PROCEEDINGS OF SCIENCE

Development of Large Crystal Size Nuclear Emulsion for Cosmic-ray Radiography

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Nuclear emulsion is a kind of photographic film and has sensitivity for ionizing radiation. The film record tracks of charged particle with angular accuracy under several mrad. We are developing nuclear emulsion with crystal size larger than conventional 200 nm one. Large crystal size nuclear emulsion has a potential of high sensitivity and contrast, so it is hopeful as future cosmic-ray radiography detector. We succeeded in producing emulsion gels which have silver bromide crystal with diameter 200, 350, 450 and 800 nm using emulsion gel manufacturing equipment in Nagoya University. After applying optimum sensitization and development processing to each crystal size, sensitivity (G.D) and noise (F.D) ware as follows.

200 nm : G.D = 33.6 ± 2.6 FD = 1.1 ± 0.2
350 nm : G.D = 42.0 ± 2.9 FD = 0.9 ± 0.2
450 nm : G.D = 46.6 ± 3.1 FD = 0.5 ± 0.1
800 nm : G.D = (34.1 ± 3.8) FD = 0.7 ± 0.2

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1. Introduction

Cosmic ray radiography is the a new non-destructive inspection technique of large-scale constructions with cosmic ray muon. Cosmic ray muon has high penetrating power and it always comes from the whole sky. In the same way of taking a X-ray photograph, we can obtain integrated density of constructions which thickness are several tens to several hundreds. We had ever applied this technique to pyramids, nuclear reactors, volcanos, and so on [1] [2]. In these observations, we used nuclear emulsion as a detector. Nuclear emulsion is a kind of photographic film and has sensitivity for ionizing radiation. The film record tracks of charged particle with angular accuracy under several mrad. Nuclear emulsion is made by coating emulsion gel on plastic base. We put the emulsion gel production machine into operation in 2010 at Nagoya University. It was enable us to develop new-type emulsion gel by ourself. Emulsion gel is mainly consisted by silver bromide crystal and gelatin. We report about properties of Large Crystal Size Nuclear Emulsion developed in Nagoya University.

2. Large Crystal Size Nuclear Emulsion

We developed a Large Crystal Nuclear Emulsion for the purpose of improving sensitivity, contrast, and long-term characteristics. Emulsion gel manufacturing equipment in Nagoya University was used to produce the new-type emulsion gel. We have succeeded in producing nuclear emulsion with the diameter of silver bromide crystals at 350, 450, 800 nm, in addition to the conventional 200 nm one. Electron microscopic image of the silver bromide crystal are shown in Figure 1.

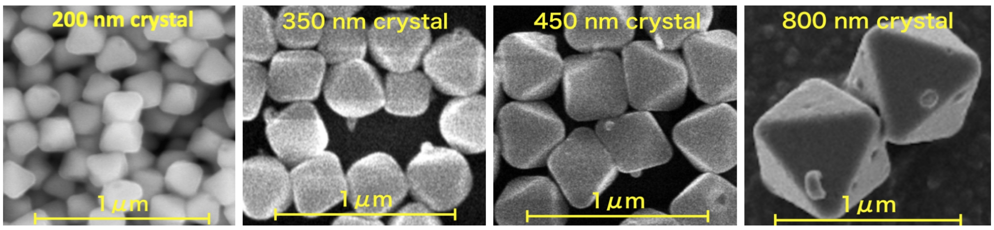

Fig.1 Electron microscopic image of the conventional 200 nm silver bromide crystal and new-type 350, 450, 800 nm crystal (SEM image).

3. Sensitivity and Noise

Optimum gold-sulfur sensitization was performed to each crystal size [3]. For the developing solution, XAA developer (FUJI FILM Co. Ltd.) was used. pH of the developing solution was optimally adjusted to each crystal size. Figure 2 shows the optical microscopic image of minimum ionized particle tracks. Table 1 shows the evaluation results of sensitivity (Grain Density) and noise (Fog Density). The volume occupancy of silver bromide was 30 %.

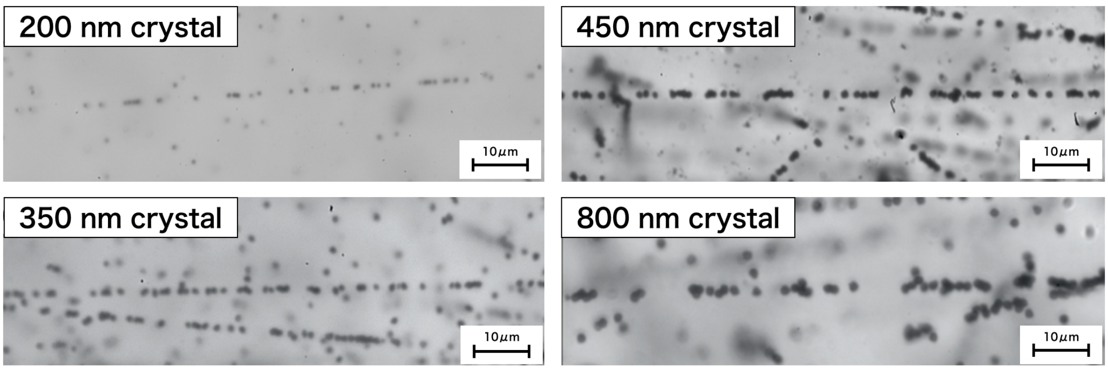

Fig.2 Optical microscopic image of minimum ionized particle tracks. The larger the silver bromide crystals, the higher the contrast.

Crystal Size (nm)	200	350	450	800
Grain Density (/100μm)	33.6 ± 2.6	42.0 ± 2.9	46.6 ± 3.1	(34.1 ± 3.8)
Number of Crystal (/100μm)	225	129	100	56
Crystal Sensitivity	0.15 ± 0.01	0.33 ± 0.02	0.47 ± 0.03	(0.61 ± 0.07)
Fog Density(/1000μm^3)	1.1 ± 0.2	0.9 ± 0.2	0.5 ± 0.1	0.7 ± 0.2

Table.1 Sensitivity and noise of Large Crystal Size Nuclear Emulsion. Sensitivity is evaluated by Grain Density (G.D) which is linear density of developed crystals. Noise is evaluated by Fog Density (F.D) which is volume density of randomly developed crystals. Grain Density of 800 nm crystals was shown with parenthesis due to reproducibility problem.

4. Conclusion

We developed nuclear emulsion with crystal size larger than conventional 200 nm one. We established producing method of emulsion gels which have silver bromide crystal with diameter 200, 350, 450 and 800 nm using emulsion gel manufacturing equipment in Nagoya University. By applying optimum chemical sensitization and development for each crystal size, we succeeded in increasing the sensitivity without changing the noise level compared to the conventional 200 nm one. Furthermore, as contrast improved as the crystal size was larger, it is suitable for future low magnification / wide field scanning.

References

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