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ABSTRACT

A new criterion for the identification of true impact sites by hypervelocity space particles on aluminized glass specimens is presented. The basic method of detection of these impact sites lies in the examination of post flight specimens for new perforations in the aluminum covering, and more specifically for damage or fracture of the glass substrate beneath the aluminum coating. It is shown that micron size iron particles impacting at 2-5 km/sec will fracture aluminum coated glass in a typically conchoidal pattern. While bearing in mind that the method is limited to examination of impacts by solid, structurally strong particles, this effect can serve as a criterion in the analysis of suspected hypervelocity space impacts. Absence of this fracture betrays the fact that the impacting particle lacked the structural strength, mass or velocity needed to fracture the glass.

INTRODUCTION

Numerous attempts have been made in recent years (1964-1967) to obtain impact signatures by high velocity and hypervelocity cosmic dust (Farlow, Blanchard and Ferry, 1966; Greenman, et al, 1966; Berg and Secretan 1967a). The reported number of different impact registration techniques equals almost the number of attempts. Each technique claims a certain degree of success although the results vary from no detectable impact signatures to a collection of impact signatures which denotes extremely high flux densities (Berg and Secretan 1967b ; Secretan, 1966; Secretan, Hemenway, Lipscott and Dubin, 1964; Gerloff, 1966).

A new impact registration technique has been developed for use in the Luster Project and for similar projects; it is believed to be unique and to offer a high degree of reliability. In each experiment the flight specimen substrate consists of glass plates or cylinders upon which a nearly pin hole free layer of aluminum has been evaporated.

Each aluminized plate specimen is examined for pin holes by a photographic method using custom designed film and specimen holders. In this operation, the opaque aluminum layer is separated from the film emulsion by a spacer 0.5 mm thick. The film is exposed to parallel light penetrating through defects in the aluminum layer. The developed film becomes a permanent pre-launch record of the location and magnitude of each pinhole or perforation having a diameter of 0.1 μ or greater. After flight, the specimen and the control are photographed again and are critically compared with the prelaunch records. The photographic method was suggested by O. E. Berg in his 1961 unpublished notes and developed by the authors while working on Gemini 9 specimen in 1966. The cylinders used on rockets were scanned with the optical scanner described by O. E. Berg at the "Meteor Orbits and Dust" Symposium, Aug. 1967.

Unfortunately, one cannot assume that all post-launch perforations are due to impacts by particles of space origin. Experiments in the laboratory have shown that perforations and flaws in the aluminum coating result from impurities imbedded in the film or in the glass surface. These flaws develop and grow in magnitude with passing time or repetitive vacuum pumping. Therefore, it becomes essential to incorporate into the experiment a criterion to establish a distinction between perforations produced by cosmic dust impacts and those due to extraneous effects. This criterion is found in the condition of the glass substrate at the point of impact.

The present observations are based on our experiments conducted with bare glass and quartz and with glass coated with vapor deposited aluminum. They show that aluminum layers of 3000 Å offer no great resistance to impacting micron size iron particles traveling at 2-5 km/sec and that each of these impacts produces a conchoidal fracture in the surface of the specimen (Figure 1). This effect can be adopted as a definite criterion in evaluating the origin of new perforations found in aluminum coated flight specimens.

PROCEDURE

The search and location of defects and fractures in the glass substrate of all our aluminized specimens has been accomplished by the same method. 1) After a pin hole has been detected in the coating of a specimen by comparing the negative contact photographs, the specimen is transferred to a metallograph equipped with a fiber optic spotlight located precisely above the microscope objective. 2) The pin hole is located by referring to the negatives and photographed for further identification at 1000x magnification. Figure 2a shows a crater in the aluminum coating. 3) The objective of the microscope is removed and replaced by a lensless dummy of the same shape and size, but equipped with a small rubber stamp "O". Ink is impressed on the "O" and by careful manipulation of the focusing knob, the specimen is marked so that the pin hole falls within the "O" circle. 4) A very small drop of saturated sodium hydroxide is laid on the aluminum within the circle and left to etch for about one minute. The specimen is then rinsed and dried with warm air. 5) The specimen is reset on the metallograph and the etched area is examined for defects in the glass. Figure 2b shows the corresponding deformation and fractures in the glass substrate after removal of the aluminum by etching.

For best image contrast the original magnification has been limited to 1000x, subject to further photographic amplification.

RESULTS

Experience gained in our previous work with aluminized glass plates and cylinders used as flight specimens, (Berg 1967, Berg and Secretan 1967) has shown that new perforations occurring during flight fall in three readily recognized categories.

Category 1 - Holes due to surface defects.

In this group the most prevalent defects are holes due to bursting or tearing of microscopic gas bubbles in the aluminum coating. They are readily recognized by their geometrical shapes and by typical tear lines formed between the flat surface and the dome shaped bubbles. Fig. 3a. Removal of the aluminum by etching generally reveals a typical flaw in the glass surface, or small dirt particles imbedded in the glass, Fig. 3b.

