Nuclear Particle Detection Using a Track-Recording Solid

by
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Abstract

This paper details the design of the nuclear particle detector located in Purdue University's "Get Away Special" package which was flown aboard STS-7 in June, 1983. The experiment consisted of a stack of particle-detecting polymer sheets. The sheets show positive results of tracks throughout the block. A slide of each sheet has been made for further analysis. Recommendations for similiar experiments performed in the future are discussed.

1. Introduction

This experiment was one of three that were chosen to ride in Purdue's 2.5 cubic foot canister. The original proposal was suggested by Christopher Wachs, a student at Purdue. The other two experiments were to study the effect of gravity on seed germination and to film the motion of mercury in a clear liquid under low gravity. Electrical and mechanical malfunctions prevented the proper operation of these experiments. The radiation experiment was divided into two parts: radiation badges and the main detector. The badges were used to give a rough reading to back up data from the main detector. The main detector itself was designed to record the passing of particles in the atmosphere. Being entirely passive, it was not effected by the other malfunctions.

2. Film Badges

Film badges are used in nuclear related industries to keep track of exposure to personel. They are differentiated from each other by the type of radiation and energy range that they are sensitive to. Two types of badges were included in the canister. The badges chosen were the types T1 and B1 from the R. S. Landauer company. These can detect neutron, x-ray, gamma, and beta doses. Two of each type were obtained from the Bionuclear Department of Purdue University, one being a control and the other placed in the canister. They were returned to the Bionuclear Department to be processed normally.

The badges do indicate that higher than normal radiation levels were present which is to be expected. The energy deposited appeared mainly as gamma and x-ray radiation along with traces of beta and fast neutron radiation. One of the badges also gave a "high energy" indication. Both badges indicate a general dose to the experiment of twenty millirems which is thought to be a realistic value. Since the detector material is not directly sensitive to the radiation indicated by the badges, it has not been determined whether there are any concurrent conclusions to be drawn.

3. Main Detector

In recent years, dielectric solid particle detectors have become a viable alternative to older, conventional methods for the detection and measurement of radiation. Charged particles passing through the detector material leave a path of damage on the molecular scale. If the detector is plastic in nature, it can then be etched in a caustic solution which preferentially attacks the damaged spots rendering them visible under an ordinary light microscope. If the material is an emulsion, it can be developed in a method similiar to that done for ordinary camera film also yielding a track that can be studied.

The original experiment idea used a silver halide emulsion, which when processed into thin sheets (called pellicles) of the proper dimensions, would be stacked and used as the detection block. As charged particles pass through the material, they would be activated similiar to camera film and could be developed to show the tracks. The manufacture of the emulsion pellicles and the developing thereafter is a timely and complicated process. This, along with its sensitivity to light and high mechanical pressure, and a need for a well controlled atmosphere, made the emulsion an impractical choice for a detector material.

As the experiment developed, it became evident that polymers would be a much better choice for a detector material. Two were singled out as being alternatives: cellulose nitrate and allyl diglycol polycarbonate (trademark by Pittsburgh Plate Glass as CR39). After some investigation, it was found that in addition to greater sensitivity and better physical characteristics, CR39 was cheaper and could be purchased in the amount needed. The cellulose nitrate material sold by Kodak was sufficient for experimental requirements but could not be purchased in the quantity desired. A sample of CR39 was acquired and tested by exposing it to an alpha source. Upon etching in a solution of sodium hydroxide and noting positive results, it was decided to go with the CR39 monomer.

In addition to the plastic, a boron converter was added in order to detect neutrons through secondary emissions of alpha particles. Alphas are the result of neutron capture in a boron nucleus. This was made by mixing boron oxide with polyeurethane wood finish and then "painting" it on a two inch by three inch piece of paper. After drying, it was placed on the stack of detector material.

The monomer was received in sheets of .025 inch in thickness. It was then cut to two inch by three inch rectangles by scribing and breaking it in a manner similiar to that used for glass. The box was cut from sheet aluminum (four sides, top and bottom) so as to give inside dimensions of two inches by three inches by two inches. (See figure 1.) A flange used to secure the box was machined as an integral part of the bottom plate. It was held together with brass metal screws and tapped holes. Each of the seventy-five sheets were engraved with a number and placed into the box along with the previously mentioned boron converter and then bolted onto the canister base.

4. Development

Upon receiving the canister from NASA after the flight, the box was unbolted and stored until the fall school session. At this time the sheets were removed from the box. A Teflon rack was made to hold the sheets during etching. Forty sheets at a time were etched in a 6.25 normal solution of sodium hydroxide kept at approximately fifty degrees celsius by a hot plate. To etch all the sheets the process was carried out twice. Each time two control sheets were included in the solution. The total etching time was eleven days for each group. During this time the solution was stirred daily. Upon completion of the etching, the plastic was visibly spotted with what appeared to be pits. The sheets were rinsed and then dried.

