*Transactions of the Korean Nuclear Society Autumn Meeting*
*Gyeongju, Korea, Oct. 27-28, 2016*

# Oxidation of Ce(III) in Foam Decontaminant by Ozone

Chong Hun Jung[a*], I. H. Yoon[a], W. K. Choi[a], J. K. Moon[a], H. B. Yang[a], and J. S. Lee[b]

[a]*Korea Atomic Energy Research Institute,*
*Advanced Decontamination Technology Research Dept.*
[b]*Gachon University, Chemical & Biological Eng. Dept.*
[*]*Corresponding author:nchjung@kaeri.re.kr*

## 1. Introduction

Facilities that handle radioactive materials deteriorate with age after a long period of operation. Consequently, a decontamination technology has been developed to prevent the proliferation of radioactive materials and reduce the radiation exposure of operators while at work. In particular, foam decontamination technology can significantly reduce the radioactive waste produced after decontamination for large equipment or facilities, because more than 90% of the decontaminating materials used with this technology consist of gases[1-3]. To improve the stability of the foam, surfactants and inorganic materials such as nanoparticles can be added.

A nanoparticle-based foam decontaminant is composed of a surfactant and nanoparticles for the generation and maintenance of foam, and a chemical decontamination agent made of Ce(IV) dissolved in nitric acid. Ce(IV) will be reduced to Ce(III) through the decontamination process. Oxidizing cerium(III) can be reused as a decontamination agent, Ce(IV). Oxidation treatment technology by ozone uses its strong oxidizing power[4]. It can be regarded as an environmentally friendly process, because ozone cannot be stored and transported like other industrial gases (because it quickly decays into diatomic oxygen) and must therefore be produced on site, and used ozone can decompose immediately[5]. The ozonation treatment of Ce(III) in foam decontaminant containing a surfactant is necessary for the effective regeneration of Ce(III).

Thus, the present study was undertaken to determine the optimal conditions for ozonation treatment in the regeneration of Ce(III) into Ce(IV) in the nanoparticle-based foam decontaminant containing surfactant.

## 2. Methods and Results

### *2.1 Experimental Methods*

A mixture of 0.5M Ce(III) (Cerium(III) Nitrate, 99.5%, Alfa Aesar) and 1% anionic fluorosurfactant Zonyl TBS (Dupont) in 2M nitric acid was prepared and used for the regeneration of Ce(III) through ozonation treatment. The potentiometric titration method was used for an analysis of the Ce(IV) concentration in the nanoparticle-based foam decontaminant[6]. Ozone was supplied by an ozone generator (Ozonetech lab-1). The oxidation reaction of Ce(III) to Ce(IV) is as follows:

$$2Ce^{3+} + O_3 + 2H^+ \rightarrow 2Ce^{4+} + O_2 + H_2O$$

### *2.2 Results & Discussion*

The parameters to be considered are the Ce(III) concentration, regeneration temperature, and ozone injection volume to derive the optimal conditions for the regeneration of Ce(III) through ozonation treatment. However, the parameter that can be changed is limited by the ozone injection volume, since the Ce(III) concentration and regeneration temperature were fixed. Therefore, the oxidation conversion rate of Ce(III) to Ce(IV) over time was examined by changing the flow rate of the gas mixture (air and ozone) corresponding to the amount of ozone desired. The flow rate of the gas mixture was in the range of 0.5-3.0 LPM.

As shown in Fig. 1, the oxidation conversion rate of Ce(III) to Ce(IV) was increased with an increase in the flow rate of the gas mixture during the oxidation time of 7.5 hours, and the oxidation conversion rate at a flow rate of 2.0 LPM and 3.0 LPM was 55% and 100% respectively. From this results, it was possible to derive the ozone injection amount required for 100% oxidation conversion of Ce(III).

