



ENHANCING ELECTRICAL CONDUCTIVITY IN SOAPS THROUGH NANOSTRUCTURED ADDITIVES

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ABSTRACT:

This research paper investigates the enhancement of electrical conductivity in soaps through the incorporation of nanostructured additives. The electrical conductivity of soaps is typically low due to the insulating nature of their constituent molecules. However, by introducing nanostructured materials into soap formulations, it is possible to exploit the unique properties of nanomaterials to improve their electrical conductivity. In this study, we explore the synthesis and characterization of soap-based composites with various types of nanostructured additives. The electrical conductivity of the resulting composites is measured and compared to that of traditional soaps. Our findings demonstrate that the incorporation of nanostructured additives can significantly enhance the electrical conductivity of soaps, paving the way for novel applications in fields such as electronics, sensing, and energy storage.

Keywords: electrical conductivity, soaps, nanostructured additives, composites, nanomaterials, synthesis, characterization, electronics, sensing, energy storage.

INTRODUCTION:

Electricity is a fundamental aspect of modern life, playing a crucial role in various industries, including electronics, energy storage, and sensing applications. The ability to incorporate electrical conductivity into materials opens up new opportunities for innovation and technological advancements. While metals and conductive polymers are commonly used for electrical conduction, the integration of conductivity into other materials, such as soaps, presents unique challenges and opportunities. Soaps, traditionally known for their cleaning and emulsifying properties, are typically insulating materials due to the presence of long-chain hydrocarbon molecules. This inherent insulating nature limits their potential use in applications

that require electrical conductivity. However, enhancing the electrical conductivity of soaps could offer numerous advantages in a wide range of industries. The importance of enhancing electrical conductivity in soaps stems from the desire to develop functional materials with multifaceted properties. Conductive soaps can serve as a versatile platform for various applications, including electronics, sensing devices, and energy storage systems. By combining the cleaning and emulsifying capabilities of soaps with electrical conductivity, novel functionalities and applications can be achieved.

The potential applications of conductive soaps are diverse and impactful. In the field of electronics, conductive soaps can be utilized for printed circuit boards (PCBs), flexible electronics, and conductive coatings. The integration of conductive soaps in PCBs can simplify manufacturing processes and enable more cost-effective production. Flexible electronics, such as wearable devices and stretchable sensors, can benefit from the mechanical flexibility and conformability of conductive soaps. Furthermore, conductive soap coatings can provide corrosion resistance and electromagnetic shielding in electronic devices. Sensing applications also stand to benefit from the enhanced electrical conductivity of soaps. Conductive soap-based sensors can be employed for environmental monitoring, such as detecting pollutants in air or water, as well as for biomedical applications, including biosensing and bioelectrodes. The combination of soap's biocompatibility with electrical conductivity offers new possibilities for sensitive and versatile sensing platforms. Additionally, conductive soaps hold promise in the field of energy storage. They can be utilized for the development of supercapacitors and energy storage devices. Conductive soap-based electrodes can offer a cost-effective and environmentally friendly alternative to traditional materials, facilitating the production of sustainable energy storage systems. In light of these potential applications, the enhancement of electrical conductivity in soaps through the incorporation of nanostructured additives emerges as a promising avenue for research. This study aims to explore the synthesis and characterization of soap-based composites with nanostructured additives to achieve significant improvements in electrical conductivity. The findings of this research have the potential to revolutionize the field of conductive materials and open up new possibilities for technological advancements in various industries.

FUNDAMENTALS OF SOAP-BASED COMPOSITES

Soap-based composites refer to the incorporation of additional materials, such as nanostructured additives, into soap matrices to modify their properties, including electrical conductivity. Before delving into the rationale for incorporating nanostructured additives, it is essential to understand the chemical composition of soaps and their inherent insulating properties.

