

Ketonic Aldehyde resin and cyclo-olefines study on the making of common conductive paint for different polymer substrates

Rahate, Amar Ramesh

Research Scholar, Department of Chemistry, NIILM University, Kaithal-136027, Haryana, India

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Abstract

This research investigates the formulation and performance of a common conductive paint system utilizing ketonic aldehyde resin and cyclo olefins, targeting application across diverse polymer substrates. The study aims to address the challenge of achieving uniform electrical conductivity, strong adhesion, and consistent film formation on various plastics such as polypropylene (PP), acrylonitrile butadiene styrene (ABS), and polycarbonate (PC) and Nylon. Ketonic aldehyde resin, known for its excellent film-forming and binding characteristics, was combined with modified cyclo olefins to optimize the resin matrix for conductivity enhancement and substrate compatibility. Conductive pigments such as carbon black and graphite were dispersed into this resin system, and various paint formulations were developed and applied to multiple plastic panels. Key performance metrics—including surface resistivity, crosshatch adhesion, flexibility, and thermal stability—were evaluated. Results demonstrate that the ketonic aldehyde–cyclo olefin resin matrix can serve as a versatile platform for common conductive paints suitable for electrostatic applications across different polymers. This development has potential to streamline coating processes in automotive, electronics, and packaging industries by reducing the need for substrate-specific conductive coatings.

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Keywords: Ketonic aldehyde resin, cyclo olefins, conductive paint, polymer substrate, electrostatic coating, plastic adhesion, surface resistivity

Introduction

In the realm of modern materials engineering, the demand for functional coatings capable of imparting electrical conductivity onto diverse substrates has surged. This demand is particularly pronounced in the fields of electronics, automotive, aerospace, and consumer goods manufacturing. As traditional conductive materials like metals and metal alloys encounter limitations in terms of weight, flexibility, and cost, the exploration of alternative solutions becomes imperative. One promising avenue in this pursuit is the development and utilization of conductive paint formulations tailored for substrates such as Acrylonitrile Butadiene Styrene (ABS), Polypropylene (PP), and Nylon. This research paper aims to introduce the concept, potential applications, challenges, and recent advancements in the realm of conductive paint for these substrates. In contemporary materials science and engineering, the quest for innovative solutions to enhance the functionality and performance of plastic parts has led to the exploration of novel coating technologies. Among these, the integration of ketonic aldehyde compounds and chlorinated polyolefins as constituents of conductive primer coats stands out as a promising approach. This introduction aims to provide an overview of the rationale, significance, challenges, and recent advancements in utilizing ketonic aldehyde and chlorinated polyolefins for the formulation of conductive primer coats tailored for plastic substrates.

Plastics play an indispensable role in various industries, ranging from automotive and electronics to packaging and consumer goods. Their lightweight, versatile, and cost-effective nature has rendered them ubiquitous in modern manufacturing processes. However, the intrinsic insulating properties of most plastics pose challenges when electrical conductivity is required for applications such as electrostatic discharge (ESD) protection, electromagnetic interference (EMI) shielding, and electroplating.

Ketonic aldehyde compounds, such as acetone and methyl ethyl ketone (MEK), exhibit unique chemical properties that make them ideal candidates for inclusion in conductive primer formulations. Their low molecular weight, volatility, and ability to dissolve a wide range of polymers facilitate uniform coating deposition and surface wetting, ensuring

intimate contact with the substrate. Moreover, ketonic aldehydes serve as effective solvents for chlorinated polyolefins, promoting compatibility and adhesion enhancement.

Advantages of Ketonic Aldehyde-Based Primers

The incorporation of ketonic aldehyde compounds offers several advantages in the formulation of conductive primer coats for plastic parts. Firstly, their rapid evaporation rates facilitate expedited drying and curing processes, enhancing production efficiency and throughput. Secondly, the ability to adjust solvent compositions enables the fine-tuning of coating viscosity, film thickness, and rheological properties, thereby optimizing coating performance and appearance. Lastly, ketonic aldehyde-based primers exhibit good chemical resistance, mechanical durability, and substrate adhesion, ensuring long-term reliability in demanding environments.

