



UNIVERSITI PUTRA MALAYSIA

**OPTICAL NONLINEARITIES AND THERMAL DIFFUSIVITY OF Ag
AND Au NANOFUIDS**

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**OPTICAL NONLINEARITIES AND THERMAL DIFFUSIVITY OF Ag AND
Au NANOFUIDS**

By

ESMAEIL SHAHRIARI

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

February 2011



DEDICATION

This thesis is dedicated to my immediate family, my daughter, my son and my wife who is convinced that she deserves to accept only the best challenges herself to give the best. I would like to thank my parents for their love and support.



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

**OPTICAL NONLINEARITIES AND THERMAL DIFFUSIVITY OF Ag AND
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Chairman: Professor Wan Mahmood Mat Yunus, PhD

Faculty: Science

In this study, nonlinear refractive index and nonlinear absorption of Ag nanometal polyvinylpyrrolidone (PVP), Au/PVP, and Au in polyvinyl alcohol (PVA) prepared by γ -radiation method were investigated using a single beam Z-scan technique. We measured the nonlinear refraction coefficient of silver nanofluid in concentrations ranging from 1.170×10^{-3} to 5.885×10^{-3} M and in sizes ranging from 17.8 to 64.1 nm. We found the nonlinear refractive index is in the range of -4.18×10^{-8} to -9.57×10^{-8} cm^2/W . This nonlinear effect increases as the concentration increases. A nonlinear relationship was obtained between nonlinear refractive index and particle size. The nonlinear absorption coefficient of Ag nanofluid at concentration of 4.71×10^{-3} M and three different sizes obtained to be 5.8×10^{-3} , 4.5×10^{-3} and 3.2×10^{-3} cm/W . The results show that the particle size gives a significant effect to the nonlinear absorption coefficient. Nonlinear refractive index and nonlinear absorption of Au



nanoparticle suspended in PVA solution at the range of concentration 1.471×10^{-4} to 7.063×10^{-4} M corresponding to particle size ranging from 7.0 to 58.0 nm was measured by using Z-scan technique. The Au nanofluid shows a good third-order nonlinear response. The sign of nonlinear refractive index is negative and the magnitude is in the range of -3.4×10^{-8} to -2.4×10^{-7} cm^2/W . This nonlinear effect is found to increase with the increasing of particle sizes. These results show that the Au/PVA nanofluid give significant values of nonlinear refractive index, thus it could be a good candidate for optical devices. The nonlinear optical characteristic of Au nanoparticle suspended in PVP solution at the range of concentration 2.354×10^{-4} to 2.354×10^{-3} M corresponding to particle size of 4.0 to 48.2 nm was also studied by using Z-scan technique. The nonlinear refractive index value is in the range of -4.34×10^{-8} to -1.06×10^{-6} cm^2/W . The nonlinear refractive index was found to increase with the increasing of concentration and particle sizes. All samples show the self-defocusing phenomenon.

A dual beam mode-mismatched thermal lens method was employed to investigate the dependence of thermal diffusivity of Ag/PVP, Au/PVA, and Au/PVP nanofluids on nanoparticles sizes and concentration. Thermal diffusivity of Ag/PVP nanofluids at concentration range of 1.170×10^{-3} to 5.885×10^{-3} M with particle size from 17.8 to 64.1 nm was found to be in the range of 1.22×10^{-3} to 2.87×10^{-3} cm^2/s . We found that thermal diffusivity of Ag/PVP nonlinearly increased with the increasing particle sizes and linearly increased with increasing the concentration of nanoparticles. Thermal diffusivity of Au/PVA nanofluids in the range of concentration 1.471×10^{-4} to 5.886×10^{-4} M and particle size ranging 7.0 to 41.2 nm was also measured and the values was ranging from 1.40×10^{-3} to 3.49×10^{-3} cm^2/s . The thermal diffusivity



increased systematically with concentration as increasing the doses. However, thermal diffusivity as a function of particle size increased unsystematically with increasing the irradiation dose. Thermal diffusivity of Au/PVP at two different concentrations, 4.708×10^{-4} M (particle size ranging from 13.0-40.3 nm) and 5.886×10^{-4} M (particle size ranging from 15.5-48.2 nm) has been measured and the value varied from 3.04×10^{-3} to 4.84×10^{-3} cm²/s. In this case, the results show that thermal diffusivity of Au/PVP nanofluids increases with increasing the particle size.

