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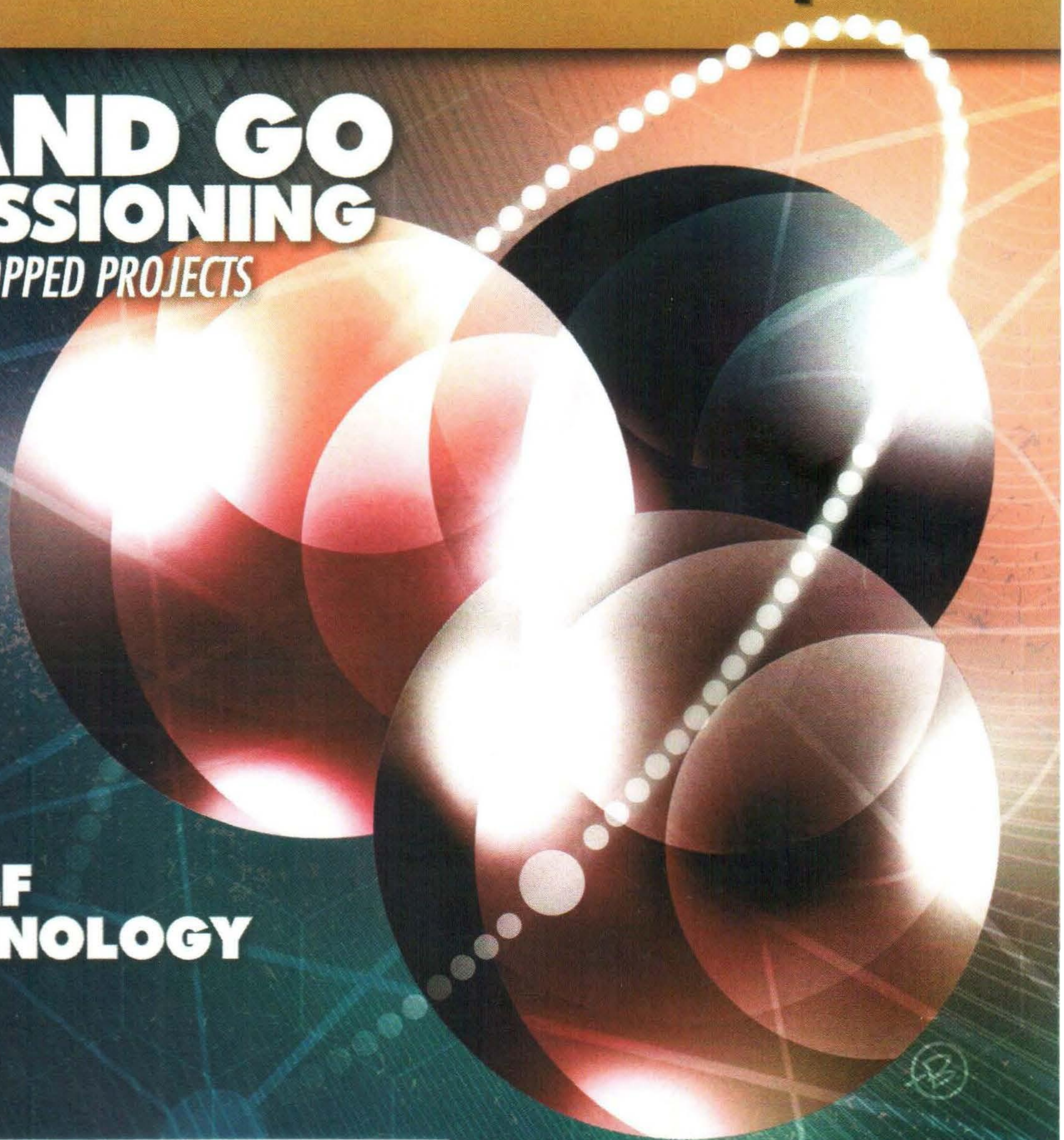
NUCLEAR DECOMMISSIONING report

