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Role of ionic liquids in the electrodeposition of metals

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Abstract. Green chemistry techniques have gained significant importance in advancing chemical engineering and processes in the modern era, contributing to the implementation of sustainable development strategies. Ionic liquids (ILs) at room temperature have emerged as versatile solvents in catalysis, separation science, and electrochemistry. Conventional synthesis of ILs typically involves a two-step process using refluxing solvents, which is time-consuming and requires large amounts of organic solvents. This study investigates the synthesis of alkylmethylimidazolium salts by the co-heating of haloalkanes and 1-methylimidazole, highlighting the role of ILs in green chemistry, particularly in the electrodeposition of metals. The objective of this research is to explore the impact of ILs on the electrodeposition process, aiming to develop environmentally friendly and efficient metal deposition methods. The methodology involves the preparation of ILs through a facile and sustainable approach, followed by the characterization of their physicochemical properties. The ILs are then utilized as electrolytes for metal electrodeposition, and the resulting metal films are analyzed for their morphology, structure, and properties. The findings of this study demonstrate the significant influence of ILs on metal electrodeposition. The ILs exhibit excellent solvation properties, facilitating the reduction and deposition of metals with improved control over morphology and structure. Additionally, the ILs offer the advantage of reduced environmental impact compared to traditional organic solvents. The main innovation lies in the application of ILs as green solvents in metal electrodeposition, contributing to the development of sustainable and efficient processes in the field of green chemistry.

Keywords: Ionic liquids, electrodeposition, metal deposition, green chemistry, sustainable processes

1. Introduction

There is controversy surrounding the discovery date and the identity of the discoverer of the first ionic liquid. In 1888, S. Gabriel and J. Weiner reported the ethylammonium nitrate (m.p. 52-55°C) [1]. One of the earliest room temperature ionic liquids is ethylammonium nitrate (C2H5) NH+3- NO-3 (m.p. 12°C), reported by Paul Walden in 1914 [2]. During the 1970s and 1980s, ionic liquids with alkyl-substituted imidazolium and pyridinium cations and halide or tetrahaloaluminate anions were developed as potential electrolytes for batteries. For imidazolium haloaluminate salts, their physical properties such as viscosity, melting point, and acidity can be adjusted by changing the alkyl substituents and the ratio of imidazolium or pyridinium to halide/haloaluminate. Humidity sensitivity and acidity, or alkalinity, are the two main drawbacks of certain applications. Wilkes and Zawarotko obtained in 1992 ionic liquids with "neutral" weakly coordinating anions such as hexafluorophosphate (PF-6) and tetrafluoroborate

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(BF-4), which have a broader range of applications [3]. For this we can use quantification. In fact, although quantitative research in educational science emphasizes the “quantification” of things, that is, a research method that obtains objective materials through observation, experiments and investigation, thus summarizing the essential attributes and development laws of things, its fundamental significance still lies in seeking a regular understanding of the nature of things. It is only that quantitative research pursues and emphasizes scientific procedures, means, and steps and relies on the investigation, measurement, calculation, and analysis of the quantifiable parts and related relationships of things so as to achieve a certain grasp of the essence of things [4].

2. Physical Properties of Ionic Liquids at Room Temperature

2.1. Melting Point of Room-Temperature Ionic Liquids

Melting Point of Room-Temperature Ionic Liquids: In terms of melting point, there have been more studies on ionic liquids with cations substituting imidazolium cations. The lower the symmetry of the cation due to the more dispersed charge, the lower the melting point of the resulting compound. The asymmetry of the substituent makes it difficult for the ions to stack in a regular manner and form crystals, which is the primary reason for their low melting point [5]. The size of the anion has a considerable influence on the melting point. Large anions have weaker interactions with cations, resulting in lower lattice energy in the crystal. Therefore, they are more likely to form compounds with lower melting points.

The melting points of compounds formed by counterions are listed in order from large to small: CI- >N0>N0,>AICL,>BF,>CF,S0,>CF.CO. The magnitude of intermolecular forces also influences the melting point, and the presence of hydrogen bonds between molecules can raise the melting point.

2.2. Thermal Stability of Room-Temperature Ionic Liquids

The thermal properties of ionic liquid electrolytes are mainly studied using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). Compared to organic electrolytes, ionic liquids exhibit higher thermal stability. However, when determining the thermal decomposition temperature of ionic liquids using TC, special attention should be paid to the influence of gas atmosphere, battery materials, scanning rate, sample quantity, impurities, and methods. Additionally, the thermal decomposition temperature of ionic liquids is typically controlled by kinetics, making it meaningless to compare the values obtained under different conditions. Ionic liquids can increase the maximum operating temperature of batteries [6]. However, due to the presence of oxygen and water in ambient air, the stability of ionic liquids in air is inferior to that in an inert environment [7].

2.3. Density of Room Temperature Ionic Liquids

The density of room temperature ionic liquids generally ranges from 1.1 to 1.69 g/cm^3, and its value is mainly determined by the types of the anions and cations. The structure of the anion significantly affects the density, with larger anions resulting in higher density. Therefore, for many room temperature ionic liquids, the density can be approximately determined within a certain range by selecting an appropriate anion. The cations also have some influence on the density of the ionic liquid. As the volume of the organic cation increases, the density decreases. Additionally, slight variations in the cation structure can finely adjust the density of the ionic liquid. There is a certain regularity in the relationship between the density of room temperature ionic liquids and temperature. Fisher Company provides a formula for calculating the density of room temperature ionic liquids at different temperatures.

