UNIVERSITI PUTRA MALAYSIA

SYNTHESIS AND THERMAL PROPERTIES INVESTIGATION OF COLLOIDAL NANOPARTICLES AND THEIR APPLICATIONS

MONIR NOROOZI

FS 2013 31

SYNTHESIS AND THERMAL PROPERTIES INVESTIGATION OF COLLOIDAL NANOPARTICLES AND THEIR APPLICATIONS

By

MONIR NOROOZI

Thesis submitted to the School of Graduates Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

May 2013

COPYRIGHT

DEDICATION

Specially Dedicated to My Beloved Family
and to My Beloved ONE ...

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in Fulfilment of the requirement for the degree of Doctor of Philosophy

SYNTHESIS AND THERMAL PROPERTIES INVESTIGATION OF COLLOIDAL NANOPARTICLES AND THEIR APPLICATIONS

By

MONIR NOROOZI

May 2013

Chairman: Professor Azmi Zakaria, PhD

Faculty: Science

Colloidal nanoparticles (NPs) have unique thermal, optical, electronic, and chemical properties that are extremely different from bulk materials due to their size. The central concerns in their preparation are the control of particle size, shape and the prevention of NPs agglomeration. In this relation, the objectives of the study are firstly, to green synthesize of silver nanoparticles (Ag NPs) in narrow distribution using green solvent and microwave (MW) irradiation as a cheap and fast method; secondly, to investigate the thermal diffusivity and the thermal effusivity of nanofluids by using PE technique; and thirdly, to increase the PE signal in optical fiber-thermal wave cavity (OF-TWC) technique by using Ag NPs film due to its strong optical absorption. In the first study, the fabrications of Ag NPs in water and ethylene-glycol as solvents at various MW reaction times were carried out. In the second study, a mathematical model of the multilayer samples by using thermal wave (TW) interferometry approach was developed and both Back- and Front-PE configurations were derived from it as special cases, the thermal diffusivity and thermal effusivity of nanofluids and the PE sensor were evaluated. In the third

study, the optical fiber tip was coated by Ag NPs to increase the PE signal in OF-TWC technique.

By increasing the MW irradiation time from 20 to 90 s the concentration of Ag NPs slightly increased and the NPs size increased from 7 to 12 nm. The Ag NPs prepared in ethylene glycol were more dispersed, more concentrated and more stable than those prepared in water. The observed difference may be ascribed to the high boiling points, molecular weight and dielectric loss of the ethylene glycol. The thermal diffusivity of nanofluids was investigated by using the Back-PE configuration in OF-TWC set-up. The linear increase in thermal diffusivity with Ag NPs volume fractions in nanofluids from 0 to 0.5 vol% has been observed, the highest value was 1.571×10^{-3} cm^2/s. However, the highest value of thermal diffusivity reduced to 1.456×10^{-3} cm^2/s after 3 h time of leave, due to the NPs agglomeration in solution. The higher thermal diffusivity of Al_2O_3 nanofluid prepared by probe sonication than by bath sonication is due to higher dispersion of NPs in water. The fragmentation by laser irradiation at low concentration reduced the agglomerated size of NPs and increased the thermal diffusivity values, e.g., from 1.444×10^{-3} to 1.498×10^{-3} cm^2/s for Al_2O_3 and from 1.477×10^{-3} to 1.537×10^{-3} cm^2/s for CuO nanofluid from 0 to 90 min irradiation. The Front-PE configuration was designed by using a PVDF film sensor to measure thermal effusivity of the sensor itself in Thermally Thick regime, and of the nanofluids for both Thermally Thick and Thermally Very Thick regimes. The thermal effusivities of the sensor obtained from the normalized amplitude, 464.5 $Ws^{1/2}m^{-2}K^{-1}$, and phase 479.1 $Ws^{1/2}m^{-2}K^{-1}$ are close to each other, and the experimental error is less than 0.3 % and differs by less than 4 % to literature. The thermal effusivity of the solvents such as deionized water, ethylene glycol and olive