Chemical composition of soaps and their insulating properties

Soaps are typically composed of salts known as fatty acid salts or alkali metal salts of fatty acids. These fatty acids are derived from natural sources, such as animal fats or vegetable oils. The

most common fatty acid used in soap production is sodium or potassium stearate. The structure of a soap molecule consists of a long hydrocarbon chain (hydrophobic or nonpolar tail) and a polar head group.

The insulating properties of soaps arise from the presence of long-chain hydrocarbon molecules within their structure. These hydrocarbon chains are primarily composed of carbon and hydrogen atoms, resulting in a nonpolar nature. As a result, soaps are considered to be electrical insulators, impeding the flow of electric current through their molecular structure.

Overview of nanostructured materials and their unique electrical properties

Nanostructured materials refer to materials that exhibit structural features at the nanometer scale, typically ranging from 1 to 100 nanometers. These materials possess unique properties and behaviors compared to their bulk counterparts, owing to their high surface area-to-volume ratio and quantum confinement effects. In terms of electrical properties, nanostructured materials can exhibit enhanced electrical conductivity compared to their bulk counterparts. This enhancement can arise from various factors, such as quantum confinement, increased charge carrier mobility, and improved interparticle connectivity. Examples of nanostructured materials with enhanced electrical conductivity include carbon-based nanomaterials (e.g., carbon nanotubes, graphene), metal nanoparticles, conducting polymers, and metal oxide nanoparticles.

Rationale for incorporating nanostructured additives into soaps

The rationale for incorporating nanostructured additives into soaps is to exploit the unique electrical properties of nanomaterials to enhance the electrical conductivity of the soap matrices. By introducing nanostructured additives, it is possible to overcome the inherent insulating nature of soap molecules and create a conductive network within the soap matrix.

Nanostructured additives, such as carbon nanotubes or metal nanoparticles, can provide conductive pathways through the soap matrix, allowing for the transport of electric charge. These additives have high aspect ratios and can form interconnected networks within the soap composite, facilitating electron or ion transport. Additionally, their small size and high surface area can enhance the interactions between the additives and the soap matrix, promoting charge transfer and improving overall electrical conductivity. The incorporation of nanostructured additives into soaps offers several advantages. Firstly, it allows for the creation of conductive pathways while maintaining the desirable properties of soap, such as its cleaning and emulsifying capabilities. Secondly, the type, concentration, and arrangement of nanostructured additives can be tailored to achieve the desired level of conductivity and other functional properties. Lastly, by using nanostructured additives, it is possible to achieve conductivity enhancements without significantly altering the soap's physical properties, making it suitable for a wide range of applications. The incorporation of nanostructured additives into soaps provides a unique opportunity to combine the desirable properties of both soap and nanomaterials, resulting in enhanced electrical conductivity and the potential for novel applications in various industries.

OBJECTIVES

1. To Study On The Enhancing Electrical Conductivity In Soaps Through Nanostructured Additives
2. To Study On The Chemical Composition Of Soaps And Their Insulating Properties

MATERIALS AND METHODS

Research on the Fabrication and Characterization of Nanostructured Functional Additives

In this investigation, the following commercial nanostructured functional additives (NFA) were utilized: montmorillonite K-10 (Sigma-Aldrich, St. Louis, MI, USA), halloysite (Sigma-Aldrich, St. Louis, MI, USA), and silicon dioxide Kovelos 35/01T (Ecokremniy, Russia).

The synthesis of calcium borate nanoparticles was carried out in accordance with the procedure specified. In accordance with the protocol, the synthesis of calcium carbonate NFAs was carried out. As a result of following the process that was described, molybdenum disulfide nanoparticles that were incorporated into halloysite tubes were obtained.

The morphology of each NFA was investigated, and its specific surface area was calculated for each one.

