UNIVERSITI PUTRA MALAYSIA

DIELECTRIC PROPERTIES OF ND-DOPED YTTRIUM IRON GARNET AND CU OR CO-DOPED NICKEL ZINC FERRITES

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By

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

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DEDICATION

I would like to dedicate this thesis to family members and all my friends.

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 **:Jumiah Binti Hassan, PhD**

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In this work, three series of soft ferrites were synthesized via solid state route. These are $Ni_{0.3-x}Cu_xZn_{0.7}Fe_2O_4$ (x= 0.0, 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30), $Ni_{0.5-x}Co_xZn_{0.5}Fe_2O_4$ (x=0.0, 0.1, 0.2, 0.3, 0.4, and 0.5) and $Y_{3-x}Nd_xFe_5O_{12}$ (x=0.0, 0.4, 0.8, 1.2 and 1.6). The X-ray diffraction patterns showing single phases for these three samples series, confirmed that the spinel and garnet structure had been formed in the Ni-Zn ferrites and YIG respectively.

Ni-Zn ferrites substituted with copper oxide showed exaggerated grain growth whereas the other series substituted with cobalt oxide had no massive changes in the microstructure. For the YIG substituted with neodymium oxide, the first sample exhibited a porous microstructure and developed to become a more compact and poreless microstructure as neodymium increased.

Measurement of the electrical properties was carried out in the temperature range from 28°C to 300°C in the low frequency region of 10 Hz to 1 MHz. Impedance

analyzer was employed in the ac data acquisition whereas a pico-ammeter and a dc voltage source were used to measure electric current at different voltages.

The results obtained from dielectric measurements indicate that microstructure of the samples plays an important role in the dielectric dispersion. A sample with higher porosity is associated with a low value of dielectric permittivity due to its high resistivity. Meanwhile a sample with a more compact structure exhibits higher dielectric permittivity due to its higher conductivity. Hence, electron hopping between Fe^{2+} and Fe^{3+} would increase in the conductive sample and give higher dielectric permittivity if compared with the resistive one.

The dielectric response for every sample in the three series of soft ferrites displayed different mechanisms throughout the investigated temperature range. Therefore, dielectric behaviour of a sample can be modeled into at least two equivalent circuits.

The complex impedance plots of both samples Ni-Zn ferrites and YIG showed overlapping semicircles. However, at high temperature the high frequency arc disappeared and there remained just one semicircle. The center of the semicircle for all samples was depressed below the real impedance axis and described by the parameter α. The results indicate that all these three series of soft ferrites can be represented by two parallel RC circuits connected in series that correspond to the contributions of grain and grain boundary.

The ac conductivity for the three series of soft ferrites showed almost similar behaviour. At lower temperature, the ac curves can be divided into two region. The

low frequency region showed that the ac conductivity was weakly dependent on frequency whereas at high frequency region, it was strongly dependent on frequency. As the temperature increased, the ac conductivity seemed independent of frequency. Extrinsic and intrinsic conductions had been inferred to occur in these samples.

It is also found that microstructural entities such as grains and porosity play an important role in the dc resistivity. The two activation energies obtained indicated that there were probably two parallel conduction mechanisms or spin reorientation phase transition occurred.

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

SIFAT DIELEKTRIK GARNET BESI YTTRIUM YANG DIDOPKAN DENGAN Nd DAN FERIT NIKEL ZINK YANG DIDOPKAN DENGAN Cu ATAU Co

Oleh

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Dalam kajian ini, tiga siri ferit lembut telah disediakan melalui tindak balas keadaan pepejal. Ferit yang dimaksudkan adalah $Ni_{0.3-x}Cu_xZn_{0.7}Fe_2O_4$(x= 0.0, 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30), $Ni_{0.5-x}Co_xZn_{0.5}Fe_2O_4$(x=0.0, 0.1, 0.2, 0.3, 0.4, and 0.5) dan $Y_{3-x}Nd_xFe_5O_{12}$(x=0.0, 0.4, 0.8, 1.2 and 1.6). Pembelauan sinar-x mengesahkan kesemua sampel dalam fasa tunggal dengan struktur spinel dan garnet.

$Ni_{0.3-x}Cu_xZn_{0.7}Fe_2O_4$ didapati mengalami proses pertumbuhan butiran yang ketara manakala $Ni_{0.5-x}Co_xZn_{0.5}Fe_2O_4$ tiada perubahan yang ketara dalam mikrostruktur. Untuk $Y_{3-x}Nd_xFe_5O_{12}$, pada mulanya menunjukkan liang yang banyak tetapi kemudian menjadi semakin tumpat dan kurang liang apabila kandungan neodymium meningkat.

Pengukuran sifat elektrik telah dilakukan pada julat suhu diantara 28°C dan 300°C pada frekuensi rendah daripada 10 Hz hingga 1 MHz. Mesin analisis impedans telah digunakan untuk memperolehi data ac manakala piko ammeter dan punca voltan dc digunakan untuk pengukuran arus terus pada voltan yang berlainan.

Daripada sifat dielektrik yang diperolehi, didapati mikrostruktur memainkan peranan yang penting. Sampel yang mempunyai liang yang banyak mempunyai nilai dieletrik yang rendah. Ini disebabkan sampel yang mempunyai lebih keliangan mempuyai rintangan yang lebih besar dan seterusnya melarang elektron yang melompat di antara Fe^{2+} dan Fe^{3+} yang menyebabkan polarisasi dalam ferit.

Sifat dielektrik untuk setiap sampel dalam tiga siri ferit ini menunjukkan mekanisma yang berlainan pada suhu yang berbeza. Jadi, satu sampel biasanya boleh diwakili oleh sekurang-kurangnya dua model litar setara dalam julat suhu kajian ini.

Komplek impedans untuk ketiga-tiga sampel ferit lembut menunjukkan dua lengkung semibulatan bertindih. Akan tetapi, pada suhu yang tinggi, lengkung semibulatan pada frekuensi yang tinggi lenyap dan meninggalkan hanya satu lengkung semibulatan. Semua semibulatan mempunyai pusat yang tertekan ke bawah paksi nyata impedans. Keputusan menunjukkan kebanyakan sampel boleh diwakili oleh dua litar RC yang selari disambung secara siri yang disebabkan oleh butiran dan sempadan butiran sampel.

Konduktiviti ac untuk ketiga-tiga siri sampel ini menunjukkan kelakuan yang agak sama. Pada suhu yang rendah, lengkung ac boleh dibahagikan kepada dua bahagian. Pada bahagian frekuensi rendah, kekonduksian ac bergantung lemah terhadap frekuensi manakala pada frekuensi tinggi, ia bergantung kuat kepada frekuensi. Apabila suhu meningkat, kekonduksian ac hampir tidak bergantung kepada frekuensi. Kekonduksian ektrinsik dan intrinsik dipercayai berlaku dalam sampel-sampel ini.

Mikrostruktur seperti butiran dan liang didapati memainkan peranan yang penting dalam kekonduksian arus terus. Dua tenaga pengaktifan diperolehi dipercayai disebabkan oleh kewujudan dua mekanisma kekonduksian yang selari atau fasa translasi putaran reorientasi telah berlaku.

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