Metal Chloride Reduction Using Argon-Hydrogen Plasmas

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Abstract: A nonthermal inductively coupled argon-hydrogen plasma is used to treat metal chloride powders. We show the ability to reduce several metal chlorides that are traditionally difficult to reduce, including alkali metal chlorides, and to obtain metal products. We propose that the use of hydrogen is essential, as it allows for improved reduction kinetics due to the atomic hydrogen and serves to scavenge excess chlorine.

1. Introduction

The production of industrial metals is a crucial, worldwide industry. The current approaches to reducing a metal ore to its metal product typically involve multiple steps, long processing times, and substantial CO_2 emissions. Chlorination is often used as one of the first processing steps for metal ore reduction, and it can also be used to extract valuable metals from slag waste or other mining byproducts. Therefore, the development of a universal process to reduce varying types of metal chlorides may allow us to simplify processes and expand our ability to recover valuable metals from waste.

In this work, we propose hydrogen-containing plasma as a promising method to achieve reduction and produce metallic materials.

2. Methods

A nonthermal inductively coupled RF plasma is used to treat metal chloride powders. Metal chloride powders are crushed, dispersed in methanol, and dropcast onto slides that are inserted into the plasma. Reduction of the powders is measured using x-ray diffraction (XRD) and x-ray photoelectron spectroscopy (XPS). XRD allows for the identification of metal or metal-oxide peaks. XPS provides the composition of reduced materials, which gives an indication of the efficiency of the plasma to remove chlorine. Optical emission spectroscopy (OES) is also used to monitor the presence of metal emission lines in the plasma due to the transformation of the metal chloride powders.

3. Results and Discussion

Figure 1 shows a summary of the data from the reduction of various metal chloride powders. The metal chlorides that are difficult to reduce are KCl, NaCl, $MgCl_2$, and the easier ones are $FeCl_2$ and CuCl. The top row of images shows the distinctive color changes of the plasma when metal chloride powder is introduced. The middle row shows OES spectra taken from the reduction of each metal chloride precursor, which display the characteristic emission lines of the metals. The bottom row shows the XRD measurements of each. For NaCl and $MgCl_2$, the reduced product shows metal oxide peaks, which indicate that a metal film was produced and later oxidized during exposure to the atmosphere during measurement. $FeCl_2$ and CuCl both show only metallic peaks.

4. Conclusion

Argon/hydrogen plasmas are shown as a promising pathway for the production of metals from metal chlorides. Both easy and difficult to reduce metal chlorides can be effectively treated with plasma to produce metallic materials. This method is easily adaptable so that it can be applied to many different precursors, and it has the potential to improve or replace existing processing methods.

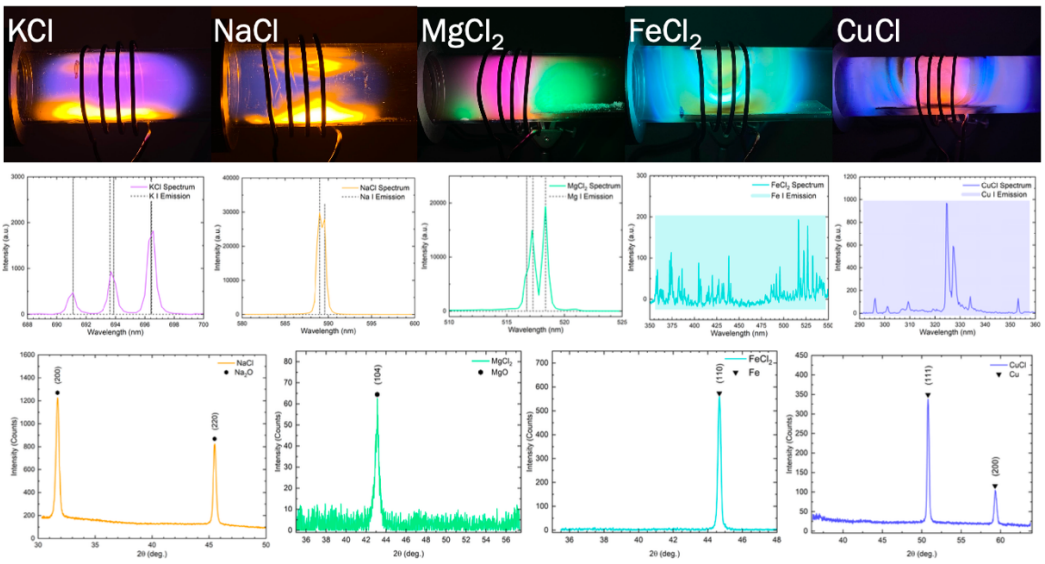

Figure 1. Top) Photos and OES spectra showing the emission of metals from metal chloride powders in the plasma. Bottom) XRD measurements of reduced materials after plasma treatment.