Charge Retention in Polymethyl Methacrylate Cubes

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Purpose

The purpose of this work is to conduct fundamental research which explores the properties and behaviors of electron-irradiated polymers. In this study, 2-inch polymethyl methacrylate (PMMA) cubes are irradiated with an electron beam, and the polymer's ability to store the loaded charge at room temperature is measured. At room temperature, the cubes slowly lose their charge over time, so this research project aims to visualize how the charge density changes over time and find a curve fit which models this phenomenon.

Charging PMMA

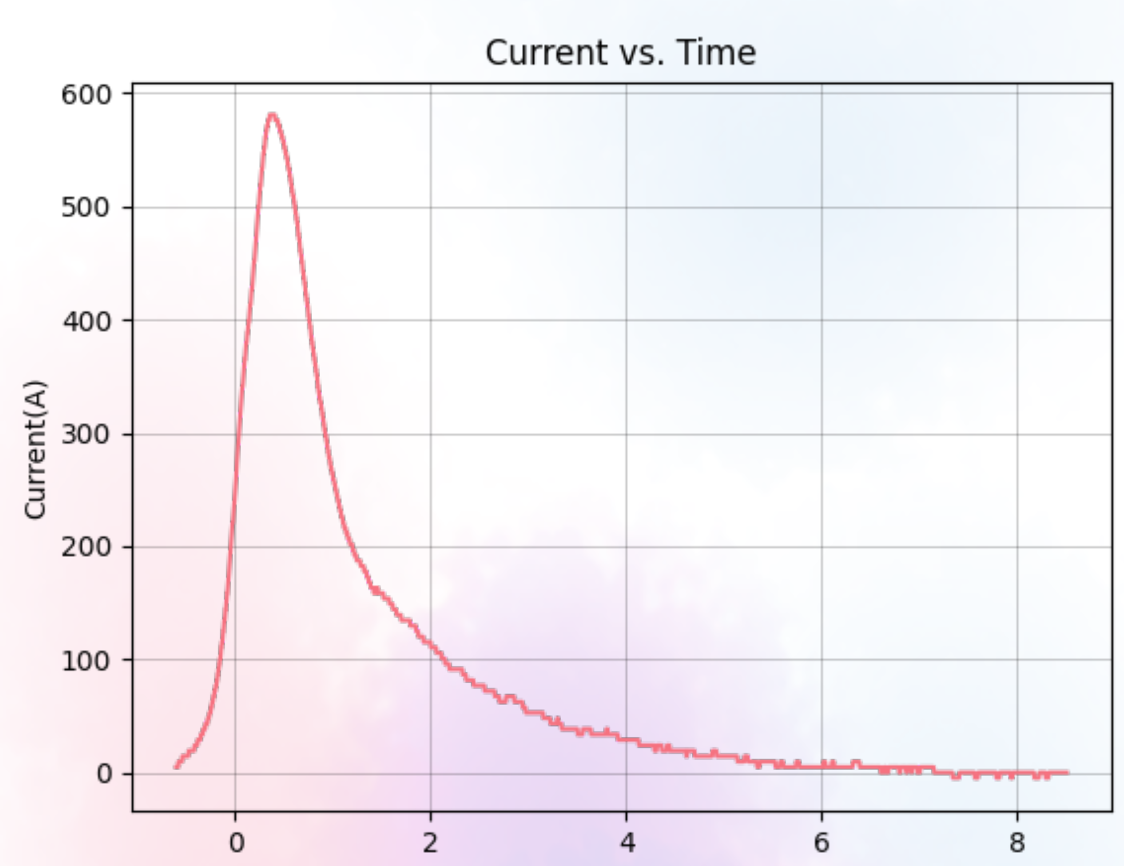
2-inch PMMA cubes were placed 60cm in front of a ~5MeV electron beam produced by an electron linear accelerator (linac). The electrons bury themselves within the cube on a single face, but do not penetrate more than a couple of centimeters due to the density and insulating properties of the material.