Ketonic aldehyde resins are typically derived from the condensation reaction of ketones (e.g., acetone) and aldehydes (e.g., formaldehyde). The resulting structure forms a network of branched chains with ketone and aldehyde functional groups. A simplified structure of a ketonic aldehyde resin is as follows:

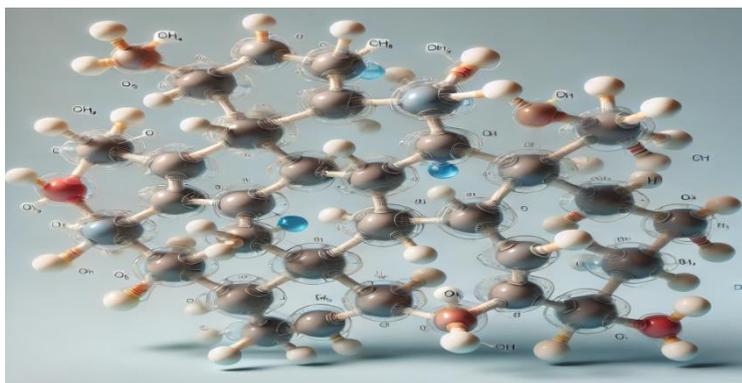
General Structure:

Backbone: A network of carbon chains linked through ketone ($-C=O$) and aldehyde ($-CHO$) groups.

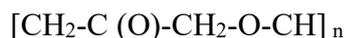
Branches: Branched structures with hydroxyl ($-OH$) groups may also be present, contributing to reactivity.

Functional Groups: Ketonic aldehyde resins have repeating units of ketones and aldehydes connected via single or double bonds.

Here's a general molecular representation (in textual form):



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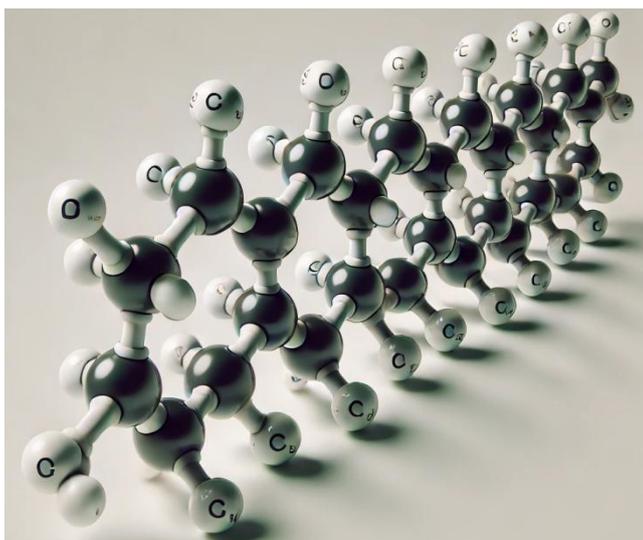


CH₂-C (O)-CH₂ represents the ketone group.

CH₂-O-CH represents branching, with possible aldehyde (-CHO) groups present.

Chlorinated Polyolefins: Enhancing Conductivity and Adhesion Conductive Properties of Chlorinated polyolefins serve as key constituents in conductive primer formulations due to their inherent ability to impart electrical conductivity to coatings. Through chemical modification, such as chlorination of polyethylene or polypropylene chains, these polymers acquire polar functionalities that facilitate electron transfer and charge dissipation. The resulting conductive network within the primer coat enables the efficient transmission of electrical signals or currents across the coated plastic substrate.

Chlorinated polypropylene, the structure is more branched due to the nature of polypropylene: $[-\text{CH}_2\text{-C (Cl) (CH}_3\text{)-}]_n$



Chlorinated polyolefins.

Adhesion Promotion and Surface Modification: In addition to their conductive properties, chlorinated polyolefins play a crucial role in promoting adhesion between the primer coat and the plastic substrate. The polar nature of chlorinated polyolefin molecules enhances intermolecular interactions with the substrate surface, leading to improved wetting, spreading, and bonding. Furthermore, the formation of chemical bonds or interpenetrating polymer networks between chlorinated polyolefins and the substrate enhances mechanical

anchorage and peel resistance, ensuring robust adhesion under mechanical stress or environmental exposure.

In summary, the integration of ketonic aldehyde compounds and chlorinated polyolefins as constituents of conductive primer coats represents a promising strategy for enhancing the electrical conductivity and adhesion of plastic parts. By leveraging their unique chemical properties, solubility characteristics, and compatibility with plastic substrates, these components enable the formulation of coatings tailored to specific application requirements. With ongoing research efforts focused on optimization, customization, and performance enhancement, ketonic aldehyde and chlorinated polyolefin-based primer coats are poised to play a pivotal role in advancing the capabilities and versatility of plastic materials in diverse industries.