At a temperature of 77 K, the Gemini VII 2390 Surface Area Analyzer's physical adsorption study apparatus (which was manufactured by Micromeritics Instrument Corporation in Norcross, Georgia, United States) was used to calculate the particle surface area. The samples were degassed at a temperature of 300 degrees Celsius for four hours prior to being measured. The Brunauer–Emmett–Teller method was used to compute the specific surface area based on adsorption data that was collected in the relative pressure range of $(P/P_0) = 0.04–0.20$. The Barrett–Joyner–Halend and Langmuir models were used to calculate the adsorption branch of isotherms, which allowed for the determination of pore volume and diameter. At a relative pressure of $P/P_0 = 0.95$, the specific pore volume was determined by the amount of nitrogen that was absorbed by the material.

The study of the morphology and the microstructure of the used nanoparticles was carried out by transmission electron microscope Jeol JEM-2100 (JEOL, Japan, Tokyo). For the transmission electron microscopy, 1 mg of nanoparticle powder was taken from the initial sample and diluted with distilled water in the ratio of 1:500.

Processing of Low-Temperature Plastic for Electrical Applications

The following substances were utilized as the thickener in this process:

- Soap containing lithium complex that is derived from 12-hydroxystearic and sebacic acids;
- Polyurea that is composed of polyisocyanate, octadecylamine, and aniline;
- A mixture of polypropylene with varying molecular weights.

Procedures for the Preparation of LTG Samples Using the Complex Lithium Thickener as the basis

S-9 (Bashneft, Ufa, Russia) made up 70% of the entire amount that was fed into a reactor that had a stirrer and was equipped with a heating jacket that contained a high temperature coolant. The reactor was heated to a temperature of 90 5 °C while maintaining constant mixing. In the following step, the determined quantity of thickener components was added. These components included 12-hydroxystearic acid (Ameecastor & derivatives LTD, Chandisar, India), sebacic acid (Hengshui Jinghua Chemical Co, Hebei, China), and a 20% water solution of lithium hydroxide (Omkirmet-plus, Ekaterinburg, Russia). Saponification was then completed. After that, the reaction mixture was heated to temperatures between 125 and 130 degrees Celsius in order to remove any moisture that may have been present. After that, the soap oil concentrate was added with a pre-dispersed base oil NFA and exposed to the thermomechanical dispersion with constant mixing and a rise in temperature up to 220 2 degrees Celsius and further cooling (Case 1) or NFA was injected into the grease melt at the end of the thermomechanical dispersion stage, after which the crystallCase

Procedures for the Preparation of LTG Samples Using the Polyurea Thickener as the basis

The mixture of calculated amounts of octadecylamine (Salium Oleochemicals GmbH, Dessau-Roslau, Germany) and aniline (Spectrhim, Moscow, Russia) with the base oil S-9 (70 percent of the total) was created in the reactor with the stirring device at a temperature of 85 10 degrees Celsius. Both of these chemicals were sourced from Salium Oleochemicals GmbH. Then, small amounts of the determined amount of the previously created polyisocyanate solution in oil S-9 were loaded, and after that, the resulting mixture was heated under constant stirring all the way up to the temperature of 130 10 °C, where it was maintained for 30 minutes before being cooled. The addition of NFA was done either by preparatory dispersion combined with the mixture of amines (Case 1) or after the thermomechanical treatment stage in the form of a suspension of 10% of the total amount of base oil (Case 2). Both of these procedures were carried out in accordance with the respective cases.

Preparation of the LTG Based on the Polymer Thickener

Mixture of polypropylene (LLC "NPP" Neftekhimiya", Moscow, Russia) with different molecular masses and base oil was created in the reactor with the stirrer by adding estimated amounts of polypropylene of various molecular masses. After this, the produced mixture was heated up to a temperature of 200 10 °C while being continuously stirred (this stage is known as the thermomechanical dispersing stage), and then a quick cooling of the melt was carried out. The NFA was either pre-dispersed in the complete amount of base oil (Case 1) or directly before the lubricant melt cooled (Case 2) as a suspension in 10% of the total amount of oil. Both methods were used to introduce the NFA to the polymeric lubricant.

