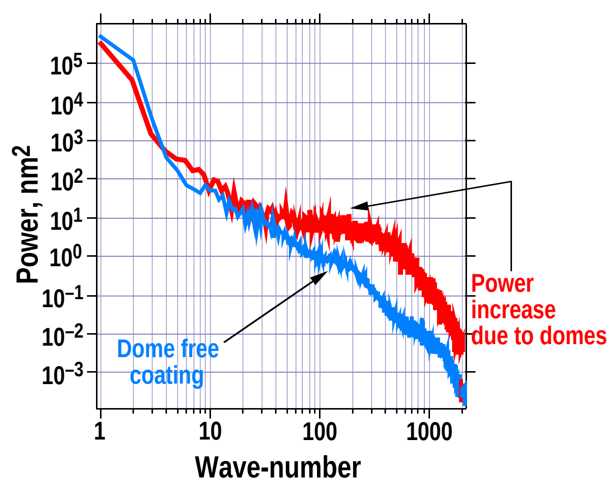

Fig. 2. Spheremapper AFM traces of OMEGA sized bare PAMS mandrels (thin line) and GDP coated PAMS mandrels (thick line). The density of domes on the GDP surface was similar to that in Fig. 1(a). Each trace is an average of two shells. The surface domes contribute to the modal spectrum mainly in the modes greater than 100, but they also result in significant power in the critical 10–100 mode range as well.

We set out to determine the cause of such poor surface finishes. These types of surface finishes were found in three different independent coating systems, with the problem occuring intermittently. Uncleanliness of the systems or feed gases is usually suspected when such surface finishes are encountered. All systems were carefully cleaned but the problem persisted. To examine possible cause of this problem, we performed a set of systematic experiments. We deposited about 10 µm of GDP on various substrates. The coated surfaces contained a large number of domes only when a large number of shells (100 or more) were coated together. Coatings on flats or on small number of shell were virtually dome free. The original PAMS mandrels were all chosen to have very clean surfaces. Thus, there appeared to be a correlation between the number of shells coated and the surface finish. The shells were bounced very vigorously in all of these runs in order to correct for the non-concentricity of the original PAMS mandrels. Gentle bouncing of a large number of shells was tried next. While the surface still contained numerous domes, the dome density was far lower than when the shells were bounced vigorously. In a number of the deposition runs a few shells were placed on stationary holder near the plasma tube away from the bounce pan. While the shells bounced in the pan had very poor surfaces, the coatings on the stationary shells were virtually dome free. Therefore, vigorous bouncing of large numbers of shells was creating seeds for domes observed on the surface.

Shells of different diameters were bounce coated both vigorously and gently in large and small batches in separate coating runs to further examine the process. Results simliar to coating of OMEGA shells were obtained with Nova size, NIF size and 1.6 mm diameter shells. If too many shells were coated together, the final surface contained many domes. The density of domes increased as the shells were bounced more vigorously. While the surface finish improved as the bouncing strength was reduced, the coatings became more and more non-uniform. It was not possible to coat a large number of shells and obtain a uniform coating free of domes. A sample of the results is shown in Fig. 3. The results for the spinning pan agitation mechanism is also shown for comparison and will be discussed later. For the same bouncing agitation, the difference for each size is the maximum number of shells, n-*max*, that can be coated together without having a dome filled finished surface. n-*max* becomes smaller as the diameter of the shells increases. In particular, it appears that n-*max* varies as the inverse of the fifth power the diameter. This rather steep dependence may be plausible when one considers that the frequency of shell to shell collisions rises rapidly as the diameter of the

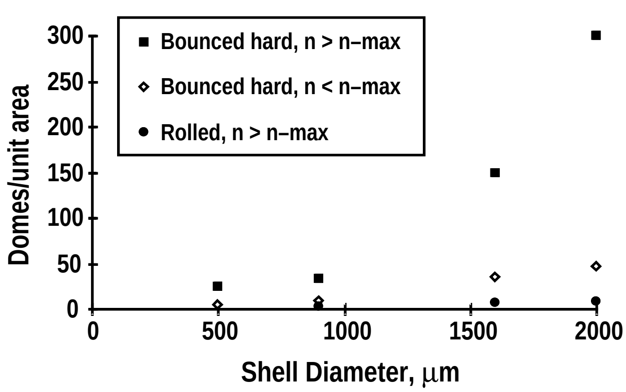

Fig. 3. Number of domes on the final GDP surface for bounce coating shells of different diameters to a nominal thickness of 12 µm. *n* is the number of shells bounced in the coating pan. n-*max* is the maximum number that can be vigourously bounced ("bounced hard") together while resulting in only a relatively small number of domes on the GDP surface. When the shells are rolled, a virtually dome free surface is obtained even when coating large numbers of shells together.

shells (and at the same time the mass of the shells) increases. As in case of OMEGA size shells, gentle bouncing improved the surface of all types of shells but the agitation was not enough for the larger shells. In particular, the coating on gently bounced NIF size shells is very non-uniform (non-concentricity = 25%).