Next in frequency of occurrence are irregular holes due to microscopic dirt particles on the glass that prevent good adhesion, causing subsequent tearing and lifting of the metallic coating.

Less common are corrosion effects that can be due to moisture combining with some organic impurity on the glass. The new hole is surrounded by fringes, reminiscent of oil slicks, Fig. 4.

Category 2 - Holes caused by unidentified particles.

In category 2 are new holes located at the base of a foreign object embedded in the coating, showing no damage to the glass. Fig. 5. The object is detected by the fact that it has perforated the surface, causing a visible hole in the aluminum coating. Generally, the hole is partly covered by the particle and an estimation of the true hole size cannot be given. In all cases the only visible part of the hole is in the order of 1-2 micron.

The object embedded in the coating is conceivably of extraterrestrial origin but has not been identified as such and has some typical characteristics described now in detail: It is generally opaque, black and irregular in shape with some metallic luster and extends 10 to 20 microns from the surface as measured with the focusing micrometer of the microscope.

The impact site is mostly surrounded by a spray of very small particles, some of them too small to make a noticable indentation in the coating; others are sufficiently large to embed themselves in the aluminum layer without causing a visible perforation.

Catagory 3 - Holes associated with fractures in the glass.

Some hard hypervelocity space particles will penetrate the aluminum and fracture the glass substrate as described in the introduction. Figures 6a and 6b are of a Luster rocket flight plate before and after etch, showing a small fracture in the glass after etch. The coating was also 3000 Å; by comparison with Figure 2b it appears that the impact on the Luster plate was a high velocity impact but milder than that of Figure 2b.

The best techniques of collection have failed because of the identity or similarity of particles found on both control and flight plates (Fechtig, H., U. Gerloff, and J. H. Weihrauch (1968). Holes produced in films during flight, (Fechtig et al 1968) offer at best an ambiguous criterion for true space impacts. The control foils show holes quite similar to those found on the flight foils. The method of detecting impacts by searching for craters on polished metal plates (Hemenway 1967) fails for small particles because of the difficulty of scanning large areas at high magnification both before and after flight and cataloguing accurately all the surface irregularities. The criterion offered here is unambiguous and readily carried out. However, it is restricted to the identification of fast particles capable of fracturing glass on impact.

CONCLUSION

Suspected impact sites caused by hypervelocity space particles on metal coated glass specimens can be identified by etching the metal at the impact point prior to an examination of the substrate. A fracture of the glass substrate beneath the suspected impact point is definite proof of a high velocity impact and therefore not contamination. If the glass shows no fracture at the site, the impact could have been caused by a low velocity event or conceivably be due to a fragile or low density particle. The effects of projectiles which are non-compact, fragile or low density particles, have not yet been experimentally determined.

DISCUSSION

The statement "The fracture in the glass is definite proof of a high velocity impact" is questioned.

Defects due to impurities in the glass have been reviewed as a cause of post flight holes. Defects due to chattering by polishing tools are more difficult to identify; the area cleared by etching the spot under investigation should be scanned carefully for local defects before a judgement is passed on the nature of the suspected defect or fracture. For instance, in our search for impacts on our "Luster" plates, a case presented itself where the glass had defective areas near the suspected impact point. The case was invalidated on this ground.

FIGURE CAPTIONS

Figure 1 Simulated micrometeoroid impact on bare glass. Projectile was iron particle, 1-micron in diameter, accelerated to 2-5 km/sec. Original magnification 1000x, enlarged 4x.

Figure 2a Simulated micrometeoroid impact on 3000 Å aluminum coating on glass. 1 micron diameter iron particle accelerated to 2-5 km/sec. Original magnification 1000x enlarged 2x. Note faint distortion pattern around crater.

Figure 2b The same as 2a, after aluminum was etched away. Conchoidal fracture surrounds the central crater depression. Original magnification 1000x, enlarged 2x.

Figure 3a Defect in aluminum coating on glass flight specimen after flight. Light from behind shines through semi-circular opening, revealing the presence of a defect, 1000x magnification.

Figure 3b After etch the cleared area reveals an impurity included in the glass. The mottled area is incompletely removed aluminum. 1000x magnification.

Figure 4 Recovered flight specimen. One of very many corrosion spots found on a group of flight specimens. Coating consisted of aluminum alternating with copper evaporated on glass. Corrosion progresses along faint scratches. Original magnification 500x enlarged 2x.

Figure 5 Recovered flight specimen. Odd looking particle imbedded in the aluminum coating and standing 10-20 microns away from surface. The crater formation at the point of impact is partly hidden. Light appears around center of crater. Original magnification 500x enlarged 4x.

Figure 6a Large spray of submicron particles surround a large one. Light shines through perforation in the aluminum coating, original magnification. 1000x enlarged 4x.

Figure 6b The same specimen after the aluminum has been etched away. Small indent is left in the glass making it a probable space impact, original magnification 1000x enlarged 4x.

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