5. Results

A visual inspection of the sheets has varified that the experiment did detect particles. The particles are revealed by conical pits in the surface of the plastic. (see figure 2.) The shape of the surface pattern can be used to determine the angle at which the particle entered the plastic. Some of the particles left only a single pit. Others left a

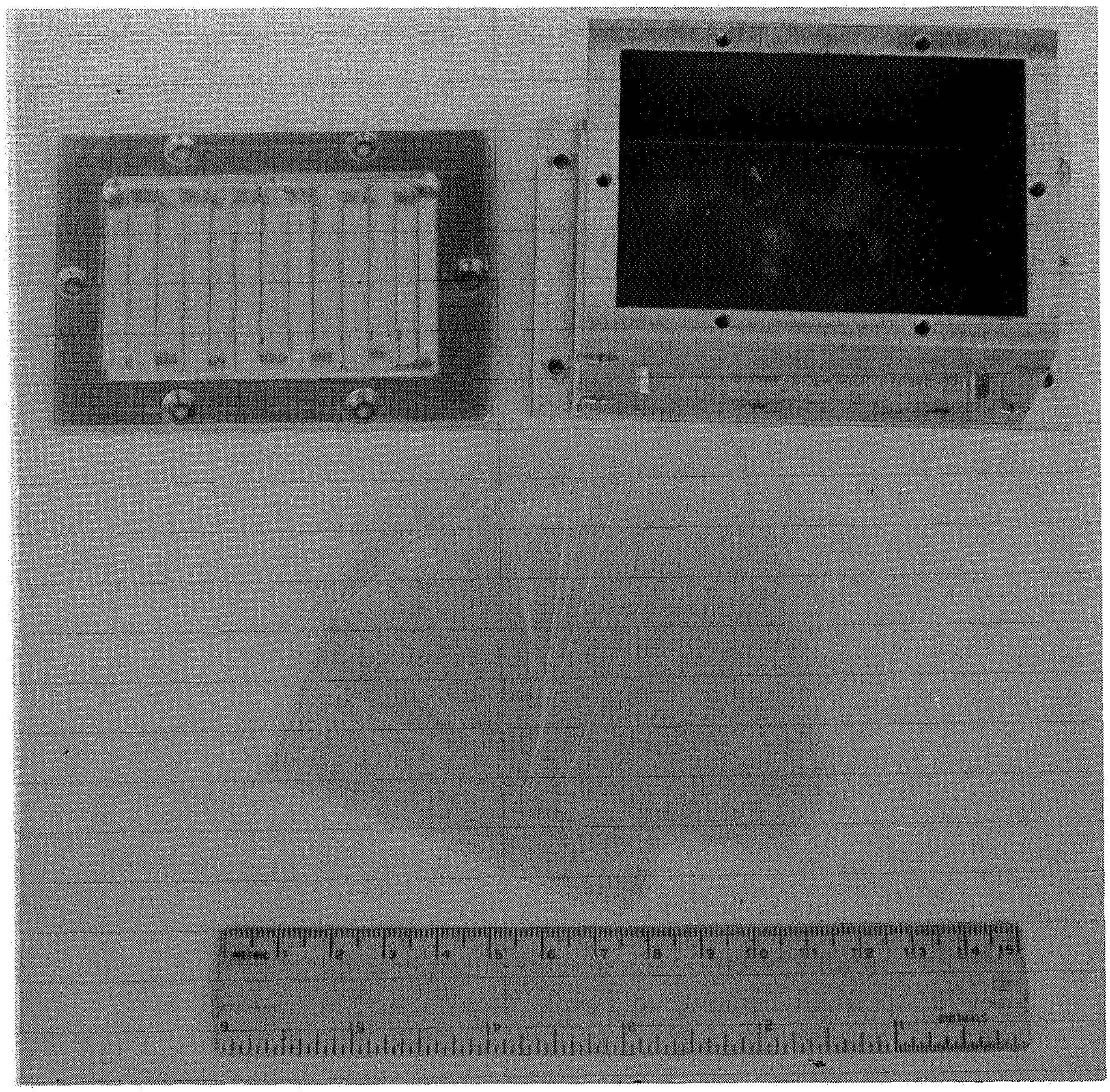

Fig. 1. The components of the main detector of the radiation experiment. Shown are the container (upper right), its lid (upper left), and the sheets of CR39 plastic.

