

University of Wollongong - Research Online

Thesis Collection

Title: Analysis of metal vapour generation by laser ablation

Author: Shervin Farjad

Year: 2007

Repository DOI:

Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

Research Online is the open access repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au

2007

Analysis of metal vapour generation by laser ablation

Shervin Farjad
University of Wollongong

Follow this and additional works at: <https://ro.uow.edu.au/theses>

University of Wollongong

Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

Recommended Citation

Farjad, Shervin, Analysis of metal vapour generation by laser ablation, M.Eng. thesis, School of Mechanical, Material and Mechatronic Engineering, University of Wollongong, 2007. <http://ro.uow.edu.au/theses/692>

NOTE

This online version of the thesis may have different page formatting and pagination from the paper copy held in the University of Wollongong Library.

UNIVERSITY OF WOLLONGONG

COPYRIGHT WARNING

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site. You are reminded of the following:

Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

ANALYSIS OF METAL VAPOUR GENERATION BY LASER ABLATION

A thesis submitted in (partial) fulfilment of the

requirements for the award of the degree

MASTER OF ENGINEERING (HONOURS)

from

UNIVERSITY OF WOLLONGONG

by

Shervin Farjad, B.E. (Hons)

School of Mechanical, Material and Mechatronic Engineering (MMM)

2007

CANDIDATE'S CERTIFICATE

I, Shervin Farjad, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Master of Engineering - Research, in the Department of Mechanical, Materials and Mechatronic Engineering (MMM), University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Shervin Farjad

28 / February / 2007

ACKNOWLEDGEMENTS

I wish to express my gratitude to my supervisor, Professor John Norrish for his patience and support during the formative stages of this thesis.

I wish to thank Joe Abbott for his collaboration during the experiments with LASER machine. Also, for their assistance during TEM and SEM experiments my thanks to Dr. Kristin Carpenter and Nick Mackie.

This is to acknowledge that the procedure of collecting fume on the TEM grid and particle analyses using *Scion* software are as Dr. Zoran Sterjovski, a researcher in University of Wollongong, developed through a project with BOC Australia.

I would like to thank my co-supervisor Dr. Brian Monaghan for his technical support during the absence of my supervisor.

I would be remiss without mentioning Dr. Mehrassa Farjad and Ehsan Keyhani whose cares made me feel at home.

Finally, I wish to dedicate this thesis to my parents, brothers and sister whom I owe what I have achieved.

ABSTRACT

A chamber for ablation purpose was designed. This system was calibrated and the minimum spot size produced by the LASER on the sample surface and its relation with sample position adjustment experimentally, was determined. Applying this chamber, a technique for controlled generation of particulate by LASER ablation has been developed. The sampling was carried out in four different atmospheres; Air, CO₂, Stainshield 66, and Argoshield 52. Furthermore, to survey and analyse the fume particle size range, *Scion Image* software was applied.

Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy were chosen for analysis of fume particles morphology and size distribution. Energy Dispersive spectroscopy (EDS) and Scanning Transmission Electron Microscopy (STEM) were also chosen for chemical analysis.

The average fume particle size observed in all atmospheres was less than 0.1 micrometer. Considering the effect of oxidation potential of shielding gases, CO₂ generated the largest fume particles compared to Ar, while adding H₂ led to a smaller particles size.

The agglomeration pattern and morphology of fume particles was analysed as well. The survey of the agglomerated fume particles morphology with the SEM is more reliable since the TEM sample preparation could disturb the agglomeration pattern.

Fume particles agglomeration tended to grow three dimensionally while ferrous compound tended to make network and agglomerate together. The fume particles in the same size range tended to agglomerate in a 'chain' pattern which could grow up to 10 micrometers. The population of agglomerated particles with different sizes together varied between 3 and 400 particles. One of the most common patterns of these agglomerations is 'spherical' pattern.

While the fume particles can be in 'faceted' or 'spherical' shape, fume particles observed in this work were mainly 'faceted', independent of applied atmosphere.

The chemical composition of fume particles is variable of target (the sample) composition. In this work Fe, Mn, Si and O₂ were the elements observed in fume particles composition, while the elements found in the fume particles did not vary in different atmospheres.

It is also proposed that future works follow the investigation of the size distribution and morphology of fume particles while different welding electrodes are targeted by LASER and atmosphere is purged with shielding gases.

