### A Course based Project Report On

### APPLICATIONS OF pH SENSITIVE INK

Submitted in partial fulfilment of

requirement for the completion of the

Engineering Chemistry Laboratory course.

### B. Tech Electronics and Instrumentation Engineering

### of

### VNR VJIET

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### DECLARATION

We hereby declare that this Project Report titled **“APPLICATIONS OF pH SENSITIVE INK”** submitted by us of **ELECTRONICS AND INSTRUMENTATION ENGINEERING** in **VNR Vignana Jyothi Institute of Engineering and Technology,** is a bonafide work undertaken by us and it is not submitted for any other certificate/course or published any time before.

Signatureofthe Student**/**Date

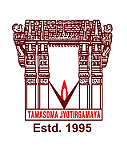
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### CERTIFICATE

This is to certify that the project entitled **“APPLICATIONS OF pH SENSITIVE INK”** submitted in partial fulfilment for the course of Engineering Chemistry Laboratory being offered for the award of B.Tech (**EIE- A)** by **VNR VJIET** is a result of the bonafide work carried out by **23071A1001, 23071A1002, 23071A1003, 23071A1004, 23071A1005** during the year **2023-2024**. This has not been submitted for any other certificate or course.

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**ABSTRACT**

pH sensors are extremely useful in various applications such as health, food and environmental monitoring. Because of this, it is much welcomed when flat, inexpensive, and highly effective pH sensors that can be produced on a wide scale are developed. In this work, we used two printing processes to create a potentiometer pH sensor based on poly aniline. The functioning electrode was created by screen printing a layer of carbon ink onto Valox®, then using ink jet printing to change the active portion of the print to print with polyaniline ink. A variety of water-based poly aniline ink formulations were evaluated with acrylic dispersion's serving as binders to maximize the printed electrodes' functioning, adhesion, print ability, and rub resistance. These electrodes exhibited exceptional sensitivity (69.1 mV/pH), marginally more than that of poly aniline.

pH sensing in healthcare demands sensors made of mechanically robust materials with excellent sensitivity and reproducibility, as well as low-cost production procedures. This paper offers a fully printed pH sensor using a specially designed conducting polymer put on a micro electrode in a flexible substrate. A formulation of polyaniline (PANI) and polypyrrole (PPy) with integrated poly electrolyte poly(sodium 4-styrenesulfonate) (PSS) was specially created for ink jet printing (IJP). The sensor has high sensitivity in the physiological range (pH 7-7.5), which is critical for a healthcare biosensor. Printing this mixture over commercial gold ink with phthalocyanine (Pc) improved sensor sensitivity and repeatability, resulting in a linear super-Nernstian response (81.2 ± 0.5 mV/pH unit) throughout a wide pH range.

To show the electrochemical pH sensing application, the surfaces of the printed Pd films are oxidized for ion-to-electron transduction, while the underlying layer is left alone for electron conduction. The solid-state reference electrodes are then incorporated with the bifunctional Pd electrodes via ink jet printing. These potentiometric sensors have sensitivity of 60.6 ± 0.1 and 57 ± 0.6 mV pH−1 on glass and polyimide substrates, respectively, with fast response times of 11 and 6 seconds. In addition, the printed sensors can be used with a low-cost multimeter to acquire accurate pH measurements of real water samples. These findings suggest that simple and cost-effective ink jet printing and integration techniques could be used to create future electrochemical monitoring systems for environmental parameters and human health situations.

**INTRODUCTION**

pH-sensitive inks are a specialized class of inks formulated to exhibit chromatic alterations in response to variations in surrounding pH levels. These inks incorporate pH indicators, a class of molecules that undergo structural modifications upon exposure to acidic or basic environments. These structural changes influence the light absorption properties of the indicator, leading to a visually perceptible color shift.