DECOMMISSIONING, ENVIRONMENTAL REMEDIATION & WASTE MANAGEMENT



STOP AND GO DECOMMISSIONING

IMPACTS & RISKS OF STOPPED PROJECTS

OFF-THE-SHELF REMOTE TECHNOLOGY

FOR DECOMMISSIONING

Decon Technique:

USING PLASMA PROCESSING TECHNOLOGY

TO DECONTAMINATE METALLIC WASTE

USING PLASMA PROCESSING TECHNOLOGY TO DECONTAMINATE METALLIC WASTE

To Enable Safe Reuse and Recycling

by Yong-soo Kim, PhD

Currently, 433 nuclear power reactors are operating worldwide and supplying about 15 percent of the world's electricity. It is anticipated that the ever-increasing energy demand will renew interest in nuclear energy, despite the Fukushima reactor accident last year, since it is still competitive economically and is far less air-polluting compared to conventional fossil power plants.

It must always be borne in mind, however, that the plants unavoidably put out a considerable amount of radioactive waste during their operation. In addition, imminent decommissioning of old and obsolete nuclear power plants are expected to generate huge amounts of nuclear waste. Eighty percent of the operating plants in the world are more than 20 years old, and about half of them are more than 30 years old.

International organizations anticipate that metallic waste constitutes the largest part of the nuclear waste. OECD/NEA estimates that approximately 30 million tons of radioactively contaminated metal scraps will be produced over the next 50 years from dismantling and decommissioning superannuated nuclear facilities. The International Atomic Energy Agency (IAEA) reported that dismantling of one Russian RBMK 1000 reactor would generate nearly 35,000 tons of Cr–Ni steel. Therefore, development of metallic waste decontamination techniques for safe reuse and recycling will be an essential part of our preparation for the forthcoming new era of nuclear energy.

Principles of the Technique

A number of processes have been proposed for radioactive metal waste decontamination. Many of the wet techniques, such as the electrolysis method, are known to generate excessive secondary waste, which restricts their applications within narrow limits. Various dry processing techniques have recently been developed, however most of them are physical processes with low decontamination rates. They also tend to cause environmental concern, such as radioactive airborne pollutant generation.

The plasma decontamination method is one of the emerging dry processing techniques. It is very effective with the least secondary waste generation, and is remotely and automatically controlled so radiation exposure to operators can be minimized.

In this technology, highly reactive radicals and atoms suitable for selective reaction with contaminant on the surface are generated by plasma power, whereby the radioactive contaminants form volatile species and evaporate. Especially in a fluorine plasma discharge, volatile fluorides are produced on the contaminated surface which is exposed to not only reactive fluorine atoms, but also energetic ions, electrons, and photons (see Figure 1). Therefore, the decontamination rate is greatly enhanced.

The plasma etching and cleaning method is a pre-demonstration technology. It is commonly and effectively utilized for cleaning high-bonding energy contaminants from surfaces of metals, metal oxides and glasses during material processing and micro-electronic manufacturing in the industry.

