AEROSOL REDUCTION/EXPANSION SYNTHESIS (A-RES) FOR ZERO VALENT METAL PARTICLES

RELATED APPLICATIONS

This application is a U.S. National Stage application of PCT/US2011/060211 filed 10 Nov. 2011, which claims priority to U.S. Provisional Patent Application Ser. No. 61/456,680 filed Nov. 10, 2010, which is hereby incorporated by reference in its entirety.

GOVERNMENT RIGHTS

This invention was made with Government support under Grant No. DE-AC52-06NA25396 DOE/NNSA awarded by Los Alamos National Laboratory. The U.S. Government has certain rights in the invention.

BACKGROUND

Metal particles in the micron scale range are important to large industries including the paint industry, the metal parts manufacturing industry, etc. Parts made with metal particles can be complex in shape. For example the metal powder can be introduced into a die and sintered, or can be made by laser sintering layers built one layer at a time using 3-D printing devices. These parts are useful for appliances, bearings and gears, cutting tools, filters, and electrodes.

Conventional production technologies for making micron scale metal particles include atomization, electrolysis, plasma spray, and solid state reduction, in atomization, molten metal is forced through nozzles to form liquid jets. These jets are rapidly cooled with water or inert gases to create particles. Consequently, purity is compromised by the inclusion of oxygen gettering species in the molten metal. In addition, this process is energy inefficient. For example, only about 1% of the pumping energy actually goes into particle formation. Electrolysis requires a variation on the standard electrolytic processes, such that particles rather than films are produced at an electrolytic cell cathode. Consequently, this process is limited to particular metals, as it requires dissolution of metal, which is often expensive. In solid state reduction, finely ground oxide particles are treated with reducing gases, at a temperature lower than the melting point of the metal to produce reduced and sintered particles. Consequently, the metals created using this multi-step method have relatively high impurity levels. Plasma spray technology does yield high purity particles of controlled shape. However, it is not widely used because the technology is inherently energy intensive, and requires expensive, sophisticated equipment.

Production of metal particles in the nanometer scale have been introduced in the last decade by methods including sono-chemistry, wet chemistry methods, co-precipitation micro-emulsion methods, and laser-driven thermal methods. Other methods for making metal particles include metal gas evaporation, metal evaporation in a flowing gas stream, mechanical attrition, sputtering, electron beam evaporation, electron beam induced atomization of binary metal azides, expansion of metal vapor in a supersonic free jet, and pyrolysis of organometallic compounds. However, all of these methods face obstacles of contamination, expensive processes, low yields, and difficulty of mass production and industrial up scaling.

It is thus desirable to provide a method/process capable of producing zero valent metal/metal alloy particles in the micron, sub-micron, and/or nanometer size range.

SUMMARY

According to various embodiments, the present teachings include a method of forming a metal particle. The metal particle can be formed from an aerosol stream. The aerosol stream can include metal precursor compound(s) and a chemical agent that produces reducing gases upon thermal decomposition. Each metal precursor compound can include positive valent metal(s). The aerosol stream can then flow through a heated inert atmosphere in a reduction expansion synthesis (RES) reactor to form a plurality of zero valent metal particles. The zero valent metal particles can correspond to the positive valent metal(s).

According to various embodiments, the present teachings also include a method of forming a metal particle. The metal particle can be formed from an aerosol stream. The aerosol stream can include a metal precursor compound and a nitrogen-hydrogen (N—H) containing molecule in a carrier gas. The metal precursor compound can include a positive valent metal. The aerosol stream can then flow through a heated inert atmosphere in a vertical reduction expansion synthesis (RES) reactor to form a plurality of zero valent metal particles corresponding to the positive valence metal. The plurality of zero valent metal particles can be collected at a bottom end of the vertical RES reactor.

According to various embodiments, the present teachings further include a method of forming a metal particle. The metal particle can be formed from an aerosol stream. The aerosol stream can include a metal precursor compound and a nitrogen-hydrogen (N—H) containing molecule in a carrier gas. The metal precursor compound can include one or more of a metal hydroxide, a metal oxide, and a combination thereof. The aerosol stream can flow through a heated inert atmosphere in a reduction expansion synthesis (RES) reactor to form a plurality of zero valent metal particles from the metal precursor compound. The plurality of zero valent metal particles can be collected from the RES reactor.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the present teachings, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments of the present teachings and together with the description, serve to explain the principles of the invention.

FIG. **1** depicts an exemplary apparatus for forming zero valent metal particles including metal alloy particles in accordance with various embodiments of the present teachings.

DESCRIPTION OF THE EMBODIMENTS

Reference will now be made in detail to exemplary embodiments of the present teachings, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. In the following description, reference is made to the accompanying drawings that form a part thereof, and in which is shown by way of illustration specific exemplary embodiments in which the present teachings may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the present teachings and it is to be understood that other embodiments may be utilized and that changes may be