ANNOTATION

of dissertation for the degree of Doctor of Philosophy PhD in the specialty

8D07104 Chemical technology of inorganic substances

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on the topic: "Creating and Studying New Composite Materials for Microwave Absorption in the Range of 8.8-12 GHz"

Relevance of the work Electromagnetic interference (EMI) is a well-known problem in radar and antenna systems and electronic devices. EMI is an unwanted electromagnetic (EM) wave that works as a noise that disturbs the natural operation of electronic devices. This noise arises from electronic devices that release EM waves, such as mobile phones, wireless devices, television/computer screens and cordless microphones in halls. Generally, EMI would be regarded as an unwanted result of modern technology that has dangerous effects on human health, intelligent devices, telecommunication devices, and military industries. Consequently, the effective disposal of EM waves from EMI is so important for public protection security and electronic safety. The development of radar or microwave absorbing materials technology has had a great impact on the military field. Radar absorbing materials (RAMs) are significant tools in electronic warfare, as they can be used to hide targets and protect them from radar detection. EM shielding materials and RAMs have been produced by international companies at high prices. In this regard, the relevance of the research topic of the doctoral dissertation is paving the way for putting the methodology and scientific bases for the manufacture of microwave absorbent materials (MAMs) in the laboratory with the required international quality. As well as competing with commercial absorbers mentioned in the literature in terms of weight, reflection loss, absorption bandwidth, and shielding efficiency.

Purpose of the work: to find optimum parameters for producing new RAMs characterized by strong minimal reflection loss (Rl_{min}), high maximum shielding efficiency (SE_{max}), broad absorption bandwidth under -10 dB ($BW_{-10\,dB}$) and low surface density (SD) in the range of 8.8–12.0 GHz.

Tasks of the work:

1) Detecting the effect of molar ratios of metal ions to citrate acid (1:1, 2:1, and 3:1), and aqueous solutions of polyvinyl alcohol (PVA) (1%, 4%, and 6%) on the RL_{min}, matching frequency (f_m), and SE_{max}.

2) Figuring out the effect of adding the dielectric loss and magnetic loss materials on the nano ferrite properties and determining the weight ratios of nanocomposites, which has the greatest positive impact on the RL_{min}, f_m, $BW_{-10\ dB}$, SD and SE_{max}.
3) Revealing the effect of the loading percentage of hybrid nanocomposite in the host matrix, and weight ratios of PANI/$Ni^{3+}_{0.25}Ni^{2+}_{0.375}Zn^{2+}_{0.25}Fe_2O_4$, and PANI/$BaNiZnFe_{16}O_{27}$ on the EMI shielding and MA properties.
4) Detecting the effect of adding carbon black (CB) and carbonyl iron (CI) to hybrid nanocomposites on the RL_{min}, $BW_{-10\ dB}$, SD and SE_{max}.

Research methods

The prepared samples were structurally characterized using XRD, FTIR, TGA, and EDX. SEM was utilized to define the morphology of the powders. Finally, the prepared samples were functionally characterized utilizing the horn antenna connected to an oscilloscope.

The scientific novelty of the research results obtained is ascertained by the fact that for the first time:

- Creating new absorbents by incorporating magnetic loss and dielectric loss materials that can decrease the loading percentage, increase the absorption $BW_{-10\ dB}$, and enhance the SE_{max} of the absorbents to cover most of the frequency band of 8.8–12.0 GHz.
- A low loading percentage of PANI/$Ni^{3+}_{0.25}Ni^{2+}_{0.375}Zn^{2+}_{0.25}Fe_2O_4$ nanocomposite in the host matrix of 25% was reached, which is one of the lowest published loading percentages globally.
- New absorbers have been revealed that can exceed the -10 dB threshold and cover the entire frequency band of 8.8–12.0 GHz by adding CB and CI to the hybrid nanocomposites. These absorbers are competitive with commercial absorbers.

Theoretical significance: The results of the dissertation research expanded the known knowledge in the field of producing EMI shielding materials and MAMs to suppress EMI and improve the effectiveness of electronic devices.

The practical significance.

1) This project (the first of its kind in the Republic of Kazakhstan as an academic attempt to prepare radar absorption materials) constitutes a nucleus for subsequent research at the

Al-Farabi Kazakh National University and the other universities in Kazakhstan in the preparation field of radar absorption materials.

2) The optimal parameters for the fabrication of microwave absorber nanocomposites at the whole frequency band of 8.8–12.0 GHz with low SD obtained from magnetic loss and dielectric loss materials were determined.
3) It was revealed that PANI/spinel ferrite (SF)/hexagonal ferrite (HF) and PANI/SF/HF/CB nanocomposites obtained from in-situ polymerization had the best results to absorb microwaves. The absorption percentage of microwaves reached about 99.9% with a loading percentage of 30%.

The main provisions for the defense of the thesis:

1) Increasing the metal ions to citrate acid and PVA concentration in the ferrite leads the RL attenuation peaks of samples to shift to lower frequencies. This allows the position of the f_m to be controlled.
2) The synergistic incorporation of magnetic loss and dielectric loss materials leads to decreasing the loading percentage of the absorber in the host matrix, increasing the absorption $BW_{-10\ dB}$, and enhancing the SE_{max} of the absorbers to cover most of the frequency band of 8.8–12.0 GHz.
3) Detecting that the RL attenuation peaks of hybrid nanocomposites moved to higher frequencies by increasing the PANI in the hybrid nanocomposites. These results lead to the possibility to control the absorption $BW_{-10\ dB}$, RL_{min}, and f_m of the absorbers.
4) Enhancing the RL value and obtaining 99.9% absorption to the microwave with improving SE and SD by adding CB and CI to the hybrid nanocomposites.