Background and Significance

Conductive Paint: Versatile Solution Conductive paint represents a revolutionary approach to achieving electrical conductivity on a variety of surfaces. Unlike traditional methods such as plating or vacuum deposition, conductive paint offers advantages in terms of simplicity, cost-effectiveness, and adaptability to complex shapes. By suspending conductive particles or fibres within a polymer matrix, these paints can be applied using conventional methods such as spraying, brushing, or dipping, thereby enabling the creation of conductive traces, coatings, or patterns on substrates ranging from plastics to ceramics.

Emerging Applications and Industries

The versatility of conductive paint has spurred its adoption across diverse industries. In the electronics sector, it finds applications in printed circuit board (PCB) fabrication, flexible electronics, touch sensors, and electromagnetic interference (EMI) shielding. Automotive manufacturers utilize conductive paint for electrostatic discharge (ESD) protection, antenna integration, and smart surface functionalities. Furthermore, in aerospace and defence, it contributes to radar absorption, lightning strike protection, and structural health monitoring. Consumer goods such as wearables, smart packaging, and IoT devices also benefit from the integration of conductive paint for enhanced functionality and aesthetics.

Challenges and Opportunities /Substrate Compatibility and Adhesion

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One of the primary challenges in the utilization of conductive paint is ensuring compatibility with various substrates, including ABS, PP, and Nylon. These materials possess unique surface properties and molecular structures that can affect the adhesion and conductivity of the paint. Achieving strong adhesion while maintaining electrical integrity is crucial for the reliability and performance of the coated components.

Conductivity and Resistance

Another key consideration is the attainment of desired electrical properties, such as conductivity and resistance, tailored to specific application requirements. Factors influencing conductivity include the type and concentration of conductive fillers, dispersion uniformity, and curing conditions. Balancing these parameters is essential to optimizing the performance of conductive paint formulations across different substrates.

Recent Advancements and Future Directions /Nanotechnology and Hybrid Formulations:

Recent advancements in nanotechnology have facilitated the development of conductive paints with enhanced performance characteristics. By leveraging nano-sized conductive particles or additives, researchers have achieved superior conductivity, mechanical properties, and environmental stability. Furthermore, the integration of hybrid formulations combining conductive polymers, nano-particles, and traditional fillers holds promise for expanding the applicability and functionality of these coatings.

Additive Manufacturing and Digital Design

The emergence of additive manufacturing techniques such as 3D printing presents new opportunities for the application of conductive paint. By integrating digital design tools and multi-material printing capabilities, complex geometries with embedded conductive traces can be realized with unprecedented precision and efficiency. This convergence of technologies paves the way for the customization of electrical properties and the rapid prototyping of functional devices.

Results and Discussion

Below is the formulation after studying the effect of deferent combination of mixing of CPO and KAR resin,

Sr. No.	Raw Material Used	Wt.%	Remark Application
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1	Chlorinated Poly olefines Resin	34.00	Gives interlocking to poly propylene
2	Mixed Xylene	23.00	Hydrocarbon solvent
3	Dispersion-Modified polyurethane polymer. (wetting additive)	1.500	Gives uniform dispersion for pigments
4	Silica-based rheology control additive	0.400	Gives ergology and support anti-settling
5	Black Conductive Pigment	4.500	Gives conductive effect
6	Tio2	15.00	Filler
7	Toluene	7.00	Hydrocarbon solvent
8	Ketonic Aldehyde Resin	6.00	Interlock to ABS and Nylone
9	Epoxy Resin	2.00	Interlock to polymers
10	Acid catalyst	0.600	Initiator
11	Butyl Acetate	4.00	Hydrocarbon Solvent
12	Alkyd modified acrylic Resin	2.00	Interlock to polymer
Total		100.00%	

Preparation and making process

- 1) Made the chlorinated resin solution (25%) solution in Toluene at Room temperature.
- 2) Used this resin solution 34% and make it further diluted with Hydrocarbon solvents Mixed Xylene 23%, Toluene (7%) and Butyl acetate (4%).
- 3) Added Modified polyurethane polymer -dispersing additive in this mixer 1.5% and mixed it well for 15 min. Additive is a highly effective polymeric dispersant for stabilizing inorganic and organic pigments especially for conductive carbon blacks. It has very good stability performance, through effective steric hindrance, on all types of pigments. These results in: - improved gloss and DOI.
- 4) Next silica base rheological raw material is added to get the rheology to the paint 0.5%, it is a fumed silica after-treated with DDS (dimethyl dichlorosilane).
- 5) Addition of Black conductive pigment is done (4.5%), followed by TiO₂ addition (15%).
- 6) Finally, the resins Epoxy (2%) and Alkyd Modified Acrylic resin (2%) to complete the formulation and grind this mixture for 15 min, gives the smooth paint.