oil obtained from the methods showed good agreement with literatures but reduced in the presence of NPs. The TW generator comprised of Ag NPs-coated onto an optical fiber end surface, showed a significant enhancement of PE signal in OF-TWC setup owing to surface Plasmon resonance and to strong optical absorption in Ag NPs. Laser irradiation to the surface melts the NPs and connects them together to form a continuous smooth Ag film on the optical fiber end surface.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SINTESIS DAN KAJIAN CIRI-CIRI TERMA KOLOID NANOZARAH DAN APLIKASINYA

Oleh

MONIR NOROOZI

Mei 2013

Pengerusi: Professor Azmi Zakaria, PhD

Fakulti: Sains

Nanozarah (NP) koloid mempunyai ciri-ciri unik terma, optik, elektronik dan kimia yang sangat berbeza daripada bahan pukal disebabkan oleh saiz mereka. Fokus utama dalam penyediaannya adalah kawalan saiz zarah, bentuk dan pencegahan aglomerasi NP. Dalam kaitan ini, objektif kajian adalah pertamanya, untuk melakukan sintisis hijau keatas nanozarah perak (Ag NPs) dalam taburan sempit menggunakan pelarut hijau dan penyinaran mikro-gelombang (MW) sebagai kaedah murah dan cepat; keduanya, untuk menyelidik keresapan terma dan efusiviti terma nanobendalir menggunakan teknik PE; dan ketiganya, untuk menambahkan signal PE dalam kaedah Serabut Optik-Rongga Gelombang Terma (OF-TWC) dengan menggunakan saput Ag NPs bersabit dari penyerapan optik tingginya. Dalam kajian pertama, fabrikasi Ag NPs dalam air dan etilena glikol sebagai pelarut pada pelbagai masa tindakan MW telah dilakukan. Dalam kajian kedua, model matematik dari

sampel multi-lapisan menggunakan pendekatan interferometri gelombang terma (TW) telah dibangunkan dan kedua-dua konfigurasi "PE-Belakang" dan "-Depan" telah diterbitkan daripadanya sebagai kes-kes khusus, keresapan terma dan effusiviti terma nanobendalir dan sensor PE telah diukur. Dalam kajian ketiga, hujung serabut optik telah disalut dengan Ag NPs untuk meninggikan signal PE dalam teknik OF-TWC.

Dengan meninggikan masa iradiasi MW dari 20 ke 90 s, kepekatan Ag NPs bertambah sedikit dan saiz NPs bertambah dari 7 ke 12 nm. Ag NPs disediakan dalam etilena glikol adalah lebih terserak, lebih pekat dan lebih stabil berbanding yang disediakan dalam air. Perbezaan pemerhatian boleh disabitkan dengan takat didih, berat molekul dan kehilangan dielektrik tinggi dari etilena glikol. Keresapan terma nanobendalir telah dikaji dengan meggunakan konfigurasi PE-Belakang dalam setup OF-TWC. Pertambahan linear dalam keresapan terma dengan pecahan-pecahan isipadu Ag NPs dalam nanobendalir daripada 0 to 0.5 vol% telah diperhatikan, nilai tertinggi adalah 1.571×10^{-3} cm^2/s. Walau bagaimana pun, nilai tertinggi keresapan terma menurun ke 1.456×10^{-3} cm^2/s setelah 3 j dibiarkan, disebabkan oleh aglomerasi NPs dalam larutan. Keresapan terma lebih tinggi bendalir Al2O3 disediakan secara pensonifikasi prob berbanding oleh pensonifikasi mandian adalah disebabkan oleh serakan lebih tinggi NPs dalam air. Fragmentasi oleh iradiasi laser pada kepekatan rendah merendahkan saiz aglomerasi NPs dan menambahkan nilai-nilai keresapan terma, e.g. 1.444×10^{-3} ke 1.498×10^{-3} cm^2/s untuk bendalir Al2O3 dan 1.477×10^{-3} ke 1.537×10^{-3} cm^2/s untuk bendalir CuO pada iradiasi 90 min. Konfigurasi PE-Depan telah direka-bentuk dengan menggunakan sensor filem PVDF untuk mengukur keresapan terma dari sensor itu sendiri dalam