The object of the research is microwave absorbers incorporated from magnetic loss and dielectric loss materials.

The subject of research is obtaining microwave absorbers prepared by different physical and chemical methods. Evaluating the characteristics of the absorbers by measuring RL, SE, absorption $BW_{-10\ dB}$ and SD.

Relation to the plan of state research programs

This dissertational work was carried out without any framework.

The personal contribution of the author of the work consists of the collection, processing and analysis of literature data on the topic of the thesis, direct planning and implementation of the experimental part. The applicant took part in the analysis, interpretation and presentation of the obtained research results and their discussion, as well as in the preparation of scientific articles.

Approbation of thesis

The materials of the thesis were reported and discussed at various international conferences:

- International Scientific Conference of Students and Young Scientists "CHEMICAL PHYSICS AND PHYSICAL CHEMISTRY" (Al-Farabi Kazakh National University, Almaty, Kazakhstan, 6-8 April 2021).
- 11th International Beremzhanov Congress on Chemistry and Chemical Technology "Fundamental and Applied Materials Science", Almaty, Kazakhstan, 19-20 November 2021.
- Youth Chemistry Conference (Nazarbayev University, Astana, Kazakhstan, November 20, 2021).
- International Scientific Conference of Students and Young Scientists"CHEMICAL PHYSICS AND PHYSICAL CHEMISTRY" (Al-Farabi Kazakh National University, Almaty, Kazakhstan, 6-8 April 2022).

Publications

The main research results on the topic of the dissertation are presented in 10 published works, including:

- One scientific article, published in a journal has an impact factor according to the Scopus database.
- Two scientific articles, published in a journal indexing to the Web of Science database.
- One scientific article, published in a journal recommended by the Committee for Control in the Sphere of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan.
- Four abstracts at international conferences.
- Two scientific articles at international journals.

Description doctoral contribution to the preparation of each publication.

- The doctoral student was directly involved in preparing and measuring samples, obtaining experimental data, processing and interpreting experimental results, and also took part in the implementation of physicochemical studies for the design of the article «Synthesis and

Microwave Absorption Properties of $Ni_{0.5}Zn_{0.5}Fe_2O_4$/CI Composite Coated with Polyaniline within Paraffin Wax Matrix» in the journal «Bulletin of the University of Karaganda – Chemistry No. 3 (107)/2022» (Web of Science database) https://doi.org/10.31489/2022Ch3/3-22-8.

- The doctoral student was directly involved in preparing and measuring samples, obtaining experimental data, processing and interpreting experimental results, and also took part in the implementation of physicochemical studies for the design of the article «Synthesis and microwave absorption properties of ($Ni_{0.5}Zn_{0.5}Fe_2O_4$/CI/CB) ternary composites» in the journal «Bulletin of the University of Karaganda – Chemistry No. 4 (108)/2022» (Web of Science database) https://doi.org/10.31489/2022Ch4/4-22-9.
- The doctoral student was directly focused on studying microwave-absorbent ferrites, obtaining experimental data, processing and interpreting experimental results, and also took part in the implementation of the design of the article «Microwave absorbing properties of ferrites and their composites» in the journal «Journal of Magnetism and Magnetic Materials Volume 529, 1 July 2021» (Scopus database, IF 2.99. Quartile Q2). https://doi.org/10.1016/j.jmmm.2021.167839.
- The doctoral student was directly involved in designing and measuring samples, obtaining experimental data, processing and interpreting experimental results, and also took part in the implementation of physicochemical studies for the design of the article «Microwave absorption and electromagnetic interference shielding properties of carbon black/MnNiZn nanocomposites-filled paraffin wax in the frequency range (8.8-12 GHz) » in the journal «KazNU Journal. Recent Contributions to Physics. №2 (81). 2022» https://doi.org/10.26577/RCPh.2022.v81.i2.011.
- The doctoral student was directly involved in designing and measuring samples, obtaining experimental data, processing and interpreting experimental results, and also took part in the implementation of physicochemical studies for the design of the article «Microwave Absorption Behavior of Low Loading Ratio of $Ni^{3+}_{0.25}Ni^{2+}_{0.375}Zn^{2+}_{0.25}Fe_2O_4$ Nanoparticles Coated with Polyaniline Within Paraffin Wax Matrix» in the journal «Advances in Theoretical & Computational Physics. Volume 5, Issue 2, 2022» https://doi.org/10.33140/ATCP.05.02.03.
- The doctoral student was directly involved in designing and measuring samples, obtaining experimental data, processing and interpreting experimental results, and also took part in the implementation of physicochemical studies for the design of the article «Electromagnetic Interference Shielding Properties of ($Ni_{0.5}Zn_{0.5}Fe_2O_4$/CI/CB) Ternary Composites-Filled Paraffin Wax Matrix» in the journal «Journal of Chemistry: Education Research and Practice. Volume 6, Issue 2, 2022» https://doi.org/10.33140/JCERP.06.02.18.