경화 전 콘크리트의 염소이온 신속측정 페이퍼 센서 개발에 관한 실험적 연구

Rabid detection of chloride ions in fresh concrete using a chromium-free paper-based analytical device (μPAD)

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Abstract : This study successfully developed a chromium-free paper-based analytical device (μPAD) for chloride detection in fresh concrete. The sensing materials were chemically synthesized and coated to the paper through drop casting. The fabricated μPAD was thoroughly tested with various concentrations of chloride ions. Upon interaction with the μPAD, the chloride ions in the solution react with a chromium-free silver compound, exhibiting a specific coloring height proportional to the absolute chloride concentration. The height of the color change during a reaction can vary based on the chloride concentration, which allows for predicting the chloride concentration in a solution. The results reveal that μPAD has extraordinary precision in identifying chloride in fresh concrete, which highlights its immense potential for future applications.

키워드 : 페이퍼 센서, 염화물 감지, 경화 전 콘크리트
Keywords : paper-based analytical device, chloride sensing, fresh concrete

1. Introduction

The chloride ion content in fresh concrete must be tested to determine the likelihood that embedded reinforcement steel rebars may corrode over time. Excessive chloride ion content can also cause structural degradation. Several methods have been developed to detect chloride ions in fresh concrete, such as chemical titration, ion-selective electrodes, potentiometric test methods, and chloride sensing strips. Among these methods, the chloride sensing strip is one of the best due to its rapid detection and low cost. Nonetheless, the sensing material of choice typically contains silver chromate, which contains hexavalent chromium in an oxidation state of +6 [1]. This compound is highly toxic and can pose significant health and environmental risks, such as ulceration and perforation of the digestive tract [2]. To address this issue, a recent study conducted research on a chromium-free paper-based analytical device (μPAD) capable of predicting the concentration of chloride in fresh concrete. This alternative method is promising as it eliminates the need for hazardous materials and provides a safer and more environmentally friendly approach to detecting chloride ions in concrete.

2. Materials and method

2.1 Preparation of chloride sensing μPAD

The paper-based analytical device (μPAD) was prepared by cutting the Whatman filter paper Grade 5 into strips of 10mm width and 110mm height. The 0.4 g of sensing material was mixed with 10 ml of 5% binder and coated to the filter paper using the drop-casting method and then dried at 60C for 6h. The schematic diagram of the μPAD preparation method is shown in Figure x.

2.2 Test in chloride and other solutions

The capability of the chloride detection of the fabricated μPAD was examined using various chloride concentrations at 25C, and the observed change in coloring height of the μPAD is noted.

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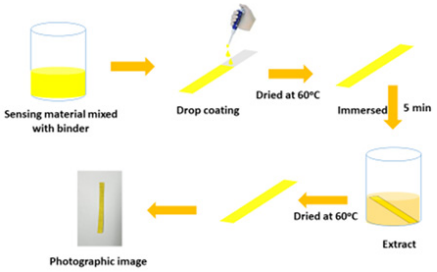

Figure 1. Schematic diagram of the preparation of μPAD

3. Results and Discussion

The comprehensive evaluation of the μPAD's capacity to detect chloride ions over a range of concentrations, as depicted in Figure 2(a)-(b). Figure 2(a)-(b) clearly portray a gradual extension of the color change, transitioning from yellow to red, in direct correlation with the increase in chloride ion concentration. The fundamental mechanism underpinning chloride detection on the μPAD hinges on the interaction between a silver-based organic complex and chloride ions, forming an organo-based silver chloride complex, thus inducing the observed color shift. As the solution traverses through the μPAD, chloride ions are steadily consumed, resulting in a height of the color changes. If the concentration of chloride ions is insufficient or completely consumed, there will be no color change. Furthermore, the assessments to appraise the μPAD's competence in detecting other ions using 1% Na_2SO_4 and $NaNO_3$ solutions, as exemplified in Figure 2(c). Interestingly, no discernible changes in color were discerned in these instances. This observation underscores the fact that the fabricated μPAD is exclusively tailored for chloride ion detection and lacks the capability to discern sulfate and nitrate ions.

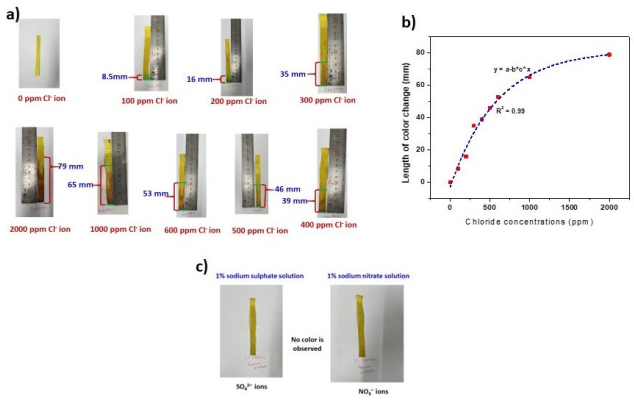

Figure 2. Test in various concentration of chloride ions (a), the relation between color changing length and chloride concentrations (b) and test in 1% sodium sulphate and sodium nitrate (c)

4. Conclusion

A chromium-free μPAD has been developed as a safer and ecologically sound alternative for detecting chloride ions in the solution, particularly in fresh concrete. The concentration of chloride ions can be accurately measured by observing a color change. This approach is superior to traditional methods that rely on hazardous substances.

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참고문헌

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