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Electrostatic Components Progress in Optical Fiber Communication Systems

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Abstract

High-performance Mn-Zn and Ni-Zn ferrites, amorphous, nanocrystalline, and metamaterials have been developed rapidly in recent years to meet the electromagnetic characteristics requirements of WPT systems. This paper begins with a comprehensive review of the magnetic materials used in WPT systems and concludes with cutting-edge WPT technology and the development and application of high-performance magnetic materials. Furthermore, this study provides an exclusive resource for researchers and engineers interested in learning about the technology and highlights critical issues that must be addressed. Finally, the potential challenges and opportunities of WPT magnetic materials are presented, and the technology's future development directions are predicted and discussed.

Because of its high transmission efficiency and acceptable transmission distance, the magnetic coupling resonant wireless power transfer (MCR-WPT) system is regarded as the most promising wireless power transfer (WPT) method. Magnetic cores made of magnetic materials are typically added to MCR-WPT systems to improve coupling performance in order to achieve magnetic concentration. However, as WPT technology advances, traditional magnetic materials gradually become a bottleneck, limiting system power density enhancement.

Keywords: Nanocrystalline • Metamaterials • Electrostatic components

Introduction

Because of its distinct advantages over traditional cable power supply methods, wireless power transfer (WPT) technology has grown rapidly in recent years. It has the potential to significantly improve the reliability, convenience, and safety of the electric energy supply while also addressing the issues of sparks and maintenance difficulties caused by traditional plug-in power transmission modes. WPT technology has broad application prospects in low-power scenarios such as mobile phones, wearable devices, implantable medical care, and smart home products, as well as high-power fields such as electric vehicles (EVs), unmanned aerial vehicles (UAVs), unmanned underwater vehicles (UUVs), electric ships and aerospace equipment.

WPT technology, without a doubt, eliminates the problem of insulation and wire wear caused by contact friction, significantly improving the safety and reliability of charging systems. In general, magnetic coupling resonant wireless power transfer (MCR-WPT) technology is regarded as the most promising WPT method due to its high transmission efficiency and long transmission distance. The MCR-WPT generates an alternating high-frequency magnetic field in the space around the transmitting coil by passing an alternating current from a high-frequency inverter power supply through the transmitting coil. The high-frequency magnetic field forms the high-frequency induction current as it passes through the receiving coil. The current then provides stable electric energy to the load via the secondary energy conversion links (rectifier and filter). MCR-WPT technology can be used to transmit power at the W kW level and is adaptable to a wide range of applications.

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Because both the primary and secondary sides of the coupling coil use a tuning circuit to operate in the same frequency resonance state, the energy exchange efficiency is very high. Furthermore, the international standard for electric vehicle wireless power transfer (EV-WPT) was proposed and adopted, which recommended using the magnetic coupling resonant method for EV wireless charging. The magnetic coupler (MC) is a non-contact loose coupling transformer composed of coil winding and magnetic core that is an essential component of the MCR-WPT system for energy conversion and transmission. The coil winding is essential for magnetic coupling, but the magnetic core made of soft magnetic materials is frequently overlooked.

Literature Review

In general, the coil winding realises the construction of the space electromagnetic field based on Faraday's electromagnetic induction law for a complete MC, including the primary and secondary sides, and the magnetic material realises the reshaping, restriction, and guidance of the space magnetic path. This is due to magnetic materials' high permeability in comparison to air, and most flux lines generated by coils will pass through the magnetic path with magnetic cores. As a result, it is recommended that high-performance soft magnetic materials be added to the magnetic coupler structure as a magnetic core, which significantly improves coupling performance and electromagnetic shielding. On the one hand, magnetic materials can effectively improve the quality factor and mutual inductance coupling coefficient, which are important in increasing the power level and transmission efficiency of the system [1-3]. Magnetic materials, on the other hand, can effectively reduce electromagnetic leakage of magnetic couplers and electromagnetic radiation to system and surrounding environment electronic equipment, which is conducive to the realisation of electromagnetic compatibility (EMC) design.

However, WPT systems generally operate in the higher frequency region of magnetic materials, resulting in additional power loss. Furthermore, the use of magnetic cores increases the system's volume, weight, and cost. WPT is a new field of magnetic materials with unique requirements and concerns that differ from traditional magnetic material application scenarios (such as transformers and motors). In terms of magnetic materials research for WPT, it is still in the stage of determining how to make good use of basic soft magnetic materials. A few magnetic material companies have proposed special magnetic materials designed and developed specifically for WPT.