Experimental Investigations, Discoveries, and Demonstration

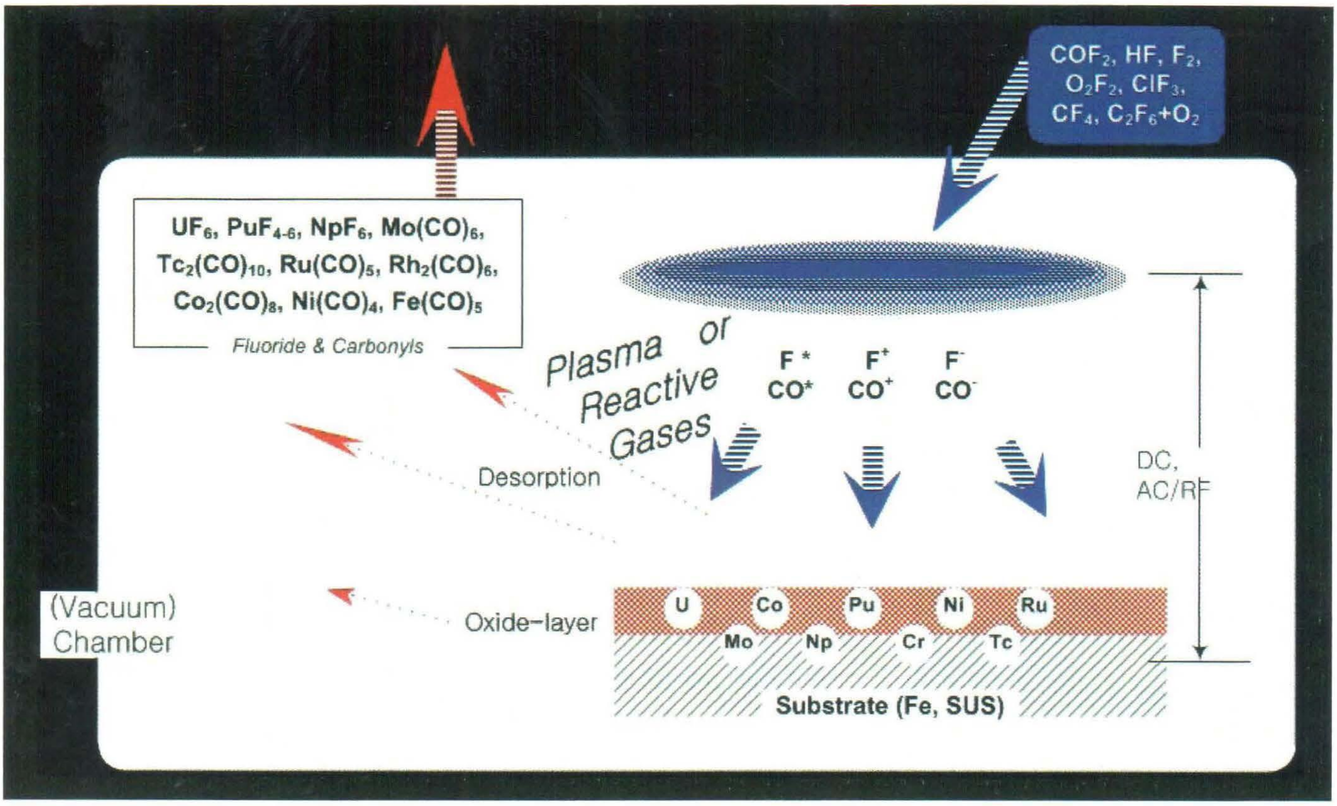
Radioactive contaminants can be generally categorized into three groups: uranium and trans-uranic (TRU) elements released from nuclear fuel systems; corrosion products (CP) such as Co, Fe, Ni, and Cr produced during aqueous corrosion of metallic parts; and fission products (FP) such as Cs, Mo, Tc, Ru, and Rh generated in fission reactions. A series of research studies discovered the technology to be applicable to decontaminate all of these major radioactive elements in the nuclear facilities.

In practice, however, removal of radioactive corrosion products is one of the major tasks in the decontamination of metallic wastes because contaminated surfaces are gradually oxidized during reactor operation.

Table 1 shows a comparison between plasma and electrochemical decontamination. The latter technique was chosen for the comparison because it is one of the typical wet treatment methods and still popularly used in many applications.