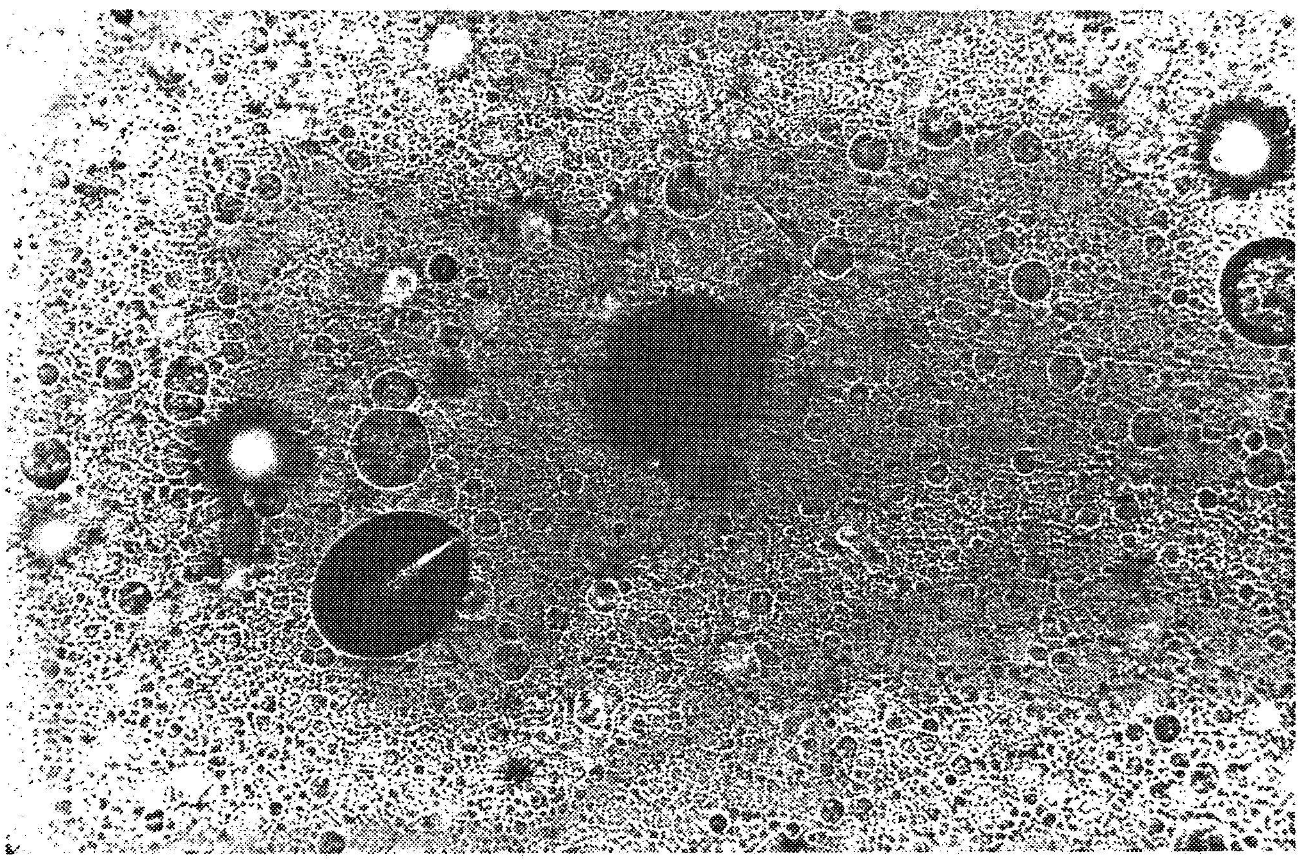

Fig. 2. An enlargement (20X) of a portion of the top sheet of plastic (the one next to the boron impregnated paper), showing the conical entrance hole of a particle. The blurred exit hole is also visible.

pair of cones in the sheet. This indicates where the particle entered the top of the sheet and then exited at the bottom. The longest of these tracks left pairs of cones through the top twelve sheets. However, most of the tracks are only single pits or in two or three sheets. It is interesting to note that some of the tracks start and end in the middle of the block.

The analysis of the sheets has been complicated by pits caused by the etching that are not particle tracks. These are easily distinguished since the pits are rounded as opposed to the pointed track pits. However, this requires that each pit be looked at to determine if it is a track rather than just counting the particles on the surface of each sheet. A count of the particles on the sheet next to the boron is about fifteen to twenty. The middle sheets are less dense than the boron coated end.

6. Future Plans and Recommendations

The results of the experiment are not obvious at first glance and an intensive catalog of all tracks needs to be made. This is a major activity and will take some time and effort. This will enable identification of particle types and energies. Also track direction relative to the shuttle and radiation planes in space will be determined.

Experience with this experiment has brought out some methods that should be used in any similiar experiments. The sheets should have an index of some sort that will allow the tracks to be accurately realigned after development. Products that reduce the amount of irrelevant surface pitting should be used to ease counting of the tracks. A small computer could be used to speed the numerical calculations and keep a catalog of the tracks. If the expense is not prohibitive, another detector such as cellulose nitrate would be used to verify data from the CR39 sheets.

7. Acknowledgements

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