UV Spectroscopy of Metal Volatilization during Thermal Plasma Processing of Waste Glass Melts

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Atomic emission spectroscopy (AES) is used to monitor volatilization during waste vitrification with thermal plasmas. Model waste specimens consist of an aluminosilicate clay spiked with 10 wt. % Fe, Ni, or Cr. Specimens are vitrified in processing atmospheres with 0, 8.5, and 17 vol. % oxygen/argon concentrations. Particulate generated from condensation of the volatilized materials is collected following each specimen run and analyzed by energy dispersive X-ray analysis to determine composition. Spectra are collected from the ultraviolet range 240-380 nm where the presence of metal vapor is readily detected. Correlation between line emission intensities and volatilization rates allows the establishment of provisional detection limits for the volatilization of Ni, Cr, Si, and Fe, of $1 \times 10^{-3}$ g/s, $4 \times 10^{-4}$ g/s, $2 \times 10^{-4}$ g/s, and $5 \times 10^{-5}$ g/s, respectively. The results of this investigation support the concept of using AES as an in-situ process monitor for feedback to optimize plasma processing of hazardous metal-containing waste.

KEY WORDS: Spectroscopy; volatilization; iron; nickel; chromium; waste vitrification.

1. INTRODUCTION

1.1. Plasma Processing

Vitrification of waste materials using thermal plasmas is a potentially effective method for the treatment of wastes contaminated with hazardous metals.¹,² The treatment involves dissolving the waste in a high silica content melt which, when cooled, results in immobilization of the metals in a non-leachable slag. This application is complicated by uncontrolled volatilization of the metals from the high-temperature melt. When the volatilized metal

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vapors encounter low-temperature gases in the processing system, the vapors condense into a fine (<1 μm) and potentially hazardous airborne dust or particulate.\(^3\) Management of the dust requires high-efficiency filtration to remove the particles from the exhaust gas and subsequent handling for reprocessing or storage in a specialized landfill. These measures add additional cost and potential future liability. For most waste treatment applications, it is desirable to minimize volatilization\(^4\); however, in some cases it may be advantageous to selectively volatilize selected components of the waste.\(^5\) In either case, control of volatilization processes during waste treatment is a desirable goal.

Control of volatilization may be accomplished by manipulating physical processing parameters such as melt temperature and ambient pressure, and chemical parameters such as oxygen partial pressure and melt composition. The effects of each of these parameters upon volatilization is complex and the precise composition of actual waste streams is often unknown. Prediction of the optimum values of the parameters to control volatilization in realistic applications is therefore problematic. Real-time process optimization requires *in-situ* feedback on the composition and kinetics of vaporization from the melt. An analytical technique for *in-situ* monitoring of volatilization during plasma processing has not been established and is the goal of the research described below.

1.2. Spectroscopy

During thermal plasma processing, volatilized materials become entrained in the high-temperature plasma (5000–20000 K), resulting in decomposition of the materials and optical excitation of the atomic constituents.\(^6\) Atomic emission spectroscopy (AES) may in principle be used to observe the line-spectra of such species, suggesting the possibility of their identification and quantification. This paper discusses the use of AES as a tool for monitoring volatilization during plasma vitrification for model waste specimens consisting of an aluminosilicate clay spiked with Fe, Ni, or Cr.

Plasmas have been used in emission spectroscopy as an excitation source for many years because of the high temperatures which are capable of volatilizing and optically exciting virtually any material.\(^7\) High-purity reducing or oxidizing plasma environments eliminate contamination and spectral interference that result from combustion products encountered in conventional flames. These features of plasma excitation account for the popularity of inductively coupled plasma atomic emission spectroscopy (ICP-AES) as an analytical tool for trace element detection and quantification.