Journal of Quantitative Spectroscopy & Radiative Transfer 117 (2013) 1–6

Contents lists available at SciVerse ScienceDirect

Journal of Quantitative Spectroscopy & Radiative Transfer

journal homepage: www.elsevier.com/locate/jqsrt

Understanding the mechanism of nanoparticle formation in wire explosion process

B. Bora [a,b,*], C.S. Wong [b], H. Bhuyan [a], Y.S. Lee [b], S.L. Yap [b], M. Favre [a]

[a] Department of Physics, Pontificia Universidad Catolica de Chile, Santiago 22, Chile
[b] Plasma Technology Research Centre, Physics Department, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 30 April 2012
Received in revised form
18 October 2012
Accepted 19 November 2012
Available online 27 November 2012

Keywords:
Wire explosion technique
Optical emission spectroscopy
Arc plasma
Pulse plasma
Powder technology
Physical vapor deposition
Nanoparticle

ABSTRACT

The mechanism of nanoparticle formation by wire explosion process has been investigated by optical emission spectroscopy in Antony et al. 2010 [2] [J Quant Spectrosc Radiat Transfer 2010; 111:2509]. It was reported that the size of the nanoparticles formed in Ar ambience increases with increasing pressure, while an opposite trend was observed for the nanoparticles produced in N_2 and He ambiences. However, the physics behind this opposite trend seems unclear. In this work, we have investigated the probable mechanism behind the opposite trend in particle size with pressure of different gases and understand the mechanism of nanoparticle formation in wire explosion process. The experiment was carried out to investigate the effect of ambient gas species (Ar and N_2) and pressure on arc plasma formation and its corresponding effects on the characteristics of the produced nanoparticles in wire explosion process. Our results show that the arc plasma formation is probably the mechanism that may account for the opposite trend of particle size with pressure of different gases.

1. Introduction

Wire explosion technique has been extensively studied in recent years to produce nanoparticles of different materials [1–6]. The effects of the ambient medium (Ar, N_2 and He) on the size of the nanoparticles were studied by optical emission spectroscopy (OES) in Ref. [2]. It was observed that the size of the nanoparticles formed in Ar ambience increases with increasing pressure, while an opposite trend was observed for the nanoparticles produced in N_2 and He ambiences (Fig. 3 of Ref. [2]). From the OES analysis, it was reported that the increase in the plasma temperature with increasing pressure is the cause for formation of larger nanoparticles with the increase in pressure of Ar gas. However, the OES analysis was not able to describe the opposite trend in variation of the particle size with pressure of N_2 and He ambiences. Similar to the Ar ambience, the plasma temperature was also reported to increase with increasing pressure of N_2 and He ambiences (see Fig 10 (b) of Ref. [2]), but the variation of particle size with pressure of Ar was opposite to that of N_2 and He gases. It was reported that the nanoparticle formation mechanism in N_2 and He ambiences is different from the Ar ambience [2]. However, the physics behind the different mechanism for the ambience of N_2 and He is still unclear. It was suggested that the thermal conductivity of different gases plays a significant role on the size of the produced nanoparticles [2]. But the explanations on the basis of thermal conductivity also could not be able to properly describe the opposite trend of particle size with pressure of different gases. It is well known that the thermal conductivity of He is higher compared to Ar and N_2, but the variation of the thermal conductivity (or temperature diffusivity) with temperature for these three gases is similar [7,8]. It is also known that the

* Corresponding author at: Department of Physics, Pontificia Universidad Catolica de Chile, Santiago 22, Chile.
E-mail addresses: biswa_bora@rediffmail.com, bbora@fis.puc.cl (B. Bora).