TABLE OF CONTENTS

	PAGE
ACKNOWLEDGEMENTS.....	II
ABSTRACT.....	III
TABLE OF CONTENTS.....	IV
1. INTRODUCTION.....	1
2. LITERATURE REVIEW.....	3
2-1. Why is the study of the fume important?	4
2-2. Welding fumes.....	4
2-2-1. Particulate fume.....	4
2-2-1-1. Aluminium.....	4
2-2-1-2. Cadmium.....	5
2-2-1-3. Chromium.....	5
2-2-1-4. Copper.....	6
2-2-1-5. Manganese.....	6
2-2-1-6. Nickel	7
2-2-1-7. Vanadium.....	7
2-2-1-8. Zinc	8
2-2-1-9. Fluorides	8
2-2-1-10. Iron	9
2-2-1-11. Lead	9
2-2-1-12. Silica	9
2-2-1-13. Other fumes.....	9
2-2-2. Gases.....	9
2-2-2-1. Carbon monoxide and Carbon dioxide	9
2-2-2-2. Ozone	10
2-2-2-3. Nitrogen dioxide.....	10
2-2-2-4. Chlorinated hydrocarbons and Phosgene	10
2-3. How do these gases threaten the human health?	11
2-3-1. Respiratory damages.....	12
2-3-1-1. Pulmonary Function.....	12
2-3-1-2. Asthma.....	12
2-3-1-3. Metal Fume Fever (MFF).....	13
2-3-1-4. Bronchitis.....	13
2-3-1-5. Pneumoconiosis and Fibrosis.....	13
2-3-1-6. Respiratory Infection and Immunity.....	14
2-3-1-7. Lung Cancer.....	15
2-3-2. Non-Respiratory damages	15
2-3-2-1. Dermatological and Hypersensitivity Effects.....	15
2-3-2-2. Central Nervous System Effects.....	15
2-3-2-3. Prostate Cancer	15

	PAGE
2-3-2-4. Reproductive Effects.....	15
2-4. Fumes and gases allowance.....	18
2-5. Recommended control methods.....	19
2-6. Fume formation mechanism.....	20
2-7. Parameters which affect the fume formation.....	20
2-8. LASER technology.....	21
2-9. LASER ablation and its Usages	21
2-10. Ablation Parameters.....	22
2-10-1. Sampling Strategy.....	22
2-10-2. Chamber Shape.....	22
2-10-3. Sample Roughness.....	22
2-10-4. Transport System and carrier gas.....	23
2-11. LASER in welding.....	23
2-12. Diode LASER	32
2-13. Shielding gases	32
2-14. Traditional fume sampling.....	33
2-15. Particle size and morphology.....	40
2-16. Factors that affect fume generation.....	44
2-16-1. Shielding gas.....	44
2-16-2. Base metal composition.....	45
2-17. Sample analysis.....	45
3. EXPERIMENTAL PROCEDURE.....	49
3-1. LASER ablation chamber design.....	50
3-1-1. Objectives.....	50
3-1-2. Chamber design.....	50
3-1-3. Prospective materials and dimensions.....	51
3-1-4. Safety issues.....	51
3-2. New chamber adaptation.....	51
3-3. Sampling method.....	57
3-4. LASER spot size output.....	57
3-5. Weighing experiments.....	58
3-6. Generating fume weight Vs. Focal length in different atmospheres.....	58
3-7. Generating fume weight Vs. Laser power in different atmospheres.....	60
3-8. Analyses.....	62
3-8-1. SEM.....	62
3-8-1-1. Sample preparation and Imaging.....	62
3-8-1-2. EDS analysis.....	64
3-8-2. TEM.....	65
3-8-2-1. Sample preparation.....	65
3-8-2-2. TEM Imaging.....	67

	PAGE
3-8-2-3. EDS and STEM analyses.....	68
3-8-2-4. Particle Size Analysis.....	69
4. EXPERIMENTAL RESULTS.....	70
4-1. LASER chamber characteristics.....	71
4-2. Weighing experiments.....	73
4-3. SEM.....	75
4-3-1. Images.....	75
4-3-2. EDS and Map of elements.....	77
4-4. TEM	79
4-4-1. Images.....	79
4-4-2. EDS and map of elements.....	82
4-4-3. Particle Size Analysis.....	84
5. DISCUSSION.....	87
5-1. Chamber characteristics.....	88
5-2. Weighing experiments.....	88
5-3. Fume particle size.....	89
5-4. Fume morphology.....	90
5-5. Fume particle compounds.....	90
5-6. Recommendation.....	91
6. CONCLUSIONS.....	92
REFERENCES.....	94
APPENDIX.....	99