ELSEVIER

Materials Characterization 58 (2007) 148 – 155

MATERIALS CHARACTERIZATION

Generation of nano aluminium powder through wire explosion process and its characterization

R. Sarathi [a,*], T.K. Sindhu [a], S.R. Chakravarthy [b]

[a] *Department of Electrical Engineering, IIT Madras, Chennai-600 036, India*
[b] *Department of Aerospace Engineering, IIT Madras, Chennai-600 036, India*

Received 21 February 2006; received in revised form 5 April 2006; accepted 9 April 2006

Abstract

The nano aluminium particles were produced in different ambience by the wire explosion process. The influence of pressure in the exploding wire chamber on the size of the particles was analyzed. Certain physico-chemical diagnostic studies, viz., wide angle X-ray diffraction (WAXD), thermo-gravimetric differential thermal analysis (TG–DTA) studies were carried out to characterize the produced nano aluminium powder. The compositions of the material were characterized through the energy dispersive analysis by X-ray (EDAX) results. The size of the particles was measured using transmission electron microscope (TEM) studies and particle size distribution analyses were carried out by adopting log-normal distribution. The mechanism of formation of nano powder by wire explosion technique was explained in detail.

Keywords: Nano particle; Aluminium particle; Plasma; Wire explosion; Log-normal distribution; WAXD; EDAX; TEM; TG–DTA

1. Introduction

Aluminium powders are common ingredients for explosive formulations. Recent advances in technology allowed the production of aluminium particles of nano size. These particles exhibit peculiar thermal behavior that was thought to be associated with stored internal energy. Generation of ultrafine particles is difficult to obtain by mechanical methods. The process of solidification of supersaturated vapor in proper inert atmosphere could form the nano particles. There are two different processes by which the supersaturated gas is formed [1,2]: chemical and the physical technique. In the chemical process, the necessary vapor is produced by appropriate chemical reaction between gases. In the physical process, the vapor is produced by pyrolytic effect. The physical process avoids unwanted products of the chemical reaction, resulting in high purity of the produced powder. In the present work, wire explosion technique (physical process) is adopted, which is a top-down approach to produce nano powders. This is basically an inert gas evaporation technique, where the particles are produced by evaporating a thin metal conductor by passing high current to it, in an inert atmosphere [3–7].

The main objective of the present work is to produce nano aluminium powder by using the wire explosion technique and to characterize them to confirm the formation of nano sized powder. The nano aluminium particles were produced in nitrogen,

* Corresponding author. Tel.: +91 44 2257 4436; fax: +91 44 2257 0509.
E-mail address: rsarathi@iitm.ac.in (R. Sarathi).

1044-5803/$ - see front matter
doi:10.1016/j.matchar.2006.04.014

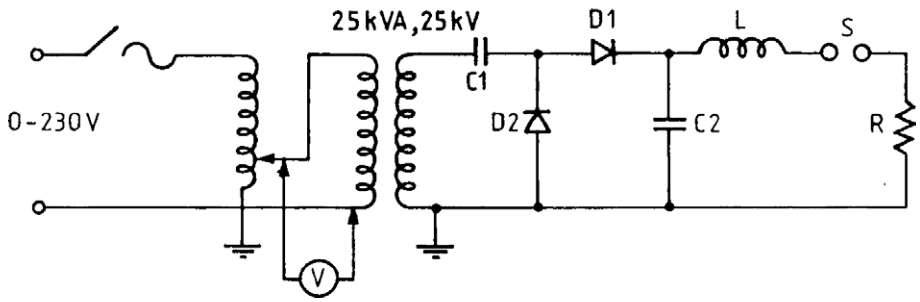

Fig. 1. Experimental setup.

argon and helium ambience. To understand the basic property of the produced nano-aluminium powder, certain physico-chemical diagnostic studies were carried out using wide angle X-ray diffraction (WAXD), and energy dispersive analysis by X-rays (EDAX). The size and shape of the powder were analyzed by using transmission electron microscope (TEM) studies. The particle size distribution studies were performed by adopting log-normal probability distribution. The relationship between the size of the particle generated in the explosion process and the ambient pressure was analyzed. The suitable ambiences for producing pure aluminium particle were identified. Also the mechanisms of nano particle formation by wire explosion process were detailed. The thermal characteristics of the material were also analyzed using thermo-gravimetric differential thermal analysis (TG–DTA) studies.

2. Experimental

The basic circuit used for exploding the wires to produce nano powders is shown in Fig. 1. The circuit parameter details are provided in Table 1. The typical voltage across R and the current flow through it were measured using the voltage probe (EP-50 k, PEEC. A, Japan) and current probe (Pearson Electronics, USA Current transformer Model No-101), respectively, as shown in Fig. 2.

The major factor determining the particle size in the wire explosion process is superheating of the evaporated material. The particle size produced by the wire explosion process reduces substantially with increasing super heating of the metal, i.e., $k=W/W_s$, where W is the energy injected into the evaporating wire and W_s is the sublimation energy of the wire, which diminishes when the diameter of the wire is

Table 1
Summary of experimental details

Capacitance	3 µF
Charging voltage	25 kV
Material	Aluminium
Wire diameter	0.5 mm
Length of the wire	150 mm
Ambience	Nitrogen, Argon and Helium

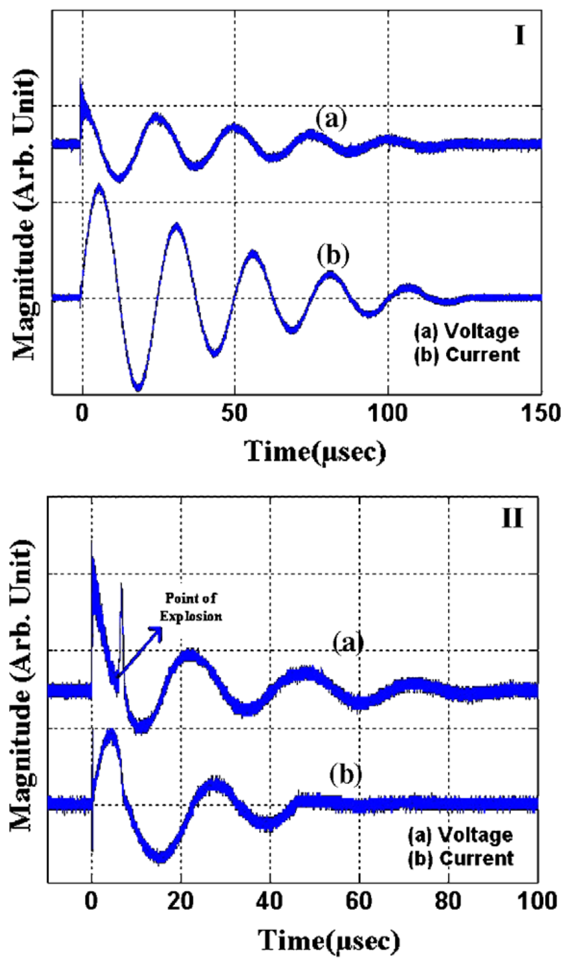

Fig. 2. Typical voltage measured across R and the current flow through it (I) without explosion (II) when explosion occurs.