Measuring a Discharge

After the cubes were charged, they were quickly placed in the low-inductance discharge fixture (Figure 1). After a predetermined amount of time, a sharp, metallic rod was propelled into the cube with a hammer, acting as the mechanical means of discharge. The current transformer measured the current produced by the discharge and is captured by the oscilloscope. The data was exported for further analysis, where the current waveform from the oscilloscope was transformed in a voltage waveform. The area under the curve of the current waveform was integrated to determine the amount of charge alleviated from the cube during the discharge.

Figure 1

The figure shows the change in current over time once the cube has been discharged, as measured by the oscilloscope.



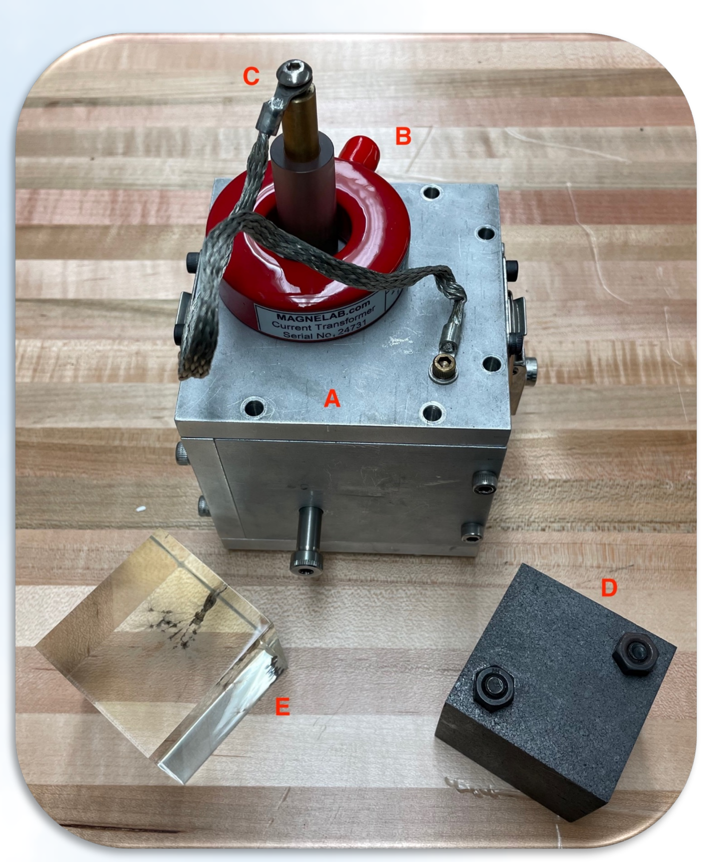


Figure 2

The technical set up for the experiment.
A – Low-inductance discharge fixture
B – Current transformer
C – Punch
D – Graphite cube
E – PMMA cube post discharge

Results

The calculated charge released through each discharge was averaged with the other values that were discharged at the same elapsed time. The averages for each group were plotted as a function of their discharge time (Figure 3) and fit with multiple functions. Through preliminary results, a power law dependance of

$$f(x) = 3.2\times10^{-5}\, x^{-0.27}$$

This was unexpected, as a power law has non-physical behavior at t=0 in this context. The Chi-Square test was applied to assess the goodness of this fit, with parameters set to minimize the χ^2 value, calculated with the equation below:

$$\chi^2 = \sum (O_i - E_i)^2/E_i$$

With a p-value of 0.984 for this χ^2 value, it is possible that the errors are overestimated, thus leading to a fit that is not truly representative of all the data.