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

**CIRI TAKLINEAR OPTIKAL DAN PERESAPAN HABA OLEH Ag DAN Au
NANOBENDALIR**

Oleh

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Februari 2011

Pengerusi: Profesor Wan Mahmood Mat Yunus, PhD

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Di dalam kajian ini, indeks pembiasan taklinear dan penyerapan taklinear bagi nano-logam Ag polyvinylpyrrolidone (PVP), Au/PVP, dan nano-logam Au dalam polyvinyl alcohol (PVA) yang disediakan melalui kaedah radiasi- γ diselidiki menggunakan teknik imbasan-Z alur tunggal. Kami mengukur pemalar pembiasan taklinear nano-bendalir perak dalam kepekatan-kepekatan berjulat antara 1.170×10^{-3} hingga 5.885×10^{-3} M dan saiz berjulat daripada 17.8 hingga 64.1 nm. Kami mendapati indeks pembiasan taklinear adalah berjulat antara -4.18×10^{-8} hingga -9.57×10^{-8} cm²/W. Kesan taklinear ini meningkat dengan peningkatan kepekatan. Hubungan taklinear ini didapati antara indeks pembiasan taklinear dan saiz zarah. Pemalar penyerapan taklinear nano-bendalir Ag pada kepekatan 4.71×10^{-3} M dan tiga saiz berlainan diperolehi adalah 5.8×10^{-3} , 4.5×10^{-3} dan 3.2×10^{-3} cm²/W.

Keputusan ini menunjukkan bahawa saiz zarah memberikan kesan signifikan terhadap pemalar penyerapan taklinear. Indeks pembiasan taklinear dan penyerapan taklinear bagi nano-zarah Au terampai di dalam larutan PVA pada julat kepekatan 1.471×10^{-4} hingga 7.063×10^{-4} Ms bergantung kepada saiz zarah berjulat daripada 7.0 hingga 58.0 nm diukur menggunakan teknik imbasan-Z. Nano-bendalir Au menunjukkan respon taklinear tertib-ketiga yang baik. Tanda indeks pembiasan taklinear adalah negatif dan magnitud adalah dalam julat antara -3.4×10^{-8} hingga -2.4×10^{-7} cm²/W. Kesan taklinear dijumpai meningkat dengan pertambahan saiz zarah. Keputusan-keputusan ini menunjukkan bahawa nano-bendalir Au/PVA memberikan nilai-nilai signifikan bagi indeks pembiasan taklinear, lalu memungkinkannya sebagai calon baik untuk peranti-peranti optik. Pencirian taklinear optik bagi nano-zarah Au terampai di dalam cecair PVP pada julat kepekatan 2.354×10^{-4} hingga 2.354×10^{-3} M bergantung kepada saiz zarah daripada 4.0 hingga 48.2 nm telah diukur menggunakan teknik imbasan-Z. Nilai indeks pembiasan taklinear adalah berjulat antara -4.34×10^{-8} hingga -1.06×10^{-6} cm²/W. Indeks pembiasan taklinear dijumpai meningkat dengan pertambahan kepekatan dan saiz zarah. Semua sampel menunjukkan fenomena swa-takfokusan.

Kaedah kanta terma mod-ketakserasian dua alur digunakan untuk menyiasat kebergantungan resapan terma bagi nano-bendalir Ag/PVP, Au/PVA, dan Au/PVP ke atas pelbagai saiz nano-zarah dan kepekatan. Resapan terma bagi nano-bendalir Ag/PVP pada julat kepekatan antara 1.170×10^{-3} hingga 5.885×10^{-3} M dengan saiz zarah dari 17.8 hingga 64.1 nm ditemui berada dalam julat 1.22×10^{-3} hingga 2.87×10^{-3} cm²/s. Kami mendapati bahawa resapan terma bagi Ag/PVP meningkat secara tidak linear dengan pertambahan saiz zarah dan meningkat secara linear

dengan penambahan kepekatan nano-zarah. Resapan terma untuk nano-bendalir Au/PVA dalam julat kepekatan antara 1.471×10^{-4} hingga 5.886×10^{-4} M dengan saiz zarah berjulat 7.0 hingga 41.2 nm juga diukur dan nilai-nilai berada dalam julat dari 1.40×10^{-3} hingga 3.49×10^{-3} cm^2/s . Resapan terma meningkat secara sistematik dengan kepekatan apabila dos meningkat. Akan tetapi, resapan terma sebagai fungsi pada saiz zarah meningkat secara tidak sistematik dengan peningkatan dos radiasi. Resapan terma bagi Au/PVP pada dua kepekatan berbeza, 4.708×10^{-4} M (saiz zarah berjulat antara 3.0-40.3 nm) dan 5.886×10^{-4} M (saiz zarah berjulat antara 15.5-48.2 nm) telah pun diukur dan nilainya pelbagai dari 3.04×10^{-3} hingga 4.84×10^{-3} cm^2/s . Dalam kes ini, keputusan-keputusan menunjukkan bahawa resapan terma nano-bendalir Au/PVP meningkat dengan pertambahan saiz zarah



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This thesis was submitted to the senate of Universiti Putra Malaysia and has been acceptance fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the supervisory Committee were as follows:

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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 at any other institutions.

ESMAEIL SHAHRIARI
Date: 17 February 2011



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