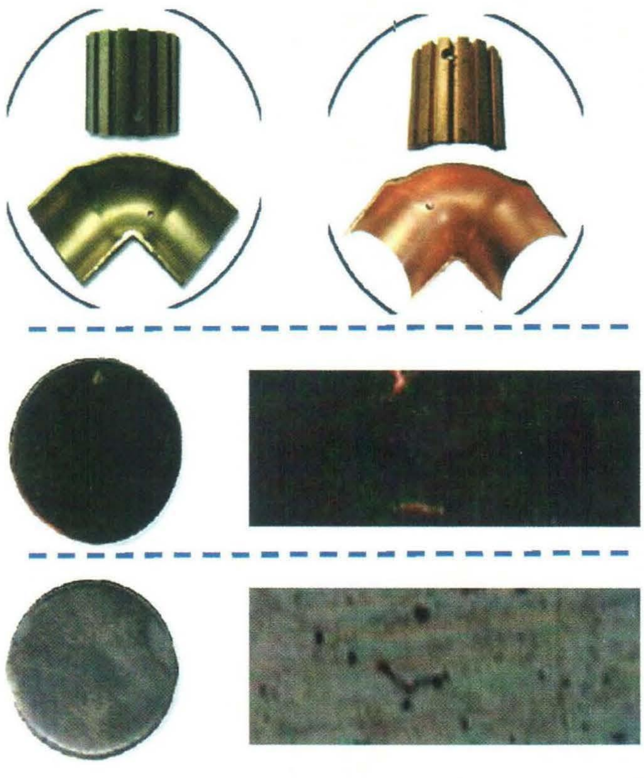
Figure 2 shows surface morphology changes before and after plasma treatment of various surfaces: Ti plated Cu piece and uranium oxide formed on SUS plate. As seen in the figure, even complex surfaces with many grooves could be easily cleaned, and uranium oxidized on the SUS surface could be completely removed.

To demonstrate the feasibility of commercial application of this technique, a contaminated aluminum piece released from a decommissioning test reactor in Korea was processed using fluorine plasma discharge. Table 2 shows that even with low DC plasma power of 150 W, surface radioisotope concentration dropped quickly with increasing operation time, and eventually went down to the clearance level in an hour. As seen in Figure 3, the surface of the aluminum piece was cleaned by the plasma treatment.



(ABOVE) Figure 1: Schematic diagram of plasma processing and plasma chemistry on the contaminated surface.

(RIGHT) Figure 2: Surface morphology changes before and after plasma treatment of various surfaces. (top) Photos of Ti plated Cu piece before and after reaction; (middle) U oxide on SUS plate before reaction; (bottom) U oxide on SUS plate after reaction.



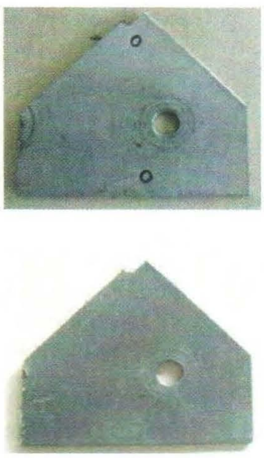
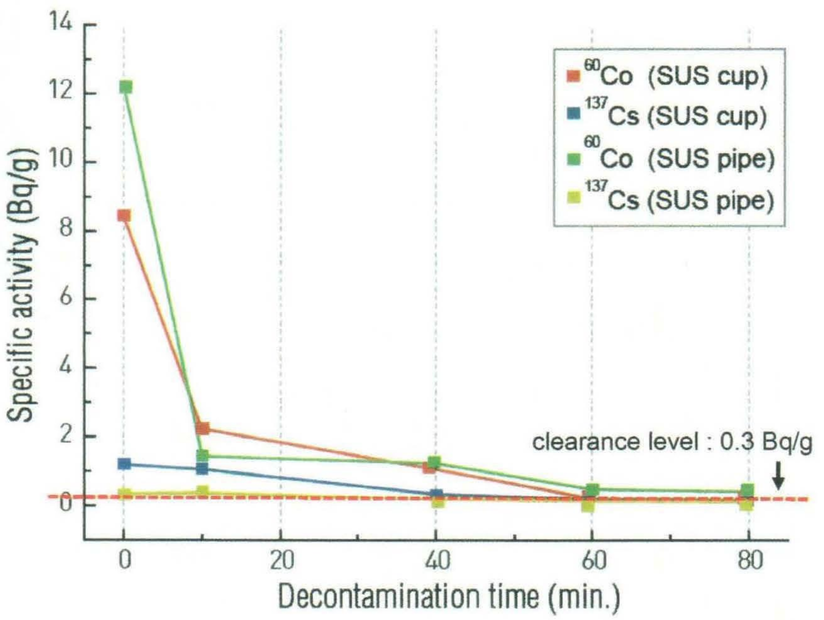


Figure 3: Photos of surface changes before (top) and after the treatment (bottom).

