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Decontamination of Irradiated Silicon Ingot using Dry Ice Snow Nozzle

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1. Introduction

The Neutron Transmutation Doping (NTD) process takes place when undoped (high purity) silicon is irradiated in a thermal neutron flux. The purpose of semiconductor doping is to create free electrons. NTD silicon is of a lower resistivity with little variance from the target resistivity [1]. HANARO utilizes two vertical holes for NTD of single crystal silicon. After the NTD process, irradiated silicon ingot is manually decontaminated. However, this work involves time-consuming and a large amount of secondary waste. So, we applied the dry ice snow cleaning method to effectively decontaminate the irradiated ingot. Dry ice snow cleaning is one of the newest cleaning methods, which has no secondary waste, ease of clean up, and no damage of substitute surface [2]. We already developed a volume variable nozzle and a control box. Also, the glove box connected to fume hood for the prevention of recontamination was manufactured (Fig. 1).

In this study, we performed a mock-up test and the surface decontamination of irradiated silicon ingot. Also, the application possibility in the NTD process was discussed.

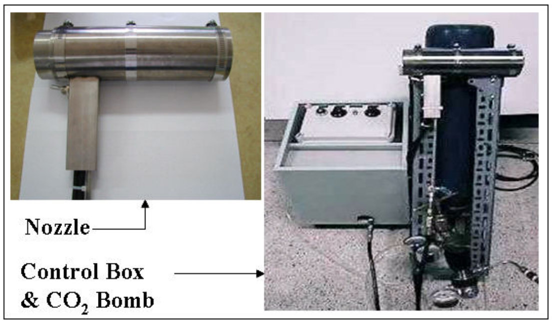

Figure 1. A photo of dry ice snow nozzle and control box

2. Experiment and Results

2.1 Dry Ice Snow Jet Cleaning

The removal mechanisms of surface contaminants using dry ice snow jet are momentum transfer, aerodynamic drag force, and partial dissolving and sublimation. When momentum transfer from the incident snow to the surface particles overcomes the adhesive forces, the particles are removed from the surface and by the high velocity gas. Momentum transfer is irrelevant to the surface particle size, but proportional to the size of incident snow. Aerodynamic drag force is proportional to the diameter of surface particles. Generally, particles to have the diameter of less than 0.5 mm cannot be removed by only the viscous flow itself. When the carbon dioxide snow impacts the surface, the force on the solid carbon dioxide snow causes formation of a transient liquid phase at the snow-particle surface interface. Oily residues of surface are dissolved by the liquid carbon dioxide and are removed when trapped during re-solidification by the rebounding snow particle. After removing the particle, dry ice snow sublimates [3-6].

2.2 Mock-up Test

To see the cleaning power of this device, fingerprint removal test was performed. A glass specimen containing fingerprints was prepared and the fingerprints on the surface were successfully removed. It took about 2 minutes to remove the fingerprints. Work surfaces are usually contaminated with oil and also dust. A plastic specimen with scratches was prepared and contaminated with mixtures of mineral oil and dust. This specimen was cleaned with the device developed in this study. After a 2-minute cleaning, the specimen recovers the original cleanness. This cleaning method seems very effective to targets with complex geometries like scratches, crevices, and holes.

2.3 Decontamination of Irradiated Silicon Ingot

The experimental setup for the surface decontamination of the irradiated silicon ingot is shown in Fig. 2.

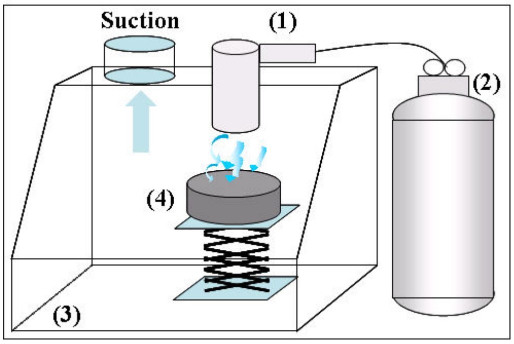

Figure 2. Decontamination scheme of irradiated silicon ingot; (1) dry ice snow nozzle, (2) CO_2 bomb, (3) glove box, (4) irradiated silicon ingot

Based on results of the mock-up tests, we decontaminated the irradiated silicon ingot. Five points, such as top-1,2, side-1,2, and bottom, were selected on the surface. The radioactivity of before and after cleaning process was measured by smear method. Cleaning time was set equal at each point. The flow rate was stabilized for about 15 seconds before cleaning. The distance between ingot surface and nozzle is about 3 cm.

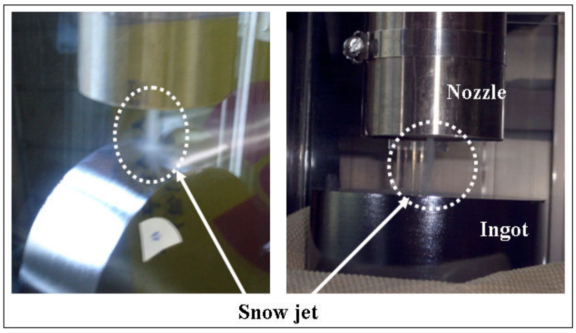

Figure 3. A photo of the ingot decontamination

	Before (Bq)		After (Bq)		Efficiency (%)	
	α	β	α	β	α	β
Top-1	0.08	0.24	0	0.03	0	90
Top-2	-	-	0.04	0.03	-	-
Bottom	1.41	0	0.49	0	65	-
Side-1	0.26	1.14	0.11	0.30	57	74
Side-2	0.20	0.48	0.10	0.34	50	30

Table 1. Decontamination efficiency of irradiated silicon ingot

The surface radioactivity certainly decreases after cleaning process. The results are shown in Table 1. The decontamination efficiency was about 50 to 90 %. The removal rate at each point was somewhat different. The lower limit standards of alpha and beta are <0.04 and <0.4 Bq/cm^2, respectively. Comparing to the standards, alpha activity after test exceeded the lower limit standard. Further tests are required to cover various conditions, such as jet direction, time, and nozzle type.

3. Conclusion

An adjustable nozzle that controls the size of dry ice snow was developed. This device is very effective in cleaning oil-contaminated surface, and is also applicable to decontamination of radioactive surface. This device can be particularly useful in surface-decontamination of any electrical devices, such as detectors and controllers that cannot be cleaned with aqueous solution.

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