Abstract

Development of natural silicate minerals based antibacterial and fluorometric sensors for heavy metal detection in wastewater and living cells

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Various anthropogenic activities like unplanned urbanization and rapid industrialization due to increasing population are ultimately leading to uncontrolled contamination and irreparable damage to the ecosystem. Among the various water pollutants, heavy metal pollution is considered to be one of the crucial issues to be paid immediate attention due to their high toxicity and tendency of bioaccumulation. Detecting the presence of such heavy metals in real-life water is a major challenge in the current time. Compared to other traditional techniques, fluorometric sensing of heavy metals has gained immense popularity due to their several advantages, like high selectivity and sensitivity, ease in onsite handling, no requirement for pre-treatment, and rapid visibility. These eco-friendly, biocompatible, cost-effective, and easily synthesizable sensor materials do not cause secondary pollution and are thus highly desirable for industrial purposes. This work aims toward the synthesis of such fluorescent sensors for heavy metal detection which also exhibits antibacterial properties. Silicate minerals, rather feldspar is the most abundant mineral on earth's crust, yet insufficient interest has been paid on its application as a fluorometric probe. Being a natural compound, it can be quite significant for industrial applications, but very little literature dealt with its optical, electrical, or biological properties. Thus, in this thesis, two naturally formed silicates were used, namely microcline (alkali feldspar, $KAlSi_3O_8$) containing potassium within its structure, and kyanite (Al_2SiO_5), which is devoid of any alkali element like potassium in its structure. Initially, both the collected minerals were ground to their nano-domain by using a ball mill grinder. Three size fractions were obtained, coarse, intermediate, and nano-sized fractions. Detailed characterizations were performed and size-dependent enhancement of electrical and antibacterial properties was analyzed. Further nitrogenous carbon dot was incorporated into the nano-sized minerals in order to enhance their fluorescence properties. While carbon dot-loaded microcline (MCD)

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successfully exhibited dual sensing of two toxic heavy metals (Fe^{3+} and Cr^{6+}), kyanite could only sense Cr^{6+} (KYCD). Their application as biosensors was also determined and theoretical validation of the sensing mechanism was conducted by employing molecular docking simulations. Further, to achieve a free-standing fluorescent sensor device, MCD, which effectively detects two heavy metals was added into the polymer matrix of poly (vinylidene fluoride-co-hexafluoropropylene) or PVDF-HFP for repetitive use. This membrane exhibited high flexibility, durability, and immense stability under various conditions. Moreover, it can efficiently sense both Fe^{3+} and Cr^{6+} even in real-life water and wastewater. The rapid fluorometric quenching is also visible to the naked eyes under UV illumination. Thus, such natural-mineral-based sensors open up avenues for a wide range of sensor development which can be industrially feasible and significantly perform under harsh environmental conditions without degradation with time.

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