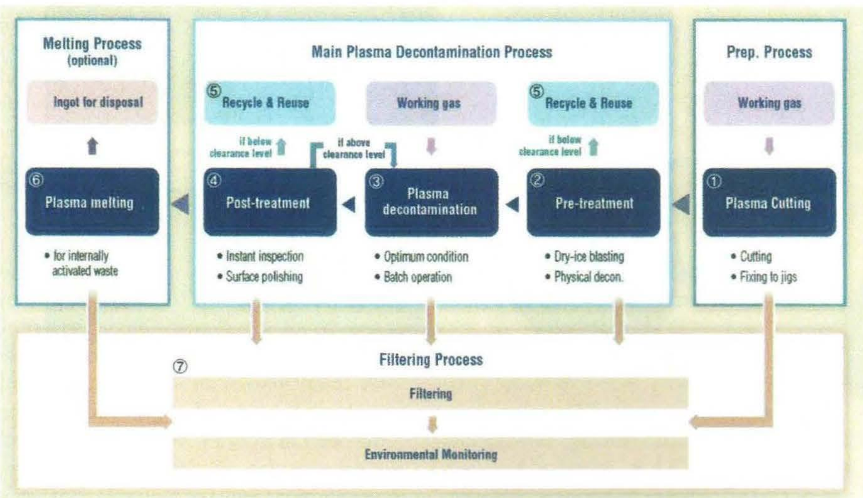
The aluminum piece was collected from a test reactor site in Korea; DC plasma power of 150 W was used in this treatment.

Characteristics	Plasma decontamination	Electrochemical decontamination
Classification	Dry processing technique. (Gaseous processing)	Wet processing technique. (Aqueous processing)
Selectivity of Contaminant	Selectively etching out radioactive nuclides. Directly applicable to oxidized radioactive waste.	Incapable of selective decontamination. Inapplicable to insulative surface (oxide or oxidized surface).
Decontamination Rate	Tens of µm/min for metallic surface. A few µm/min for oxidized surface.	A few µm/min only for metallic surface.
Process Control and Optimization	Easy to control the process. Capable of complex surface decontamination.	Difficult to control electro-chemical reaction to various nuclides. Incapable of complex surface decontamination.
Secondary Waste	Generated only from filtering system. Substantial amount is generated.	

(TOP LEFT) Table 1: Plasma decontamination vs. electrochemical decontamination.



(MIDDLE) Table 2: Radioisotope concentration changes of contaminated aluminum piece by plasma treatment



(BOTTOM LEFT) Figure 4: Process flow diagram of the plasma processing technology

Development of Modular Equipment Design for Ultimate Treatment of Metallic Waste

Based on the experimental findings and industry suggestions, once-through modular equipment has been designed for batch operation. The equipment fundamentally consists of six system modules: preparatory process: pre-treatment process: plasma decontamination process: post-treatment process: melting process (optional): and filtering system (see Figures 4 and 5).

In the preparatory process, large metal waste is cut into suitable size for easy decontamination using a plasma cutting machine. This technique is not only speedy, but also generates no fugitive dust. The cutting method is remarkably safe since the procedure takes place in a low vacuum chamber.

The contaminated cut waste goes through pre-treatment processing in which dry-ice pellets spray over the contaminated surface through nozzles. CO2 pellet blasting has been proven to be very successful. In this process, a significant portion of adsorbate, such as paint, grease and physically adsorbed pollutant, is decontaminated.

