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THIN FILM PENETRATION BY HYPERVELOCITY MICROPARTICLES

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16. Abstract

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SUMMARY

Carbonyl iron microparticles were accelerated electrostatically to velocities up to 25 km/s. Particles with selected velocities were impacted on thin parylene films mounted on 100-mesh electron microscope grids. The ratio of average hole-diameter to average particle-diameter increases from 1 to 7 as the velocity increases from 2 to 20 km/s. Particles whose diameters are greater than the film thickness punch a hole through the film whereas particles whose diameters are less than the film thickness break up during the impact interaction and thus enlarge the hole diameter beyond the particle diameter.

INTRODUCTION

A number of micrometeoroid detectors depend upon the interaction of the impacting micrometeoroid with a thin film. For example, Goddard Space Flight Center has developed a thin film telescope* detector which has been successfully flown on a number of probes and satellites (ref. 1). This unit determines particle velocity by time-of-flight measurements between two thin-film arrays (Figure 1). The ionization produced by a particle penetrating the thin films is measured and also serves to initiate the "start" and "stop" pulses for the time-of-flight determination. The amount of ionization is indicative of the particle energy and composition but the quantitative relationship is, as yet, not fully known.

To gain a better quantitative understanding of the interaction we have impacted thin films (0.2 μm thick) of parylene with carbonyl iron spherules of known masses and velocities.

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*The telescope detector consists essentially of a velocity measuring component and a momentum (or energy) sensitive component. These are usually mounted in a tube such that the direction of the impacting micrometeoroid can be determined and that the micrometeoroid penetrates the velocity-measuring component prior to impact on the momentum (or energy) sensor. Time-coincident output pulses are generally required from both sensors for an event to be considered a true impact as opposed to accidental or noise output pulses. The term 'telescope detector' is used in analogy to two-component nuclear particle detectors which perform similar measuring functions for nuclear particles.

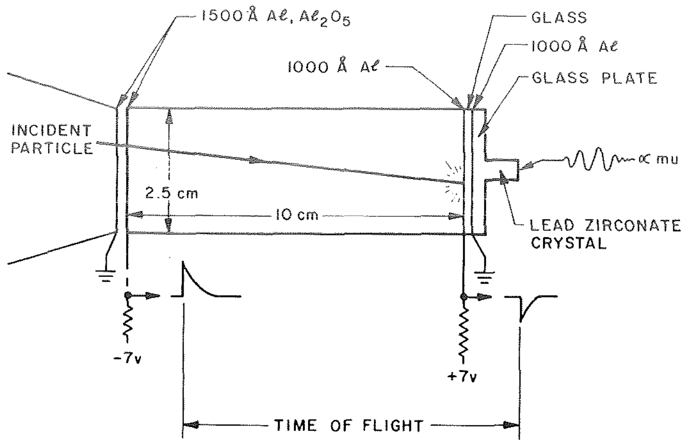

Figure 1.- Micrometeroid detector developed by Goddard Space Flight Center

Although these initial data do not yield definitive results, they are interesting nonetheless in that they demonstrate some quantitative relationships and indicate the directions in which future work should proceed.

EXPERIMENT

Carbonyl iron spherules (Figure 2), with velocities up to 25 km/s, were impacted on thin plastic films. Acceleration to hypervelocities was accomplished electrostatically, using a 150-kv ion accelerator converted to microparticle acceleration (ref. 2). The performance of the accelerator is shown in Figure 3 where particle velocity is plotted as a function of particle size. Particle masses and velocities were selected and measured using the system described in reference 2.

Discs of parylene (TM - Union Carbide), 3 mm diameter, were punched from a 3-inch diameter, 0.2 μm thick sheet of material. The discs were glued to a 100-mesh electron microscope grid, which was placed in a standard Hitachi electron microscope grid holder. The film was then examined with a transmission electron microscope for holes, cracks, and excessive glue. Grids with acceptable films were removed from the electron microscope still attached to the holder and mounted in the accelerator target chamber. This procedure assured that the parylene films were never touched after being inspected in the electron microscope. Double thin films of parylene were made by gluing discs to both sides of the electron microscope grid.

The films were impacted by microparticles in a selected velocity range. During bombardment, the velocities and masses of the impacting particles were measured. After bombardment, the film and holder were removed from the target chamber and reexamined, using the transmission electron microscope. The number of holes in the film and their sizes were recorded.