Components:

Base Ink: This acts as the carrier for the color-changing components. It can be a conventional ink formulation used in various printing processes.

pH Indicators: These are the key players in the color change phenomenon. They are organic molecules with specific functional groups that respond to changes in pH. The structure of a pH indicator features an acidic or basic group (depending on the indicator type) that can donate or accept protons (H+ ions) in response to varying pH levels.

Color Change Mechanism: When a pH indicator encounters an acidic or basic environment, its functional group gains or loses a proton. This alteration in structure causes a shift in the molecule's ability to absorb specific wavelengths of light. The change in light absorption translates to a visible color change.

Types of pH Indicators: There's a wide range of pH indicators available, each with a distinct pKa (acid dissociation constant) value. This value determines the pH range at which the indicator exhibits its color change. Commonly used indicators include phenolphthalein (red in basic, colorless in acidic), methyl orange (red in acidic, yellow in basic), and litmus (red in acidic, blue in basic).

Working Mechanism:

Preparation: The pH indicator is incorporated into the base ink formulation, often along with binders, solvents, and other additives to optimize printability and stability.

Exposure to pH Change: When the printed ink comes into contact with a solution or environment with a different pH level from what it was designed for, the pH indicator molecules in the ink experience a shift in their protonation state due to the change in acidity or alkalinity.

Color Change: As the pH indicator molecules undergo structural modification, their light absorption properties change. This translates to a visible alteration in the color of the printed ink.

Factors Affecting Performance:

Selection of pH Indicator: The choice of indicator significantly impacts the performance of the ink. Factors like the desired color change range, sensitivity to pH variations, and compatibility with the base ink formulation need to be considered.

Ink Formulation: The composition of the base ink can influence the stability and printability of the pH-sensitive ink. Compatibility between the indicator and other ink components is crucial.

Environmental Conditions: Light exposure, temperature, and humidity can affect the stability and longevity of the color change in pH-sensitive inks.

Chemical Sensing: Beyond basic analysis, pH-sensitive inks can be used in sensor development to detect specific chemicals that alter the surrounding pH.

Educational Tools: These inks can be used in science education to create interactive demonstrations of pH changes.

By understanding the intricate interplay between pH indicators and ink formulations, researchers and developers can create pH-sensitive inks tailored for specific applications, making them a valuable tool across various fields.

**IMPORTANCE OF pH SENSITIVE INK**

Security Printing: A Multi-Layered Defense

Hidden Messages: Imagine a document with a seemingly plain design that incorporates a pH-sensitive ink pattern invisible to the naked eye. When exposed to a specific chemical used for erasing or altering information, the pattern reacts by changing color, revealing tampering attempts.

Micro text Authentication: Microscopic text printed with pH-sensitive ink can be embedded within a document's design. This text is only readable under magnification and changes color if tampered with, providing another layer of security.

Packaging Integrity Indicators: For high-value goods or pharmaceuticals, pH-sensitive seals or labels can be used on packaging. These seals might have a two-color design, where the colors mix upon breaking the seal, indicating tampering.

2. Food Spoilage Detection: A Race Against Time

Time-Based Color Change: Spoilage indicators can be designed with a specific pH range in mind. As food spoils and the pH level inside the package increases or decreases, the ink gradually changes color. This allows consumers to easily identify when food has reached its peak freshness and is no longer safe.

Multi-Color Spoilage Indicators: Some indicators can even incorporate multiple pH-sensitive inks that change color sequentially. This provides a more nuanced picture of spoilage progression, allowing consumers to take action before the food becomes completely inedible.

3. Medical Diagnostics: Beyond the Urine pH Strip

Advanced Diagnostic Strips: While urine pH testing is common, researchers are developing dipsticks with multiple pH-sensitive pads for simultaneous testing of various bodily fluids. This can offer a more comprehensive picture of a patient's health.

Internal Diagnostics: pH-sensitive inks are being explored for use in ingestible capsules or patches for monitoring internal pH levels in the digestive tract. This could be helpful in diagnosing and managing conditions like ulcers or gastroesophageal reflux disease (GERD).

