



THE REPUBLIC OF INDONESIA DEFENSE UNIVERSITY

**DEVELOPMENT OF ZIRCONIUM AND ZINC-SUBSTITUTED
NICKEL FERRITE COMPOSITE FOR RADAR ABSORBING
MATERIALS IN MILITARY APPLICATION**

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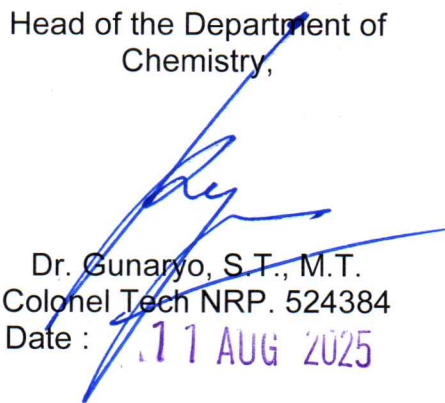


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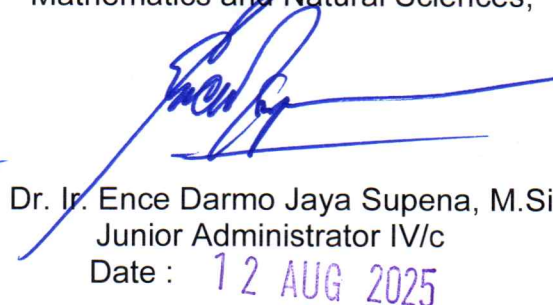
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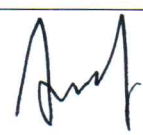
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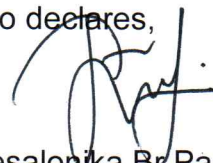
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“Aku ditolak dengan hebat sampai jatuh, tetapi Tuhan Menolong aku.”
(Mazmur 118:13)



Bogor, July, 2025

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ABSTRAK

PENGEMBANGAN KOMPOSIT NIKEL FERIT YANG TERSUBSTITUSI ZIRKONIUM DAN SENG UNTUK BAHAN PENYERAP GELOMBANG RADAR DALAM APLIKASI MILITER

Pengembangan bahan penyerap radar (RAM) yang efektif sangat penting untuk meningkatkan teknologi siluman dalam aplikasi militer. Penelitian ini bertujuan untuk menyintesis dan mengarakterisasi komposit zirkonium dan nikel ferit tersubstitusi seng ($\text{NiZr}_x\text{Zn}_x\text{Fe}_{2-2x}\text{O}_4$) yang dikombinasikan dengan polipirola (PPy) sebagai matriks konduktif. Ferit disintesis menggunakan metode kopresipitasi dengan variasi komposisi $x = 0, 0,25, 0,5, 0,75$, dan 1, dilanjutkan dengan polimerisasi *in situ* dengan PPy. Karakterisasi menggunakan XRD, SEM, VSM, dan VNA menunjukkan bahwa substitusi Fe dengan Zr dan Zn mempengaruhi kristalinitas, sifat magnetik, dan kinerja penyerapan gelombang mikro komposit. Sampel dengan $x = 0,75$ menunjukkan magnetisasi saturasi tertinggi ($M_s = 32,97 \text{ emu g}^{-1}$) dan *Reflection Loss* optimal yang mencapai -8,33 dB. Nikel ferit tersubstitusi/PPy dengan ketebalan 1 mm menghasilkan nilai RL yang lebih tinggi yaitu sebesar -16,68 dB menunjukkan efek sinergis antara kehilangan dielektrik PPy dan kehilangan magnetik ferit dengan *through power* 97,85%. Hasil ini menunjukkan bahwa komposit $\text{NiZr}_x\text{Zn}_x\text{Fe}_{2-2x}\text{O}_4/\text{PPy}$ memiliki potensi yang kuat sebagai RAM yang efektif untuk aplikasi siluman militer.

Kata Kunci : Komposit, Material Penyerap Gelombang Radar, Nikel Ferit, Polipirola

ABSTRACT

DEVELOPMENT OF ZIRCONIUM AND ZINC-SUBSTITUTED NICKEL FERRITE COMPOSITE FOR RADAR ABSORBING MATERIALS IN MILITARY APPLICATION

The development of effective radar absorbing materials (RAMs) is crucial for enhancing stealth technology in military applications. This study aims to synthesize and characterize zirconium and zinc-substituted nickel ferrite ($\text{NiZr}_x\text{Zn}_x\text{Fe}_{2-2x}\text{O}_4$) composites combined with polypyrrole (PPy) as a conductive matrix. The ferrite was synthesized using the coprecipitation method with compositional variations $x = 0; 0.25; 0.5; 0.75; \text{ and } 1$, followed by *in situ* polymerization with PPy. Characterization using XRD, SEM, VSM, and VNA revealed that substitution with Zr and Zn affects the crystallinity, magnetic properties, and microwave absorption performance of the composite. The sample with $x = 0.75$ showed the highest saturation magnetization ($M_s = 32.97 \text{ emu g}^{-1}$) and optimal reflection loss reached -8.33 dB . Substituted nickel ferrite/PPy with 1 mm thickness produces higher RL value of -16.68 dB indicating a complementary relationship between the dielectric loss of PPy and the magnetic loss of ferrite with through power 97.85% . These results suggest that the $\text{NiZr}_x\text{Zn}_x\text{Fe}_{2-2x}\text{O}_4/\text{PPy}$ composite has strong potential as an effective RAM for military stealth applications.

Keywords : composite, radar absorbing material, nickel ferrite, polypyrrole

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LIST OF ABBREVIATION



dB	: Decible
EDX	: Energy Dispersive X-Ray
EMI	: Electromagnetic Interference
FWHM	: Full Width at Half Maximum
Hc	: Coercivity
JCPDS	: Joint Committee on Powder Diffraction Standards
Mr	: Remanent Magnetization
Ms	: Saturation Magnetization
MUT	: Material Under Test
PEC	: Perfect Electric Conductor
PPy	: Polypyrrole
RADAR	: Radio Detection and Ranging
RAM	: Radar Absorbing Material
RC	: Reflection Coefficient
RCS	: Radar Cross Section
RL	: Reflection Loss
RWA	: Radar Wave Absorber
SEM	: Scanning Electron Microscopy
TC	: Transmission Coefficient
VNA	: Vector Network Analyzer
VSM	: Vibrating Sample Magnetometer
XRD	: X-Ray Diffraction