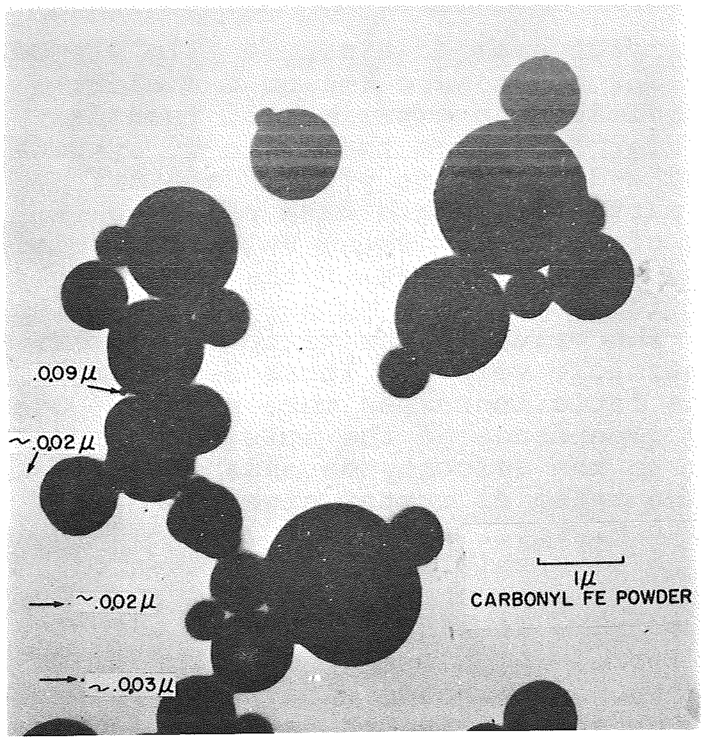

Figure 2.- Electron photo-micrograph of carbonyl iron powder

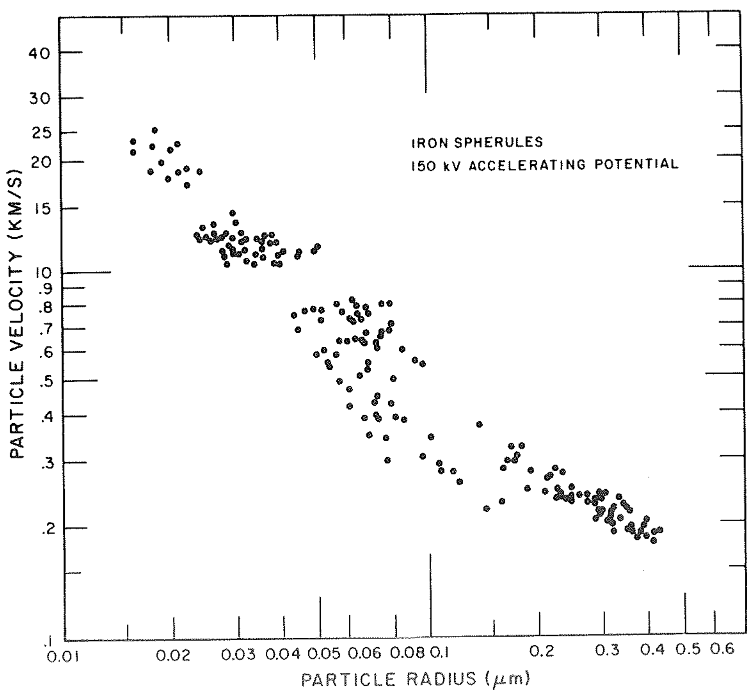

Figure 3.- Microparticle velocity as a function of particle size

RESULTS

Figure 4 shows a typical impact area on a single film viewed with the electron microscope. The holes were (∿1 μm diameter) are caused by large, slow particles. The experimental results are summarized graphically in Figure 5 where the ratio of average hole-diameter to average particle-diameter is plotted against the velocity of the impacting particles. Each data point represents punctures by a number of particles whose velocity range is given by the horizontal bar. Uncertainties in the value of the ratio are given by the vertical bar. The number of particles used is given for each point. The value of the ratio increases from 1 to 6 as the impacting particle velocity increases from 2 to 10 km/s; above 10 km/s the ratio increases more slowly. One should note that this velocity dependence of the hole size to particle size ratio is similar to the velocity dependence found by Auer, et al. (ref. 3) for the ratio of crater size to the particle size when hypervelocity microparticles are impacted on a semi-infinite target. Auer's relationship is also represented in Figure 5. Since his microcrater data extends only up to 10 km/s it is not possible to compare it with our higher velocity puncture data which exhibit a decreasing slope of the curve. It would be interesting to extend the microcrater data to investigate if a similar "flattening out" characteristic can be observed.