0022-4073/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jqsrt.2012.11.018

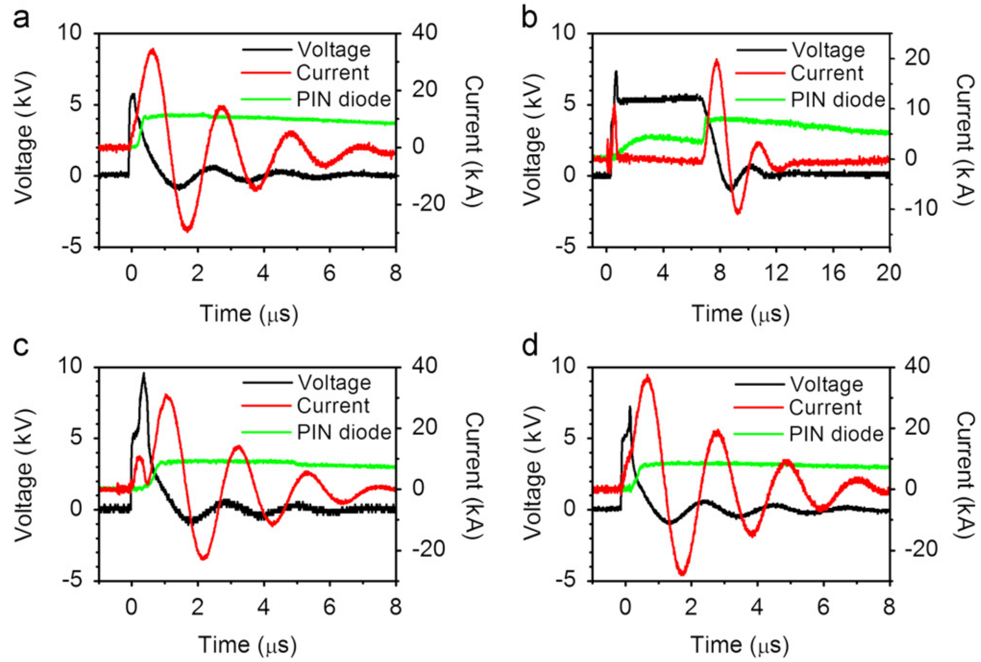

Fig. 1. Typical voltage, current and PIN diode signals obtained from wire explosion process at (a) 500 mbar pressure of Ar, (b) 500 mbar, (c)100 mbar and (d) 50 mbar pressure of N_2 ambience.

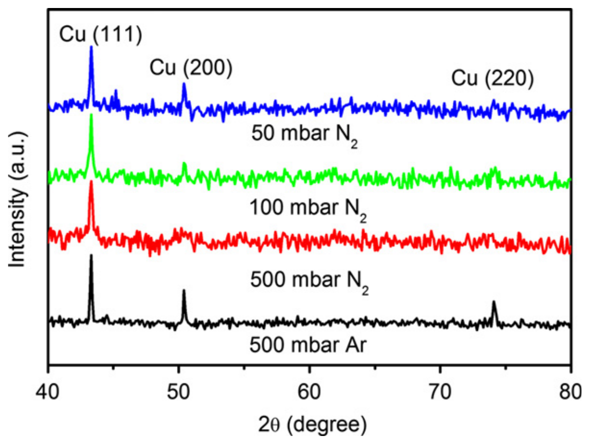

Fig. 2. Typical XRD patterns of the nanoparticles synthesized at different pressure of Ar and N_2.

thermal conductivity of all three gases decreases with decreasing pressure. Thus, if the thermal conductivity is the only factor, then the variation in the particle size with pressure should have a similar trend for all the three gases. It is worth mentioning here that the synthesis of AlN nanoparticle by exploding Al wire in N_2 as well as in a NH_4 environment had shown a reduction in particle size with reducing pressure [9], which is opposite to the experimental observations in Ref. [2]. In addition, decrease of particle sizes with reduction in pressure for the ambiences of Ar, He and N_2 was observed when Cu nanoparticles were synthesized by wire explosion technique [7], which is also opposite to the observations in Ref. [2]. Thus, we believe that in addition to the thermal conductivity, there could be some other factors, which significantly influence the nanoparticle formation mechanism in wire explosion process. Very recently, it has been pointed out that arc plasma formation takes place in wire explosion process and it may influence the initial temperature of the liquid–vapor mixtures by reheating, and hence lead to change the sizes of the produced nanoparticles [3]. It is well known that Ar is easily broken down compared to He and N_2, which may lead to earlier formation of the arc plasma for Ar ambience. It is also reported that the decrease of air pressure in wire explosion process reduces the arc plasma formation time [3]. Therefore, it is interesting to investigate the arc plasma formation in wire explosion process and its subsequent effects on the characteristics of the produced nanoparticles, which may probably provide a fruitful explanation of the opposite trend in variation of the particle size with pressure observed in Ref. [2] for different gases.

In this work, an investigation was carried out to understand the arc plasma formation and its effect on the characteristics of the produced nanoparticles in wire explosion process assuming that the present investigation may help in understanding the different mechanisms that cause the opposite trend in particle size with pressure of different gases as observed in Ref. [2]. Cu nanoparticles were synthesized by exploding a Cu wire at different pressure of Ar and N_2 ambiences. The particles were characterized by X ray diffraction (XRD) and transmission electron microscope (TEM). Arc plasma formation time for different experimental conditions was investigated and correlated with the particle size distributions adopting a log-normal probability distribution function. OES was carried to understand the wire explosion and arc plasma generation process and its subsequent influences on the characteristics of