4. Textile Applications: From Fun to Functional

Mood Indicator Clothing: Scientific Basis in Development: While the concept of clothing reflecting emotions through sweat pH changes is intriguing, the scientific basis for a direct correlation between emotions and sweat pH variations is still being explored. More research is needed to determine the accuracy and reliability of this application.

Sweat-Activated Activity Trackers: pH-sensitive inks can be used in sportswear to create visual indicators of exertion level. As sweat pH changes with increasing intensity during exercise, the clothing might gradually change color, providing a real-time gauge of workout effort. This can be particularly useful for athletes training at specific intensity zones.

**OBJECTIVES**

Here are a few objectives for pH sensitive inks:

1. **Educational Tools:** pH sensitive inks can be used to create interactive science experiments and educational materials to teach about acids, bases, and pH levels.

2. **Quality Control:** pH sensitive inks can be used in industries such as food, cosmetics, and pharmaceuticals to monitor and ensure the desired pH levels of products during manufacturing and packaging processes.

3. **Medical Applications:** pH sensitive inks can be used in medical diagnostics to indicate pH changes in body fluids, helping with the detection and monitoring of certain health conditions.

1. **Environmental Monitoring:** pH sensitive inks can be used to monitor the pH levels of water bodies, soil, and other environmental samples, providing valuable information for ecological studies and pollution control.

5. **Bloodstain Analysis**: pH sensitive inks can be used to analyze bloodstains at crime scenes. By detecting changes in pH levels, investigators can gather important information about the age and origin of the bloodstains, aiding in the reconstruction of events.

6. **Document Examination:** pH sensitive inks can assist in the examination of forged or altered documents. By identifying variations in ink pH, forensic experts can determine if different inks were used or if any tampering has occurred.

7. **Drug Analysis:** pH sensitive inks can be utilized in drug analysis to detect and identify substances. By measuring the pH of drug samples, forensic scientists can gather valuable information about the composition and purity of the substances.

These objectives demonstrate the valuable role that pH sensitive inks can play in forensic science, helping investigators gather evidence and uncover crucial information in various forensic applications.

**BROAD ANALYSIS OF PH SENSITIVE INK**

Unveiling the Secrets: Applications of pH-Sensitive Inks in Forensics

In the realm of forensic investigations, where every detail holds immense significance, pH-sensitive inks offer a unique perspective. These ingenious inks, formulated to change color based on acidity or alkalinity (pH), can play a crucial role in gathering evidence, reconstructing crime scenes, and even aiding in suspect identification. Let's delve deeper into the captivating applications of pH-sensitive inks in the fascinating world of forensics, exploring their potential to illuminate the truth.

1. Locating Latent Bloodstains:

The Challenge: Blood evidence is often a cornerstone of forensic investigations. However, bloodstains can be faint or obscured by dust, dirt, or cleaning agents. Traditional methods for bloodstain detection, like luminol sprays, can be unreliable due to interference from other substances.

The Solution: pH-sensitive inks, specifically formulated to react with the hemoglobin in blood, can offer a more targeted approach. By spraying a solution containing these inks onto a potentially contaminated surface, investigators can visualize latent bloodstains that might be invisible to the naked eye. The ink's color change upon contact with blood provides a clear indication of its presence, even on fabrics or porous surfaces.

Benefits: The use of pH-sensitive inks for bloodstain detection offers several advantages. They are less susceptible to interference from common household chemicals compared to luminol. Additionally, the color change provides a permanent record that can be photographed and documented for further analysis in the lab.

2. Mapping Bodily Fluid Distribution:

The Importance: Reconstructing the sequence of events at a crime scene is crucial for forensic investigators. Understanding the distribution of bodily fluids, like blood, semen, or saliva, can provide valuable insights into the perpetrator's actions and the victim's movements.