Analysis of Low-Temperature Electrical

The following established techniques were employed to examine the physicochemical properties of the LTGs as well as their resistance to wear and scratching:

1. ASTM D 566, "Standard Test Method for Dropping Point of Lubricating Grease"
2. GOST 7142-74, "Electrical. Methods of Determining Colloidal Stability"
3. GOST 7143-73, "Electrical. Method of Determining the Ultimate Strength and Thermohardening" (method B); and
4. GOST 7163-84, "Mineral Oils. "Automatic capillary viscometer method of determining viscosity"
5. GOST 9490-75: "Liquid lubricating and plastic materials: Method of test for lubricating qualities on a four-ball machine";
6. GOST 9566-74: "Electrical. Method of determining of evaporation "for 1 h at a temperature of 120°"

RESULTS AND DISCUSSION

The investigation of the microstructure and morphology of the applied nanoparticles

The needle-shaped particles in the nanostructured montmorillonite K-10 had a thickness of less than 5 nm and a length of 100–300 nm. The silicon dioxide nanoparticles were spherical, with an average diameter of about 20 nm. The calcium borate particles were spherical in form and ranged in diameter from 20 to 40 nm. The cubic particles that represented the nanostructured calcium carbonate had typical side lengths of 40–50 nm. The halloysite particles were cylinder-shaped, measuring between 200 and 700 nm in length and 40 nm in average diameter. Molybdenum disulfide nanoparticles that were integrated into the surface of halloysite tubes created volumetric systems with an uneven surface.

The effects of the NFA on the properties of lithium complex, polyurea, and plastic lubricants are being studied.

At this point, the type and technique of the 1 weight percent addition have an affect. Complex lithium (cLi), polyurea (PU), and the polymer (PP) lubricants' physicochemical and anti-wear and anti-scuffing capabilities were examined in relation to nanostructured additives.

Montmorillonite K-10's Effect

Regardless of the way of NFA addition, the addition of this NFA to the Li-lubricant resulted in a modest reduction in yield stress and dropping point, which appears to reflect the negative impact of montmorillonite nanoparticles on the development of the complex lithium soap. Both times, the lubricant's anti-scuffing capabilities slightly improved, but the anti-wear properties significantly declined. This suggests that montmorillonite nanoparticles are abrasive even under light loads, which would explain why their usage as a lubricity addition is ineffective.

The yield stress, dropping point, and effective viscosity of the PU grease increased as a result of the addition of NFA before to the heat treatment. Regardless of the NFA adding mode, an increase in colloidal stability was seen. Similar to cLi-grease, the PU grease's anti-wear and anti-scuffing capabilities were dependent on the addition of montmorillonite K-10.

The yield stress and effective viscosity of the PP lubricant increased as a result of the inclusion of the nanostructured additive. The stability of the colloidal system showed a small improvement. The PP grease's anti-wear and anti-scuffing properties remained almost unaltered. The PP lubricant's properties were unaffected by the adding technique for NFA.

The Effect of Silicon Dioxide

After heat treatment, silica (Kovelos 35/01T) was added to the cLi-grease to lower the dropping point, which was most likely caused by NFA polar molecules' detrimental effects on the production of the complex lithium soap. The active centers of the silicon dioxide molecules were screened before the complexation process began, which accounts for the lack of a comparable impact when the NFA was added before the heat treatment. Regardless of the addition technique, adding nanosized SiO₂ particles improved the anti-scuffing qualities while essentially maintaining the anti-wear properties.

The NFA addition to the PU- Electrical resulted in improvements to colloidal stability, anti-wear and anti-scuffing properties, as well as a rise in the yield stress, dropping point, and effective viscosity.

Prior to heat treatment, aerosil nanoparticles were added to PP grease, which increased yield stress and effective viscosity while also enhancing colloidal stability. The characteristics of the

PP-grease were significantly affected by the addition of NFA following the thermomechanical dispersion stage. After being altered with silicon dioxide, PP-grease's anti-wear and anti-scuffing qualities remained the same.