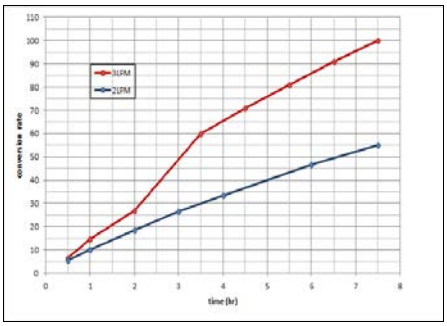


Fig. 1. Ce(III) conversion rate on the variation of the mixed gas flow rate.

The effect of the TBS surfactant on the oxidation behavior of Ce(III) to Ce(IV) were investigated. Similar oxidation behaviors of Ce(III) appeared, regardless of

the presence of a surfactant TBS. Therefore, it was found that the oxidation of Ce(III) with ozone is effective in nanoparticle-based foam decontaminant containing surfactant TBS.

The oxidation time required for the 100% oxidation conversion of Ce(III) was examined by changing the ozone injection amount. Fig. 2 shows the typical results on the oxidation conversion rate of Ce(III) with a variation of ozone injection amount at a gas mixture flow rate of 2.0 LPM. As shown in this figure, the oxidation conversion rate of Ce(III) to Ce(IV) was increased when increasing the ozone injection amount, and the oxidation time for 100% oxidation conversion of Ce(III) at an ozone injection amount of 9.0 g/h and 6.6 g/h was 6.0 h and 7.5 h, respectively.

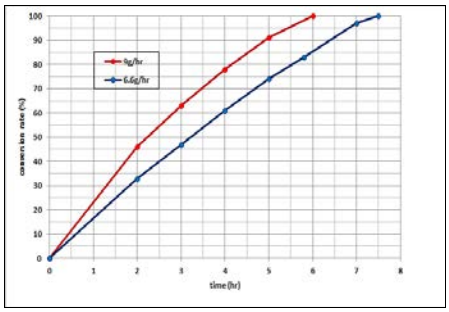


Fig. 2. Ce(III) conversion rate(%) on the variation of ozone low rate at a mixed gas flow rate of 2LPM.

## 3. Conclusions

This study was undertaken to determine the optimal conditions for ozonation treatment in the regeneration of Ce(III) to Ce(IV) in nanoparticle-based foam decontaminant containing a TBS surfactant.

The oxidation conversion rate of Ce(III) was increased with an increase in the flow rate of the gas mixture and ozone injection amount.

The oxidation time required for the 100% oxidation conversion of Ce(III) to Ce(IV) at a specific ozone injection amount can be predicted from these experimental data.

## ACKNOWLEDGEMENTS

This work has been carried out under the Nuclear R&D Program (2012M2A8A5025655) funded by Ministry of Science, ICT & Future planning.

## REFERENCES

[1] I. Penfold, R. K. Tucker, and J. Zhang, Langmuir 21 10061 (2005).
[2] B. Fournel, S. Angot and P. Joyer, “Decontamination of Phebus experimental target chember using sprayed foam,” ICONE 10, Arlington, USA (2002).
[3] J. P. Turchet, B. Fournel and G. Estienne, “Pipe decontamination involving string-foam circulation”, ICONE 10, Arlington, USA (2002).
[4] V.P. Shilov and A.M. Fedoseev, “Role of peroxynitrite in oxidation of $f$-element ions in solutions”, Frumkin Institute of Physical Chemistry and Electrochemistry (2013).
[5] Kazutoshi Shishido, Sanehiro Muromachi, and Ryo Ohmura, “Preservation of molecular ozone in a clathrate hydrate: three-phase (gas + liquid + hydrate) equilibrium measurements for $O_3$ + $O_2$ + $CO_2$ + $H_2O$ systems”, International Scholarly and Scientific Research & Innovation 7(2) (2013).
[6] C. H. Jung, H. B. Yang, et. Al., “Measurement of Ce(IV) concentration in foam decontaminant containing fluorosurfactant” Transactions of the Korean Nuclear Society Spring meeting, Jeju, Korea, May 12-13 (2016).