Reconstruction of Low-Energy β Rays in Nuclear Emulsion

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Introduction

Nuclear emulsion is a three-dimensional tracking detector with extremely high spatial resolution for all charged particles. This unique spatial resolution has led to numerous scientific achievements over the years. In recent years, there has been a growing demand for experimental studies using low-energy β rays (on the order of MeV) recorded in nuclear emulsions, including applications such as neutrino less double beta decay searches [1], radiation analysis of rocks [2], and effectiveness evaluations in proton therapy [3]. However, no established method exists to automatically detect and reconstruct the curved tracks of such low-energy β rays. This has remained a significant challenge across these research areas.

Experimental Procedures

We developed an analysis program based on the following procedure:

1. Smooth the images to reduce noise.
2. Remove dense tracks such as those from α particles.
3. Cluster the remaining hit pixels to identify silver grains and determine their coordinates.
4. Connect nearby silver grains step by step based on angular and distance thresholds to form short segments.
5. Further connect these segments across longer distances, again using angular and distance thresholds, to reconstruct entire tracks.

Tomographic images of nuclear emulsions exposed to β rays emitted from Sr-90 were acquired at 0.5μm intervals using an optical microscope. β-ray tracks were first identified manually through visual inspection. Using the visually identified β-ray tracks, the developed program was tested under three conditions: (1) ideal data with no noise, (2) data with randomly distributed noise, and (3) actual tomographic image data. The performance of the program was evaluated by assessing whether it could successfully detect β rays automatically under each condition.

Results and Discussion

The program successfully reconstructed β-ray tracks under several different conditions. In addition, issues encountered during the reconstruction process were also identified and analyzed.

We have developed a program capable of automatically detecting and reconstructing β rays, for which demand has been increasing in recent years. However, several challenges remain. These include insufficient identification of silver grains, as well as computational divergence or reconstruction failure depending on the input data characteristics. Future work will focus on improving the analysis program to address these issues—specifically enhancing the accuracy of silver grain identification and optimizing the reconstruction process to reduce computational load. This will enable more precise and reliable β-ray analysis.

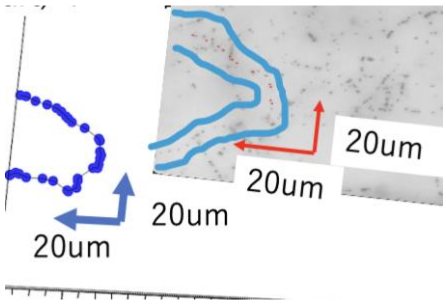

Fig. 1. Beta rays in the reconstructed nuclear emulsion.

References

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