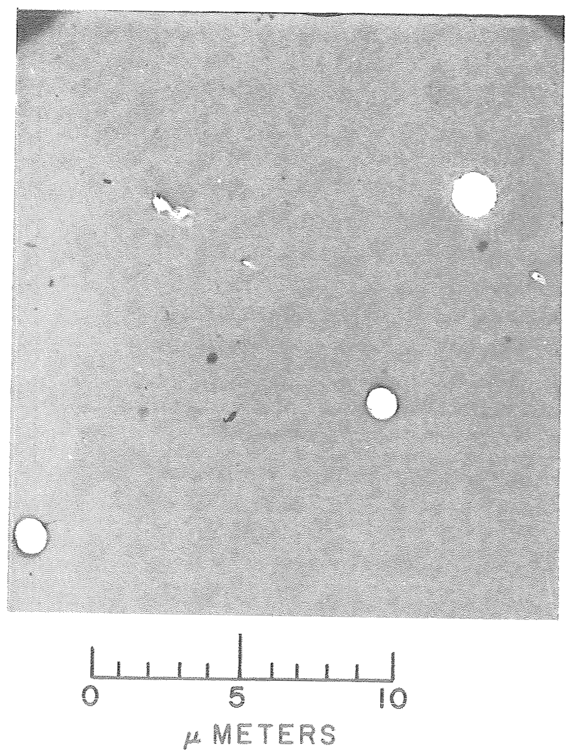

Figure 4.- Typical impact area on a single thin film showing penetration

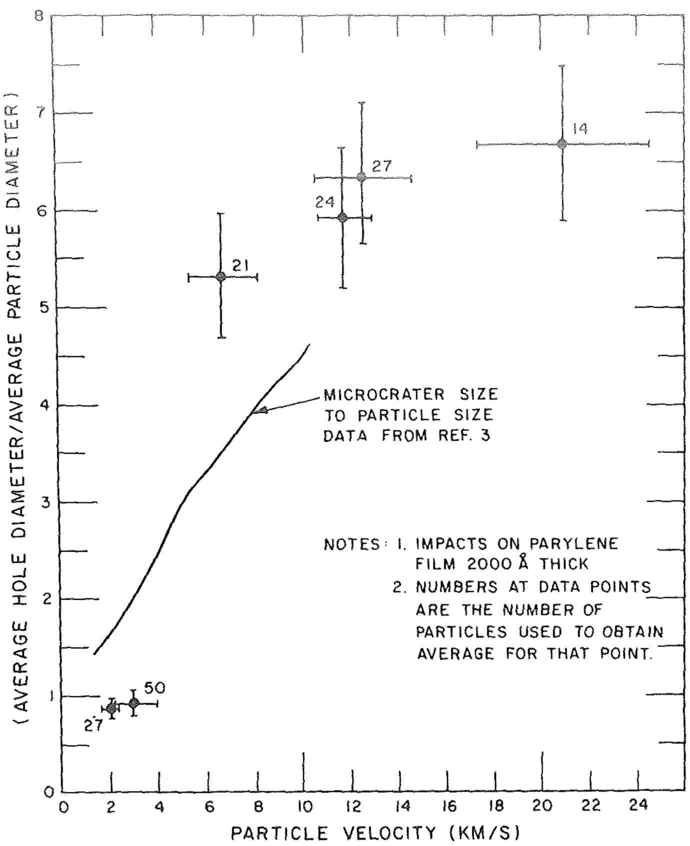

Figure 5.- Hole size - particle size ratio as a function of particle size

Another presentation of the puncture data is given in Figure 6 where the ratio of average hole-diameter to average particle-diameter is plotted against the average particle-diameter. The number of particles and the minimum, median, and maximum velocities of these particles are shown for each data point. Bars are not used to avoid cluttering the presentation.

At lower velocities the particle diameters exceed the film thickness, whereas at the high velocities the particle diameters are less than the film thickness. Figure 7 shows punctures of a double film, mounted at a slight angle to the beam, made by one large (0.5 μm diameter) and several small (0.25 μm and ∿0.1 μm diameter) hypervelocity particles. The large projectile (upper right-hand corner) passed cleanly through both films giving up little kinetic energy on doing so; an indication of this is the similarity in size of the two holes. The smaller particles broke up in the first film expending all their kinetic energy doing so. Debris of this break up can be seen on the second film. This mechanism explains qualitatively why the hole-diameter/particle-diameter ratio increases so rapidly when the particle size approaches the film thickness. This disintegration has also been reported by Auer, et al. (ref. 3) using 0.8 μm Fe projectiles on 0.8 μm Al foil.