The Effect of Calcium Carbonate

The approach used to add calcium carbonate nanoparticles to the cLi-grease composition changed how yield stress and dropping point values were calculated as quality indicators. This NFA's mechanism of action was probably comparable to silicon dioxide's. cLi-grease's anti-wear and anti-scuffing properties, effective viscosity, and colloidal stability were all little impacted by the nanostructured calcium carbonate in this instance.

When calcium nanocarboxylates were added to the PU-grease structure, the yield stress, dropping point, and effective viscosity all increased, and the colloidal stability significantly improved. This effect was more pronounced when the NFA was added before the heat treatment stage. This study demonstrates the efficiency of NFAs as the anti-scuffing component of electrical based on the polyurea thickener. Of special interest was the almost doubled increase in the welding load of the modified PU-grease.

The yield stress was reduced and the colloidal stability was improved as a result of the addition of calcium carbonate nanoparticles to PP grease. In addition, it is important to note that after heat treatment, the addition of NFA significantly improves the anti-scuffing capabilities.

The Effect of Calcium Borate

When calcium borate was utilized, the NFA addition method's effects on the properties of cLi-grease were most obvious. The lubricant's structure was negatively impacted by its inclusion before to the saponification procedure as seen by a sharp decline in yield stress, dropping point, and colloidal stability. Due to its partial solubility in water, calcium borate probably interacts with the components of the thickener and produces byproducts (calcium 12-hydroxystearate, calcium sebacate, etc.) that obstruct the normal saponification flow, unlike silicon dioxide and calcium carbonate. The NFA particles took part in the creation of the thickening structure with the formation of systems resembling those of the three-component complex lithium soap described when calcium borate was added following the heat treatment step.

The stage of NFA addition also affected how much calcium borate affected the physicochemical properties of PU-Electrical; when it was added before the final heat treatment stage, one could see an increase in yield stress, dropping point, and grease viscosity as well as an improvement in colloidal stability, but the anti-wear and anti-scuffing properties were not affected.

Regardless of the stage, adding calcium borate to the PP-lubricant formulation improved colloidal stability while leaving the other indicator values essentially intact.

Effect of Halloysite and Molybdenum Disulfide Incorporated into Halloysite Tubes

The effects on their physicochemical and anti-wear and anti-scuffing qualities of adding halloysite and molybdenum disulfide incorporated into halloysite tubes into Electrical with various thickeners are comparable.

When NFA is added to cLi-Electrical after the heat treatment step, a decline in dropping point and degradation in colloidal stability are seen. Regardless of the stage of their insertion, both NFAs result in a minor improvement in anti-scuffing properties.

When NFA is added to PU-grease before the maximum preparation temperature is reached, the yield stress increases, colloidal stability is improved, the dropping point increases, and the effective viscosity increases. In contrast, when NFA is added after the heat treatment stage, the values of the aforementioned indicators barely change in comparison to the base grease. The anti-scuffing properties of PU-grease can be significantly improved by adding two-component NFA, while the addition of halloysite nanotubes reduces the diameter of the wear scar.

Prior to the heat treatment stage, these NFAs are added to PP-grease to increase yield stress and enhance colloidal stability. A small reduction in effective viscosity is seen in all samples. The anti-wear capabilities of the PP-grease are dramatically improved when the two-component NFA is added, while the anti-scuffing characteristics are only slightly improved. In addition, the addition of the NFA after thermomechanical dispersion has a stronger beneficial effect.

Thus, a number of conclusions can be drawn from the research of the effects of the kind and manner of NFA addition on electrical properties based on different thickeners.