Nonetheless, as WPT technology research has progressed, the contradiction between the requirements of high efficiency, high power density, low cost, and lightweight, and the shortcomings of current WPT magnetic materials has gradually become apparent. The existing traditional magnetic materials will be challenging to adapt to the high-transmission performance requirements of the WPT system and may become a bottleneck restricting the further development of WPT technology.

Discussion

The first realisation of electric energy transmission from wire to wireless can be traced back to the last century, when Hertz demonstrated the existence of electromagnetic waves and Nicola Tesla successfully lit a phosphorescent lamp with his Tesla coil. However, some embodiments involve an excessively large electric field. The microwave radiation type wireless charging system was first proposed and used to supplement energy for a special helicopter up until 1964. Although microwave radiation is excellent for transmitting information, the divergent radiation space causes significant energy loss when transmitting power and the power transmission efficiency is very low.

The MW-WPT transmission principle is similar to the US-WPT transmission principle. Nonetheless, its frequency range and energy capacity are significantly different, whereas the MW-WPT can even realise wireless transmission of MW-level energy. Because MW-WPT and US-WPT transmissions are radiant, a significant portion of the power is dissipated by radiation and cannot be captured by the receiving side, resulting in extremely low transmission efficiency. Directional antennas can already achieve directional MW-WPT thanks to improved antenna technology [4,5]. However, directional MW-WPT is extremely sensitive to the transmission medium, does not tolerate obstacles in its transmission path, and necessitates real-time tracking and positioning of microwaves, which is difficult to implement.

With the advancement of technology, some kilowatt power level EC-WPT systems that can realise the wireless transfer of electric energy over a long distance have been proposed. Furthermore, coupling capacitors are designed for a variety of applications. However, in order to improve the power level, the system's operating frequency must be increased to more than MHz. The current semiconductor technology constrains ultra-high switching frequencies and high-power performance. Furthermore, continuous high-frequency operation easily causes high-voltage stress on electronic devices in the compensation network. Gallium nitride switching technology and multiphase modular design will be critical in overcoming the high-power EC-WPT system development bottleneck.

Soft ferrite materials are currently the most widely used magnetic materials in WPT systems, as well as typical magnetic core materials recommended by Qi standards. They have outstanding performance in consumer electronics and EV wireless charging. When compared to Ni-Zn ferrite, Mn-Zn ferrites have a higher saturated magnetic flux density, higher permeability, and lower resistivity. Furthermore, below 2 MHz, Mn-Zn ferrites perform better than Ni-Zn ferrites. Mn-Zn ferrite materials account for approximately 80% of all ferrite materials used. Mn-Zn ferrite materials are classified into two types based on their application conditions and performance indicators. One type is high permeability ferrite (generally greater than 15,000), which is commonly used in low-frequency broadband transformers and communication equipment inductance components. The other type II. Under high frequency and magnetic flux density, the loss of power ferrites does not vary significantly with temperature increase in a specific range [6,7].

Because amorphous alloys are in a thermodynamically nonequilibrium sub-stable state, they crystallise to obtain precipitated crystalline phases with grain sizes less than 20 nm under appropriate heat treatment process conditions, resulting in the preparation of nanocrystalline materials or nanocrystalline/ amorphous composites. With their excellent magnetic properties, amorphous and nanocrystalline alloys can replace silicon steel, permalloy, and ferrites. They are widely used in a wide range of electromagnetic fields, including distribution transformers, sensors, and electromagnetic shielding. With the rise of near-field communication and wireless charging, the use of amorphous and nanocrystalline materials in electromagnetic shielding and WPT is gaining popularity.

Conclusion

Finemet-type, Nanoperm-type Fe-based nanocrystalline alloys, and Hitperm-type FeCo-based nanocrystalline alloys are the three systems in which nanocrystalline soft magnetic materials have been developed. Because the anisotropy of the average magnetic crystal of nanocrystalline alloys is low, the magnetostriction coefficient can be reduced to near zero by modifying the composition and process. Because of the exchange coupling between the amorphous matrix and the nanocrystalline grains, the alloy's permeability and saturation flux density can be effectively increased. As the demand for wireless fast charging grows, the coil will generate a stronger alternating magnetic field, resulting in greater transmission power. This increases magnetic induction between the primary and secondary sides of the magnetic coupler, resulting in core saturation, decreased magnetic permeability, and a weakening of the magnetic coupling effect. Furthermore, core losses are proportional to magnetic induction strength, and magnetic saturation frequently results in increased losses and heating at the same time.

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Conflict of Interest

Authors declare no conflict of interest.

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