The Technique: Investigators can utilize a combination of pH-sensitive inks tailored to react with specific bodily fluids. By spraying these inks on the crime scene surface, differentiation between various fluids becomes possible based on the distinct color changes each ink produces. This visual mapping aids in reconstructing the sequence of events and identifying potential areas of contact between the perpetrator and the victim.

Limitations: While pH-sensitive inks offer valuable information, it's important to remember that they cannot definitively identify the type of bodily fluid. Confirmation through laboratory analysis is still essential for forensic purposes.

3. Fingerprint Enhancement on Challenging Surfaces:

The Difficulty: Fingerprint recovery is a mainstay of forensic investigations. However, fingerprints on non-porous surfaces like glass, metal, or plastic can be challenging to visualize using traditional methods like dusting with powders.

The Innovation: Researchers are exploring the potential of pH-sensitive ink formulations that can adhere to fingerprint residue. The ink's interaction with the slightly acidic components of sweat present in fingerprints can lead to a color change, enhancing the fingerprint's visibility on difficult surfaces.

The Future: This application of pH-sensitive inks is still under development, but it holds immense promise for forensic investigations. The ability to recover fingerprints from unconventional surfaces can lead to new breakthroughs and aid in solving cold cases.

4. Detecting Tampering with Evidence:

The Threat: Tampering with evidence is a serious concern in forensic investigations. Perpetrators might attempt to alter or destroy evidence to hinder the investigation.

The Safeguard: pH-sensitive inks can be incorporated into evidence tags or seals. Any attempt to tamper with the evidence, through the use of adhesives or chemicals, could alter the local pH, triggering a visible color change on the tag or seal. This would serve as a clear indication of tampering, alerting investigators to potential manipulation.

Enhanced Security: The use of pH-sensitive inks for tamper detection adds an extra layer of security to the chain of custody. It discourages tampering attempts and ensures the integrity of evidence throughout the investigative process.

5. Investigating Inkjet Cartridge Counterfeiting:

The Crime: Counterfeiting of inkjet cartridges is a growing concern, causing financial losses and frustration for consumers.

The Technique: Manufacturers can embed pH-sensitive inks into genuine cartridges. These inks can be formulated to react with specific chemicals unique to the manufacturer's ink formulation. During forensic analysis, investigators can expose the suspected counterfeit cartridge to a solution containing the pH-sensitive ink.

The Identification: If the cartridge is counterfeit, the introduced pH-sensitive ink will not react as expected, potentially revealing a different color change or no change at all. This approach can aid in identifying counterfeit cartridges and bringing perpetrators to justice.

6. Development Considerations and Future Directions:

Specificity: A crucial challenge in forensic applications is ensuring the pH-sensitive inks exhibit high specificity for the target analyte (blood, semen, etc.) to minimize false positives from

CONCLUSION

Firstly, pH-sensitive inks operate on the principle of colour change in response to variations in pH levels. This property is harnessed through the use of pH indicators or responsive polymers, which undergo distinct changes in colour or transparency within specific pH ranges. The reversible nature of these changes allows for multiple uses and applications.

Secondly, the materials used in pH-sensitive inks vary depending on the desired application and the required pH range sensitivity. pH indicators such as phenolphthalein, bromothymol blue, and methyl red offer distinct colour changes within specific pH ranges, making them suitable for different applications. Responsive polymers, on the other hand, can be tailored to exhibit pH sensitivity over a broader range or to respond to specific pH conditions.

Furthermore, the design of pH-sensitive inks involves considerations such as ink formulation, substrate compatibility, and durability. Formulating pH-sensitive inks requires careful selection of solvents, binders, and additives to ensure stability and functionality. Compatibility with various substrates, including paper, textiles, and plastics, expands the potential applications of pH-sensitive inks across different industries.