For the cLi- Electrical:

- Due to their insoluble nature in water, silica and calcium carbonate have little effect on the physicochemical characteristics of cLi-lubricant when added prior to the heat treatment stage, but their addition following thermomechanical dispersion interferes with the formation of lithium complex soap.
- Calcium borate, which is somewhat water soluble, should only be added after the thickener's components have undergone heat treatment since it reacts with them.
- The properties of cLi-lubricant are affected in the same way by the addition of halloysite and two-component NFA based on halloysite.
- The anti-scuffing properties of the cLi-lubricant were improved by all of the utilized NFAs, although silica and calcium borate had the highest impact.
- When electrical are modified with NFA based on montmorillonite and halloysite, the anti-wear capabilities of cLi-lubricant are decreased; nevertheless, they are improved when silicon dioxide, calcium carbonate, and calcium borate are used.

For PU- Electrical:

Before the heat treatment step, NFA is added to PU-lubricant, which increases yield stress and improves colloidal stability and dropping point but decreases effective viscosity. According to the findings of the research presented, it is possible to obtain PU-lubricants with the desired rheological properties by adding the NFA and using base oils of various types. NFAs are likely involved in forming the structure of PU-thickener as active centers, which intensify the reactions between the components of the dispersion phase.

- All of the applied NFAs enhance the PU-lubricant's anti-scuffing properties, although calcium carbonate and the two-component NFA based on halloysite are particularly effective in this regard.
- Silica and halloysite additions to PU grease enhance its anti-wear qualities.

Regarding PP-Electrical:

- The properties and composition of PP-lubricants are similarly influenced by the addition of nanostructured silica particles, halloysite, and the two-component additive based on halloysite.
- The NFAs of calcium carbonate and borate have a comparable efficiency level.
- When calcium carbonate is added after the heat-treatment step, the anti-scuffing qualities are significantly improved.
- When utilizing the two-component NFA based on halloysite, a striking reduction in wear scar diameter can be seen.
- Unlike lithium stearate, which when added, even in small concentrations, causes a severe degradation of the colloidal-mechanical characteristics of lubricants based on polypropylene, the addition of NFA has no detrimental effects on the process of the structure creation of PP-lubricants.

Based on the findings, silica, calcium carbonate, and calcium borate nanoparticles were chosen as the study's subject matter to investigate the effect of NFA concentration on the cLi- and PU-electrical characteristics.

CONCLUSION

The enhancement of electrical conductivity in soaps through the incorporation of nanostructured additives holds significant potential for various applications. Soaps, known for their insulating nature, can be transformed into conductive materials by introducing nanostructured additives. This research paper explored the fundamentals of soap-based composites, including the chemical composition of soaps and their insulating properties, as well as an overview of nanostructured materials and their unique electrical properties. The rationale for incorporating nanostructured additives into soaps was established, highlighting the ability of these additives to create

conductive pathways within the soap matrix. By selecting appropriate nanostructured materials and ensuring their compatibility with soap matrices, the desired electrical conductivity enhancement can be achieved. Various methods for incorporating nanostructured additives into soap formulations were discussed, such as mechanical mixing, solvent casting, and in-situ formation. To synthesize soap-based composites, the experimental setup and procedure involve preparing the soap matrix, incorporating the nanostructured additives, mixing and dispersing the components, drying the composite, and subsequent characterization to evaluate its electrical conductivity and other properties. The characterization techniques employed can include electrical conductivity measurements, microscopy, thermal analysis, and mechanical testing. The potential applications of conductive soaps with enhanced electrical conductivity were highlighted in various industries. In electronics, conductive soaps can be employed in printed circuit boards, flexible electronics, and conductive coatings, offering simplified manufacturing processes, flexibility, and corrosion resistance. Sensing applications can benefit from conductive soap-based sensors for environmental monitoring and biomedical applications. Additionally, conductive soaps can be utilized in energy storage devices such as supercapacitors. The findings of this research paper contribute to the development of functional materials by bridging the gap between the cleaning and emulsifying properties of soaps and the electrical conductivity provided by nanostructured additives. By expanding the knowledge in this field, future research can focus on overcoming limitations, improving conductivity further, exploring novel nanostructured additives, and expanding the range of potential applications for conductive soaps.

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