During plasma decontamination processing, the main process of the technology generates powerful reactive plasma gas suitable for decontamination condition, which is optimized according to the decontamination target elements. During the process, the regulated etchant gas mixture and its total pressure are remotely and automatically controlled to keep the optimum condition. The etchant gas selectively reacts with radioactive elements on contaminated metal surfaces and completely eliminates them by etching out. An ion-

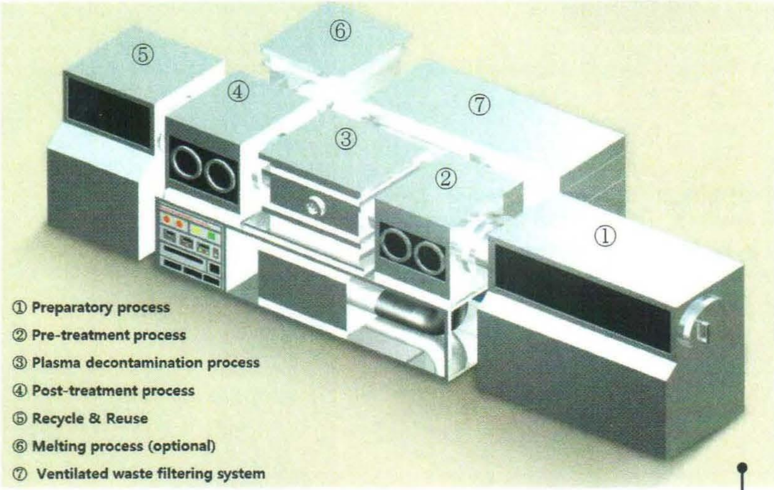


Figure 5: Modular plasma processing equipment for ultimate radioactive metallic waste decontamination

assisted etching technique is additionally used to enhance the decontamination rate, if necessary. The volume of the uniform plasma processing zone can be easily extended up to a few cubic meters, depending on the dimension of target waste.

During post-treatment processing, the decontamination results are checked via an in-situ monitoring system. When proper decontamination processing is confirmed, surface cleaning or finishing is followed for recycling and reuse. If contaminant residuals are found, they are checked to determine if they are internally activated or not. If additional treatment is required, the waste is transferred back to the plasma processing chamber.

The only process applicable for internally activated metal waste is the melting process for final disposition. The melting process, which is optionally chosen for the technology, is plasma melting where casting is processed with a metal ingot for final disposal.

The filtering and adsorption process is the final step, which safely eliminates secondary radioactive waste in the gaseous state. In short, this modular plasma processing equipment takes in radioactive metallic wastes and puts out cleaned metal pieces for reuse/recycle or a metal ingot for final disposal.

The Benefits of Plasma Decontamination Technology

Plasma decontamination with properly designed equipment boasts exceptional technology in various aspects. It is an environmentally-friendly process using no toxic decontamination chemicals, and minimal secondary waste is generated since it is a dry process technology. Since the entire process is operated under low-vacuum conditions, there is no chance of radionuclide contaminant spreading in the environment, and radiation exposure of operators is minimized by employing a remote, automatic control system.

The processing speed is remarkably fast with high decontamination rates. This maximizes efficiency, as well as economic feasibility, to ensure the decontamination of chemically bonded contaminant inside oxide film, which cannot be processed in conventional wet technology.

The technology ultimately can be applied to the decontamination process of large metal waste, such as waste steam generators discharged from old nuclear power plants. In particular, valuable metals, such as nickel, used in nuclear power plants can be collected for reuse and recycling.

About the Author:
Yong-soo Kim has worked for the application of the plasma processing technique to the nuclear waste treatment for the last decade. He has published several journal papers and obtained patents in this field. Dr. Kim received his PhD from the University of California, Berkeley in 1992. He is now a professor in the nuclear engineering department of Hanyang University, Seoul, Korea. Recently, he founded HN Enertech company which is a university-based company. He can be reached at yongskim@hanyang.ac.kr
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