The applications of pH-sensitive inks span a wide range of fields, including healthcare, food packaging, environmental monitoring, and security. In healthcare, pH-sensitive inks find utility in diagnostic tests, drug delivery systems, and biomedical devices, enabling real-time monitoring of physiological conditions and drug release kinetics. In food packaging, pH-sensitive inks serve as indicators of food spoilage or contamination, enhancing safety and quality control measures. Environmental monitoring applications include water quality assessment, soil analysis, and pollution detection, where pH-sensitive inks provide rapid and cost-effective screening methods. Additionally, pH-sensitive inks contribute to security features in documents, currency, and consumer products, offering anti-counterfeiting measures and tamper-evident solutions.

Despite the numerous advantages and applications of pH-sensitive inks, several challenges remain to be addressed. These include optimising ink performance and stability, enhancing colour resolution and sensitivity, improving substrate adhesion, and reducing production costs. Addressing these challenges will require interdisciplinary collaboration among researchers from chemistry, materials science, engineering, and other fields, as well as continued investment in research and development efforts.

Looking ahead, the future of pH-sensitive inks holds promise for further innovation and advancement. Potential areas for future research include the development of novel pH indicators and responsive polymers with enhanced sensitivity, selectivity, and environmental compatibility. Integrating pH-sensitive inks with emerging technologies such as printed electronics, microfluidics, and wearable devices could open up new opportunities for sensing and diagnostics. Moreover, exploring sustainable ink formulations and manufacturing processes will be crucial for minimizing environmental impact and promoting widespread adoption.

In conclusion, pH-sensitive inks represent a versatile and dynamic class of materials with diverse applications and significant potential for innovation. By leveraging their unique properties and addressing ongoing challenges, pH-sensitive inks can continue to make valuable contributions to various industries and pave the way for new advancements in sensing, diagnostics, and beyond.

FUTURE SCOPE

pH-sensitive ink has promising future applications across various fields due to its ability to change color in response to pH changes. Here are some potential future scopes:

1. Medical and Healthcare: pH-sensitive ink could be used in medical diagnostics to indicate pH levels in bodily fluids such as blood, urine, or saliva. This could aid in monitoring pH imbalances associated with conditions like acidosis or alkalosis. Additionally, pH-sensitive ink could be incorporated into wearable devices for continuous health monitoring.

2. Food Safety and Quality Control: pH-sensitive ink can be utilized in food packaging to indicate the freshness or spoilage of perishable goods based on pH changes. It could also help detect the presence of contaminants or adulterants in food products.

3. Environmental Monitoring: pH-sensitive ink could be employed in environmental monitoring systems to detect changes in pH levels in water bodies, soil, or air. This could aid in assessing water quality, soil health, and air pollution levels.

4. Smart Textiles and Wearables: pH-sensitive ink could be integrated into textiles to create colour-changing fabrics that respond to changes in sweat pH. This could be particularly useful in sports performance monitoring, healthcare applications, and wearable technology.

5. Chemical and Biological Sensors: pH-sensitive ink could serve as a component in chemical and biological sensors for detecting specific substances or pathogens based on pH changes. This could have applications in environmental monitoring, industrial processes, and medical diagnostics.

6. Educational Tools: pH-sensitive ink can be utilized in educational settings to demonstrate concepts related to acidity, alkalinity, and pH measurement. It could be incorporated into science kits, educational toys, and laboratory experiments to engage students and enhance learning.

7. Art and Design: pH-sensitive ink offers creative possibilities for artists and designers to incorporate colour-changing effects into artworks, interactive installations, and product designs. This could lead to innovative and visually appealing creations.

8. Security and Anti-Counterfeiting: pH-sensitive ink could be used as a security feature in documents, currency, or products to prevent counterfeiting. Colour changes triggered by pH alterations could serve as a tamper-evident indicator or authentication mechanism.

Overall, the future scope of pH-sensitive ink is broad and diverse, spanning across industries such as healthcare, food technology, environmental science, textiles, education, art, security, and beyond. Continued research and development in this field are likely to unlock new applications and opportunities for innovation.

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