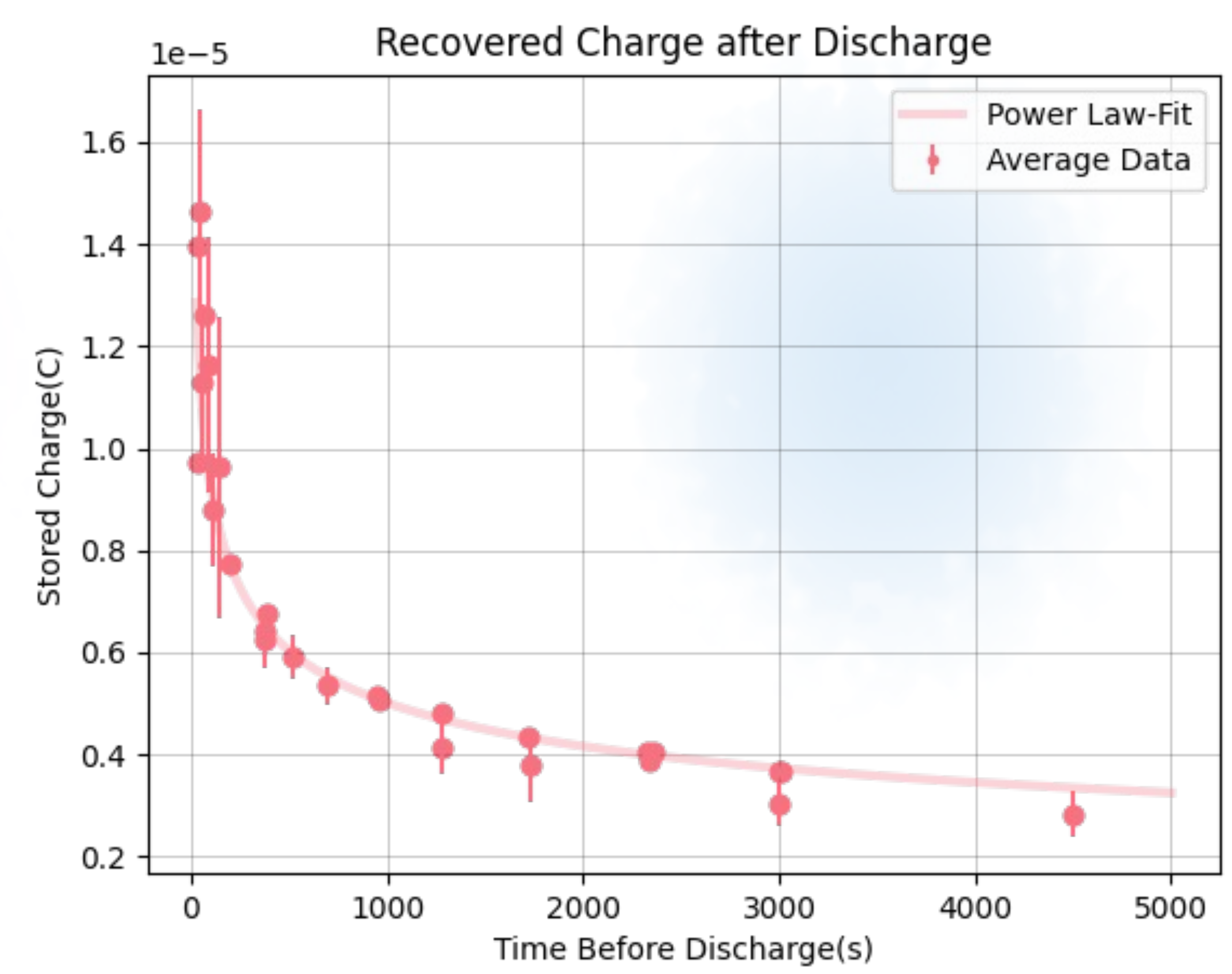


Figure 3

The data points are averages of the alleviated charge for each consistent time grouping, demonstrating the ability of PMMA to hold charge at room temperature.

Future Work

More rigorous analysis of the current data is needed. Further, testing different types of plastics, including different manufacturers of PMMA, annealing PMMA, and testing the correlation between internal stress and the capacity of charge within each cube are current plans for advancing the charge storage capacity of PMMA.

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