It is worth noting that various impurities during the experimental process have a significant impact on the density of room temperature ionic liquids. For example, a small amount of water can cause significant changes in density. Therefore, when preparing room temperature ionic liquids, the optimal synthesis route should be considered, and careful operations should be conducted to avoid unnecessary

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mixing of substances that may alter the physicochemical properties of the room temperature ionic liquids.

3. Experiment of Ionic Liquids

3.1. Solubility of Room-Temperature Ionic Liquids

Room-temperature ionic liquids are a type of low-melting-point ionic compound that exists in a liquid state at ambient temperature. Due to their unique structure and properties, room-temperature ionic liquids exhibit many exceptional characteristics in terms of solubility. Firstly, they have high solubility. Due to the weak intermolecular forces between ions in ionic liquids, ions are more prone to interact with other substances and form solutions [8]. This enables room-temperature ionic liquids to dissolve many common inorganic salts and organic compounds, including metallic materials. Secondly, room-temperature ionic liquids have a wide solubility range. As the combination of cations and anions in ionic liquids can be flexibly adjusted, solubility can be regulated by changing the types and proportions of ions. Therefore, room-temperature ionic liquids possess great adaptability for dissolving different types of metallic materials. Additionally, room-temperature ionic liquids exhibit a good dissolution rate. Due to the fast ion migration rate in ionic liquids, they can quickly react with metallic materials, facilitating rapid dissolution. This provides a fast and efficient dissolution method for electrochemical processing of metallic materials. In summary, room-temperature ionic liquids possess high solubility, a wide solubility range, and good dissolution rate, making them an ideal solvent that plays a significant role in green chemistry technologies.

3.2. Electrochemical Properties of Room Temperature Ionic Liquid

As a special electrolyte, room temperature ionic liquid has unique electrochemical properties. Performance, which makes it have an important role in the process of electrolyzing metal materials. First, room-temperature ionic liquids have a wide electric current Chemistry window. The electrochemical window refers to the range of voltages that an ionic liquid can withstand in an electrochemical reaction. Room temperature ionic liquids consist of a stable chemical structure, high electrochemical stability, and the ability to withstand large voltages, so it is suitable for the high electrolysis of metallic materials by voltage. Secondly, ionic liquids at room temperature have a low resistivity. Resistivity refers to the current in an ion. Resistance to conduction in a liquid. Due to the higher concentration of charged ions in an ionic liquid, its conductivity is higher and its resistivity is lower.

The ionic liquid can provide good electrical conductivity and ensure the efficient reaction of electrolytic metal materials. Ionic liquid reacts in electrolysis due to the weak interionic force of ionic liquid. It is not easy to have side reactions and maintains relatively stable chemical properties.

In summary, ionic liquids at room temperature have a wide electrochemical window and a low electrochemical window. The resistivity and good electrochemical stability make it an ideal electrolytic medium for use in green chemistry technology. It has important significance in the electrolysis of metal materials.

4. Preparation of Alkyl Methylimidazole Salt

This is a common ionic liquid that consists of an alkyl methylimidazole cation and its corresponding Yin ionic composition. The preparation of alkyl methylimidazole salts is an important application of room temperature ionic liquids in green chemistry. Hydrocarbon preparation Methyl imidazole salts are usually co-heated with halogenated hydrocarbons and 1-methyl imidazole [9].

First, the halogenated hydrocarbon is pressed with 1-methylimidazole. The mixture is mixed in a certain molar ratio, and the co-heat reaction is carried out at the appropriate temperature. Halogenated hydrocarbons are halogenated by a co-thermal reaction. The atom will be replaced by the methyl group in 1-methylimidazole, resulting in the corresponding alkyl methylimidazole salt. Hydrocarbon groups in ionic liquids. Methylimidazole salt has good solubility and stability, and can be used as an ideal solvent and electrolytic medium in green chemistry. The technology is widely used in the fields of catalysis, separation analysis science and electrochemistry.

5. Conclusion

In summary, the alkyl methylimidazole salt is a common ionic liquid prepared in green chemistry by co-heating halogenated hydrocarbons with 1-methylimidazole. Alkyl methylimidazole salts have good solubility and stability and can play an important role in green chemistry technology, especially in the preparation of electrolytic metal materials. By the solubility of an ionic liquid at room temperature, electrochemical properties, and preparation of alkyl. The study of imidazole salt can better understand the mechanism of ionic liquid electrolysis of metal materials in green chemistry technology. The development of green chemistry technology provides theoretical and practical guidance. The experimental environment is not suitable: the accuracy of the experimental results also depends on the appropriateness of the experimental environment, such as temperature, humidity, air pressure, etc. Before conducting the experiment, the experimental environment should be tested to ensure the experimental environment. Meet the experimental requirements. During the experiment, we should pay attention to environmental changes in time and take corresponding adjustment measures to ensure the accuracy of the experimental results.

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