IV. ALTERNATIVE BOUNCING TECHNIQUES

The problem of using a piezo based shaker to coat larger size PAMS shells has been encountered previouly by Saculla *et. al.*[7] A pan mounted on a swaying rod driven by a mechanical shaker had improved the surface finish in their case. We have found a dramatic reduction in the number of domes if the larger (OMEGA size and larger) shells are coated in a spinning tilted pan. A 15 tilt angle was enough to cause constant agitation of the shells without any sticking problems when the pan was spun at approximately 60 revolutions per minute (RPM). The spinning action of the pan keeps the shells agitated while reducing the probability of collisions between shells. The shells in effect keep chasing each other in this configuration instead of running into each other as in the piezo shaker setup. At the beginning of a given coating run, many shells usually stick to the pan and the tapper rod is used to knock these shells loose. After the shells receive a small amount of coating they roll freely without sticking. Figure 4 shows the reduction of the density of domes when this agitation mechanism is used as opposed to bounce coating shells rather vigorously. Twelve NIF size shells were coated in each case. The shells coated using the piezo bouncer agitation has a very dome filled surface, while those coated in the spinning pan were virtually dome free. With this agitation scheme we were able to coat over 100 OMEGA size shells with virtually dome free surface. The major concern in rolling agitation was the possible non-uniform coating of the shells due to insufficient agitation. We examined this by coating PAMS mandrels with very good average non-concentricity (NC) of less than 5%. The resulting GDP mandrels also had a NC of less than 5% indicating uniform coating of the mandrels in the rolling pan.

V. ORIGIN OF DOMES

The diameter of a dome is related to the coating thickness and the diameter of the seed particle.[1,8] The seeds result in cone like growths within the coating as the coating thickness increases. Because of the non-homogeneity in the size of the surface domes, either the seeds must be of different sizes or the seeds must have attached themselves to the shells at different times during the coating. SEM cross-sectional examination was used for examination of this type of growth. We chose highly

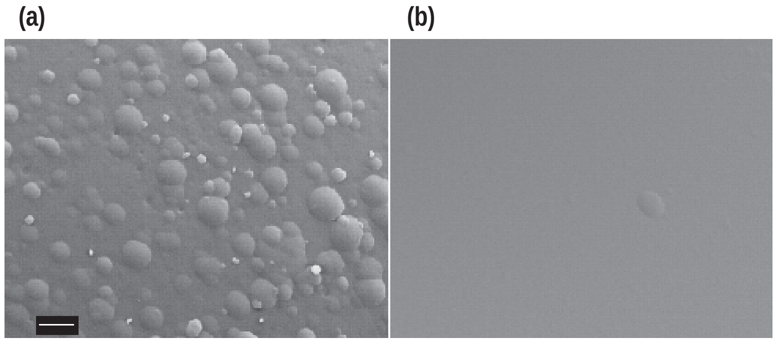

Fig. 4. (a) The surface of a 2 mm PAMs shell coated with 12 μm of GDP in a bounce pan. The surface is littered with domes. (b) A similar PAMs mandrel coated in the rolling pan with 12 μm of GDP. The surface is virtually dome free, while coating thickness was very uniform around the shell. 12 shells were coated together in each case.

dome filled surfaces of NIF sized shells to minimize the search for domes in the SEM. Figure 5 shows a cross-section of the such a shell. The predicted cone like growth of the domes is clearly visible. It is interesting to note that the origin of the domes is not at the inner surface, but rather is in general 2 to 3 μm above the inner the surface. This is consistent with the lack of domes on coating of 3 μm or less. Therefore, it appears that the seeds are produced by the abrasion of the GDP coating, and not the PAMS mandrels. This was further supported by vigorous bouncing of a large number of OMEGA size PAMS in a pan in the absence of any GDP. The surface of the shells did not deteriorate in the process. The chipping of the GDP coating and not the original PAMS in hard collisions between shells may result from an increase in brittleness of thicker coatings. Despite, this evidence more tests have to be done to verify this hypothesis for the origin of seeds for the domes.

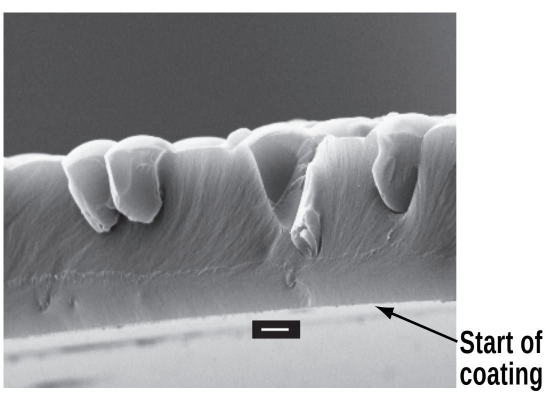

Fig. 5. SEM cross-section of an approximately 2 mm bounce coated GDP shell made by the depolymerizable technique. The cone-like growth of domes is easily apparent. However, it appears that none of the cones extends all the way to the start of the coating. The deepest cones seem to originate at a coating thickness of 2 to 3 μm. This is consistent with the observation that coatings thinner than ≈ 3 μm do not have dome filled surfaces.

VI. CONCLUSION

While the piezo bouncing system has been extremely successful in coating smaller Nova targets, it appears to have major limitations for coating 1 mm or larger shells. This is especially true in the production environment where larger numbers of shells have to be coated together. The larger diameters of the OMEGA and NIF targets result in increased collisions between the targets in the piezo bouncing scheme, leading to very dome-filled coatings. A tilted spinning pan has been shown to provide sufficient agitation of shells for uniform coatings, while producing virtually dome free surfaces.

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