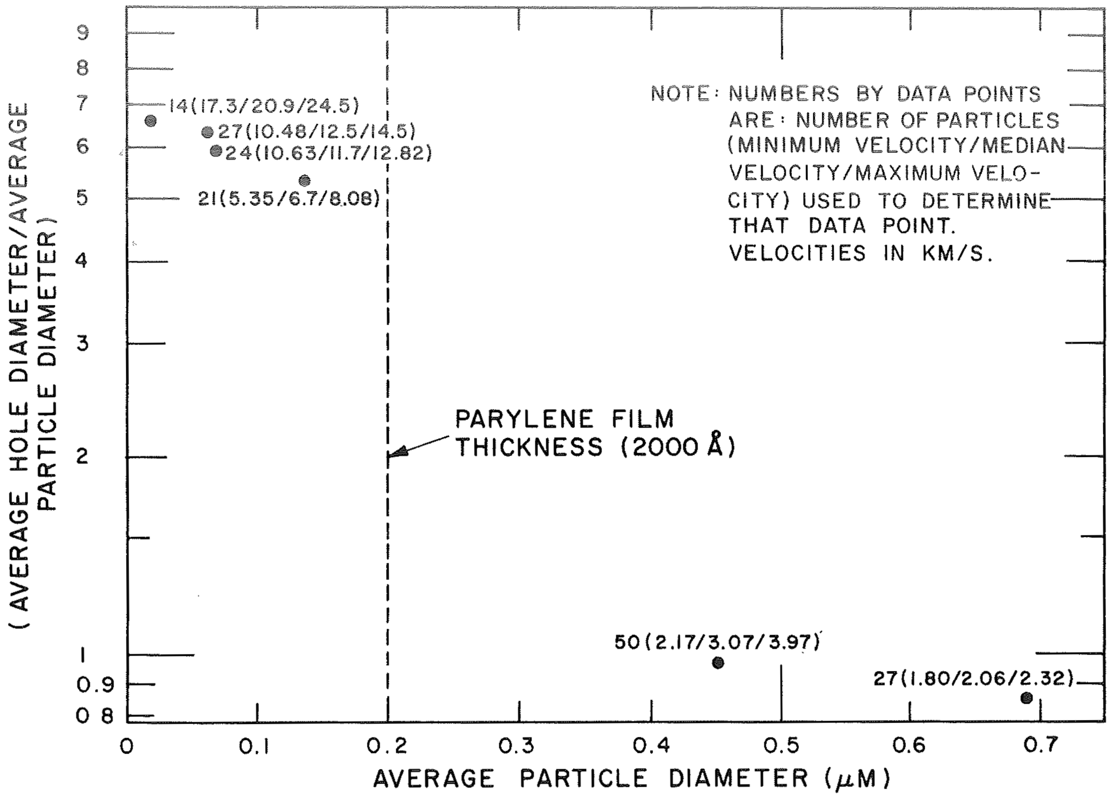

Figure 6.- Hole size - particle size ratio as a function of particle size

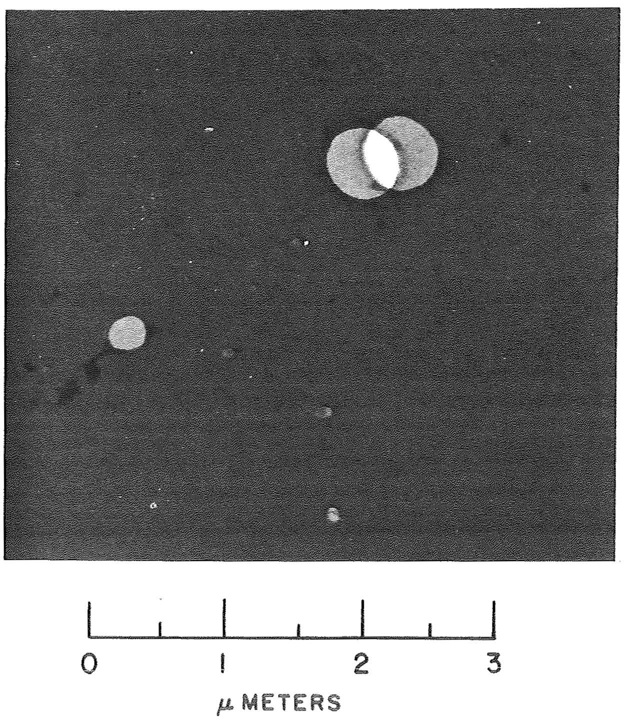

Figure 7.- Double thin film showing penetration by large and small particles

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