kawasan TEBAL secara-terma, dan dari nanobendalir untuk kedua-dua kawasan TEBAL secara-terma dan AMAT TEBAL secara-terma. Efusiviti-efusiviti terma sensor didapatkan daripada amplitud ternormal, 464.5 $Ws^{1/2}$ $m^{-2}K^{-1}$, dan fasa 479.1 $Ws^{1/2}$ $m^{-2}K^{-1}$ adalah rapat diantara satu sama lain, dan ketidakpastian eksperimen adalah kurang dari 0.3% dan berbeza kurang dari 4% berbanding literatur. Efusiviti terma pelarut-pelarut seperti air ternyah-ion, etilena glikol dan minyak zaitun didapatkan dari kaedah ini menunjukkan persetujuan baik dengan literatur tetapi berkurangan dengan adanya NPs. Generator TW terdiri dari Ag NPs-tersalut diatas permukaan hujung serabut optik menunjukkan peningkatan signifikan signal PE dalam setup OF-TWC disebabkan resonans Plasmon permukaan dan penyerapan optik tinggi dalam Ag NPs. Iradiasi laser kepermukaan meleburkan NPs dan menghubungkan mereka bersama untuk membentuk filem Ag licin selanjar diatas permukaan hujung serabut optik.

ACKNOWLEDGEMENTS

First and foremost, I would like to extend my praise to Allah s.w.t. that gives me the patience, strength, determination, and courage to produce this thesis.

It is a great pleasure to acknowledge my supervisor, Prof. Dr. Azmi Zakaria for his guidance, suggestion, assistance, patient, tremendous support and invaluable advice throughout the duration of this project. I would also like to extend my sincere appreciation to my co-supervisors Prof. Dr. Mohd Maarof Moksin and Assoc. Prof. Dr. Zaidan Abdul Wahab for their advice and helpful discussion during this period of study.

I would like to thank the staff in Department of Physics and the Institute of Bioscience UPM for their co-operation throughout my work. I would also like to give my gratitude to Mohd Shahril Husin and my dear friends Sepideh Soltaninejad and Aiza Masyati Masut for all their personal and professional help. My sincere thanks to all my friends, and to my lab-mates in the Photoacousitic Laboratory who have directly or indirectly contributed towards the success of this study. In fact, all the students in the faculty of science were friendly and helpful, thank you for making my study a memorable and enjoyable one.

Especially, I dedicate this humble effort to my affectionate father (late), Houshang Noroozi, and my beloved mother, Kobra Motalebbi, who inspired me to higher ideals of life. Finally, I am greatly pleasured to acknowledge all the supports and encouragements of my beloved family; my husband, Mohammad Golestan, my sons, AliReza, Mehrdad , Adib, and my siblings throughout my studies.

I certify that a Thesis Examination Committee has met on 28 May 2013 to conduct the final examination of Monir Noroozi on her thesis entitled "Synthesis and Thermal Properties Investigation of Colloidal Nanoparticles and Their Applications" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Elias bin Saion, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Wan Mahmood Mat Yunus, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Abdul Halim bin Shaari, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

K. P. Vijayakumar, PhD
Professor
Universiti Cochin
India
(External Examiner)

NORITAH OMAR, PhD
Assoc. Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 2 August 2013

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as partial fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were follows:

Azmi Zakaria, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Mohd Maarof Moksin, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

Zaidan Abdul Wahab, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 2 AUGUST 2013

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institutions.

MONIR NOROOZI

Date: 28 May 2013

TABLE OF CONTENTS