UNIVERSITI PUTRA MALAYSIA

PARALLEL EVOLUTIONS OF MORPHOLOGY AND MAGNETIC PROPERTIES AND THEIR ATTENDANT RELATIONSHIPS IN POLYCRYSTALLINE YTTRIUM IRON GARNET

RODZIAH BINTI NAZLAN

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By

RODZIAH BINTI NAZLAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

January 2012

DEDICATION

To my beloved family and friends..

The world is moving faster;
We're on a changing course.
But you have helped me deal with life;
You've been a stable force.

When I have had to follow;
New directions, you were there.
When the world was hard on me;
You always seemed to care.

When nothing held together;
Made the slightest bit of sense.
You have always helped restore;
My inner confidence.

Everyone needs someone;
Who's reliable and true.
Through the moments I've endured;
I'm grateful there was you.

Thanks For Always Being There..

Abstract of thesis presented to Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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Chairman : Associate Professor Mansor Hashim, PhD

Faculty : Science

The parallel microstructure and magnetic-property evolutions in several polycrystalline Yttrium Iron Garnet (YIG) samples as a result of a sintering scheme were studied in detail, focusing on the attendant occurrence of their relationships: an aspect seemingly neglected, hitherto, in the garnet literature for past seven decades.

Samples with nanometer sized starting powder were synthesized by employing the high-energy ball milling (HEBM) technique and then sintering toroidal compacts of the milled powder. Two batches of samples were produced for single-sample and multi-samples sintering, each covering a range of sintering temperatures from 600°C to 1400°C. The samples were characterized by transmission electron microscopy (TEM), X-ray Diffraction (XRD), scanning electron microscopy (SEM), hysteresisgraph, impedance/material analyzer and picoammeter for their evolution stage in crystalline phases, microstructure, magnetic hysteresis-loop parameters,

magnetic permeability components, Curie temperature and electrical resistivity respectively.

With great experimental care, both the single-sample and multi-samples sintering batches yielded highly similar variation of magnetic properties versus microstructure of YIG. The results showed an increasing tendency of the saturation magnetization and saturation induction with grain size, which is attributed to crystallinity increase and to reduction of demagnetizing fields in the grains. The variation in coercivity could be related to anisotropy field changes within the samples due to grain size changes. In particular, the starting appearance of room temperature ferromagnetic order suggested by the sigmoid-shaped B-H loops seems to be dependent on a sufficient number of large enough magnetic domain-containing grains having been formed in the microstructure. Viewed simultaneously, the hysteresis loops appear to belong to three groups with different magnetism-type dominance, respectively dependent on phase purity and grain size distributions. A scrutiny of the permeability components, μ' and μ'', shows that there also tend to similarly belong to the above three sintering temperature related groups. The Curie temperature remained relatively stable, unaffected by the above evolutions, thus confirming its intrinsic character being dependent only on the crystal structure and compositional stoichiometry. The increased electrical resistivity while the microstructure was evolving is believed to strongly indicate improved phase purity and compositional stoichiometry.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENGEVOLUSIAN SELARI HUBUNGAN SEMASA ANTARA MORFOLOGI DAN SIFAT MAGNETIK DALAM POLIHABLUR YTTRIUM IRON GARNET

Oleh

RODZIAH BINTI NAZLAN

Januari 2012

Pengerusi : Profesor Madya Mansor Hashim, PhD

Fakulti : Sains

Pengevolusian selari mikrostruktur dan sifat magnet dalam sebilangan sampel polihablur Yttrium Iron Garnet (YIG) sebagai hasil skim pensinteran telah dikaji secara terperinci, dengan memfokuskan kepada kewujudan semasa hubungan mereka: suatu aspek yang sehingga kini diabaikan, di dalam literatur garnet sejak tujuh dekad yang lalu.

Sampel-sampel dengan serbuk permulaan bersaiz nanometer telah disintesis dengan menggunakan teknik pengisaran bola bertenaga tinggi (HEBM) dan seterusnya dengan mensinter kompak toroid serbuk yang telah dikisar. Dua kumpulan sampel telah dihasilkan iaitu pensinteran sampel tunggal dan pensinteran multi-sampel, setiap satunya merangkumi suhu pensinteran daripada 600°C ke 1400°C. Sampel-sampel tersebut telah dicirikan dengan menggunakan mikroskop elektron transmisi (TEM), pembelauan sinar-X (XRD), mikroskop elektron imbasan (SEM), hysteresisgraph, penganalisa impedans/bahan dan picoammeter masing-masing pada

peringkat evolusi mereka dalam fasa-fasa penghabluran, mikrostruktur, parameter magnetic gelung histeresis, komponen-komponen ketelapan magnetik, suhu Curie dan kerintangan elektrik.

Dengan pengawalan eksperimen yang baik, kedua-dua kumpulan sampel tunggal dan multi-sampel telah menghasilkan variasi yang hampir sama dalam sifat magnetik melawan mikrostruktur YIG. Hasil kajian menunjukkan kecenderungan peningkatan dalam kemagnetan tepu dan induksi tepu dengan saiz butiran, yang disebabkan oleh penghabuluran bertambah dan pengurangan medan nyahmagnet di dalam butiran. Kepelbagaian dalam daya paksa pula boleh dikaitkan dengan perubahan medan anisotropi di dalam sampel yang disebabkan oleh perubahan saiz butiran. Secara khususnya, permulaan kewujudan sifat ferromagnetik pada suhu bilik telah dicadangkan melalui gelung B-H berbentuk sigmoid yang kelihatan bergantung kepada bilangan mencukupi domain magnetik-mengandungi butiran yang cukup besar yang terbentuk di dalam mikrostruktur. Dilihat pada masa yang sama, gelung histeresis kelihatan tergolong kepada tiga kumpulan dengan dominasi jenis kemagnetan yang berbeza, masing-masing bergantung kepada ketulenan fasa dan taburan saiz butiran. Penelitian terhadap komponen-komponen ketelapan, μ' dan μ'' menunjukkan bahawa terdapat juga kecenderungan untuk bersama tergolong dalam tiga kumpulan suhu pensinteran seperti di atas. Suhu Curie relatifnya kekal stabil, tidak terjejas oleh pengevolusian seperti di atas, sekaligus mengesahkan bahawa ciri-ciri intrinsik hanya bergantung kepada struktur hablur dan stoikiometri komposisi sahaja. Peningkatan kerintangan elektrik semasa mikrostruktur mengevolusi dipercayai menunjukkan ketulenan fasa dan stoikiometri komposisi menjadi lebih baik.

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I certify that an Examination Committee has met on 31 January 2012 to conduct the final examination of Rodziah binti Nazlan on her Master of Science thesis entitled "An Exposition of Attendant Relationship Between Parallel Evolving Morphology and Magnetic Properties in Polycrystalline Yttrium Iron Garnet (YIG)" 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 rewarded the Master of Science degree.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. 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 acknowledge. 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 institution.

RODZIAH BINTI NAZLAN

Date: 31 January 2012

TABLE OF CONTENTS