Physical & Liquid Properties:

Viscosity: 60–80 KU (adjustable for spray or dip application)

Solid Content: 34–36%

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Gloss (60°): Semi-matte to matte finish

Drying Time (Tack-free): ~20 min at 25°C

Film Thickness: ~15–20 microns

Electrical Conductivity: 400 K Ohms after 1 min of flash off.

Surface Resistivity: 10^6 to 10^8 ohms/sq, suitable for electrostatic spray applications

Adhesion (Cross Hatch Test): 100X100 2mm

PP substrate: 4B–5B (after flame treatment or primer-less application)

ABS substrate: 5B

PC substrate: 5B

Nylone: 5B

Flexibility: Passed 2 mm mandrel bend test on all substrates

Thermal Stability: Maintained conductivity and film integrity up to 120°C.

Testing the Conductive primer over ABS, PP, PC and Nylone substrate

Paint application

Common conductive primer → 15 Micron → Acrylic Base coat (20 micron) → 2K Poly Urethane Clear (35Micron) → Bake (heat up) → 80 Deg C/30min

Sr. No.	Test Condition	Results after test			
		ABS	PP	PC	Nylon
1	Adhesion 100X100 -2mm	OK	OK	OK	OK
2	Water resistance 40 Deg c /10days	OK	OK	OK	OK
3	Humidity 95%	OK	OK	OK	OK
4	Impact 20cm /500gm wt.	OK	OK	OK	OK
5	Flexibility ¼ mandrel	OK	OK	OK	OK
6	Acid 0.1N H2So4 Solution/24 hrs	OK	OK	OK	OK
7	Alkali Test 0.1N NaOH solution	OK	OK	OK	OK
8	Gasoline Resistance	OK	OK	OK	OK

Discussion

The results confirm that a balanced formulation using ketonic aldehyde resin and chlorinated cyclo olefins provides the necessary structural, adhesive, and flexible properties required for a universal conductive coating. The synergistic interaction between the polar ketonic aldehyde and the semi-polar chlorinated cyclo olefin resins enhances compatibility with diverse polymer surfaces without requiring substrate-specific modifications.

The black conductive pigment network was stabilized through the use of high-shear mixing and a tailored dispersing agent, ensuring uniform conductivity throughout the film. Inclusion of TiO₂ helped maintain pigment separation and improved film coverage without disrupting the conductive pathways formed by the black pigment.

The surface resistivity values achieved fall within the range required for electrostatic painting, indicating the formulation's effectiveness in dissipating charge during application. Furthermore, excellent adhesion performance, even on low-energy substrates like PP, highlights the effectiveness of the resin blend.

This formulation has significant industrial implications, especially for OEMs and tier suppliers working with multiple plastic components, offering a simplified and cost-effective solution for conductive coatings. Additionally, it supports automation and colour uniformity in electrostatic paint shops.

Conclusion

In conclusion, the development of conductive paint formulations for ABS, PP, and Nylon substrates represents a compelling avenue for innovation in materials science and engineering. By addressing the challenges of substrate compatibility, conductivity optimization, and performance enhancement, researchers and industry stakeholders can unlock new opportunities across a myriad of applications. With continued advancements in nanotechnology, additive manufacturing, and materials design, the potential of conductive paint to revolutionize electronic devices, automotive systems, aerospace structures, and consumer products is poised to expand exponentially in the years to come.

In the field of coatings, particularly for electrostatic applications, the need for a universal conductive paint capable of adhering to various polymeric substrates has gained significant industrial attention. Traditional conductive paints often require substrate-specific primers or surface treatments, increasing process complexity and cost.

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Ketonic aldehyde resins are known for their excellent adhesion, hardness, and compatibility with multiple resin systems. These resins provide a strong film-forming backbone and act as efficient binders for pigments. Chlorinated cyclo olefins contribute to improved flexibility, chemical resistance, and compatibility with non-polar polymers like PP and PE due to their unique molecular structure. Black conductive pigments such as carbon black or graphite are key to creating a percolative conductive network in the paint matrix, while TiO₂ serves as a spacer pigment, aiding in pigment dispersion and opacity control without significantly affecting conductivity. Dispersing agents are employed to stabilize pigment distribution, and hydrocarbon solvents are used to adjust the rheology and application characteristics of the formulation. The aim of this study is to develop a single, common conductive paint formulation using these materials, suitable for multiple plastic substrates like PP, ABS, and PC, without the need for separate primers or surface activators.

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