New Photocatalyst $LiNbO_3$ for Corrosion Reducing and Environment Friendly Sustainable Concrete Construction

Ranjit K. Nath, M. F. M. Zain, and Abdul Amir H. Kadhum

***Abstract*—By the carbonation process concrete construction absorbs carbon dioxide from surrounding environment. This absorbed carbon dioxide reacts with the calcium oxide, which is already present in Reinforced concrete (RC) and form calcium carbonate an acidic compound that enhances corrosion on the surface of the reinforcement. Addition of photo catalytic materials to the RC structure during its construction phase could reduce the corrosion problem of RC materials. This material hinders calcium oxide to form acidic compound and creates a complex compound. In combination with light, this complex compound is oxidized, and residual compound will exist in or surface of RC material. In this study we find out a new photo catalytic material $LiNbO_3$ in concrete construction, adjustable with RC material for reducing corrosion problem and enhancing oxidization process of volatile organic compounds (VOC).**

***Index Terms*—Carbonation, corrosion, photo catalytic material, reinforced concrete.**

I. Introduction

Photocatalyst is needed for a cleaner environment and a better quality of life that leads to thoughts of a more eco-compatible use of light [1]. In this context photochemistry could be applied to construction materials that could provide a very interesting solution.

The increase in patents during the last decade indicates a huge interest, especially from Japan and Europe, in the application of photocatalyst in building materials [2]. Regarding the reduction of air pollution due to traffic in urban areas, the application on pavement surfaces or on the building surfaces in cementitious materials gives optimal solutions [3]. To increase the efficiency of the photocatalyst, its presence at the surface of the material is crucial. It has to be accessible by sunlight to be activated [1]. Consequently, the pollutant has to be absorbed on the surface and oxidized or reduced to a less harmful element. Due to the photocatalytic action, the whiteness of the building will remain and dirt will be washed away more easily due to the hydrophilic properties or will be decomposed [4]. The application of photocatalytic panels at the facades of buildings is investigated in the European PICADA project [5].

Till now, the majority of the work in this area has involved TiO2 in construction purpose [6]. This material has a band gap energy of 3.2 eV and therefore it absorbs light energy which is close to ultraviolet range (~380nm). In 2011, Matt Stock and Steve Dunn found that $LiNbO_3$ could be produced more products under UV and visible irradiation than TiO_2 despite its wider band gap (3.78 eV). The high yield product using $LiNbO_3$ is explained by its strong remnant polarization (70μc/cm2) [7], which is not found in TiO_2 [8].

When concrete or any other cement-based material in contact with the embedded reinforcing steel is carbonated, the steel surface is depassivated. Therefore, the reinforcing steel is no longer protected from corrosion. Corrosion may also commence when chloride, phosphate, moisture and oxygen gain access to the steel surface [2]. One of the means of protecting steel reinforcement in concrete from chloride induced corrosion is the addition of corrosion inhibiting additives [9]. In presence of photocatalyst $LiNbO_3$ in concrete the corrosion problem of RC materials can be reduced [2], [10], by increasing pH value and oxygen content.

Photocatalyst in concrete also keeps the concrete surface clean to optimize environmental benefit like degradation of organic pollutants, destruction of bacteria and viruses, decomposition of dyes or synthesis of some compounds [2].

In this study, a new photocatalyst $LiNbO_3$ is used in concrete construction and its beneficial effects on concrete material are examined.

II. Properties of $LiNbO_3$

Lithium niobate is a ferroelectric material suitable for a variety of applications. Its versatility is made possible by the excellent electro-optic, nonlinear, and piezoelectric properties of the intrinsic material. It is one of the most thoroughly characterized electro-optic materials, and crystal growing techniques consistently produce large crystals of high perfection [8].

For infrared generation by difference frequency mixing, the peak power limit is considerably lower than for 1.064 µm, being about 40 MW/cm^2. Efficiencies for difference frequency mixing generally are smaller than shg efficiencies with KDP or BBO, which is due to the lower peak powers that can be tolerated by the crystal and the fact that the longer wavelength photons that are generated in the process are less energetic. Typical powers for 10 nanosecond long pulses with 5 mm diameter beams are 30 mJ/pulse of 0.640 µm minus 40 mJ/pulse of 1.064 µm to produce 2.5mJ/pulse at 1.54 µm, and 32 mJ/pulse of 0.532 µm minus 32 mJ/pulse of

Manuscript received May 6, 2013; revised July 16, 2013. This work was supported in part by the Institutional scholarship provided from the Universiti Kebangsaan Malaysia and the Ministry of Higher Education of Malaysia.

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DOI: 10.7763/IJBBB.2013.V3.293

0.640 μm to produce 0.25mJ/pulse at 3.42 μm [11].

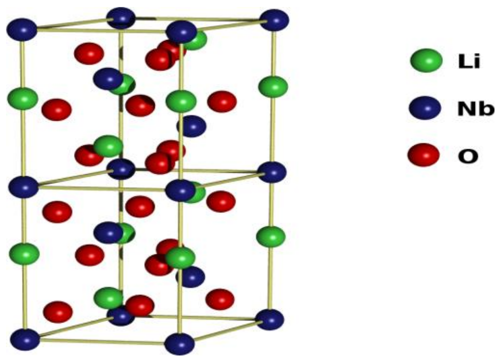

Fig. 1. Unit cell of $LiNbO_3$.

III. Electron Transfer Activity of Photocatalyst

LiNbO3 is found in the form of white powder [8]. The top of valence band is composed of 2p orbital from the O_2- atoms while the bottom of the conduction band is composed of 5s orbital from the Nb+ atom.

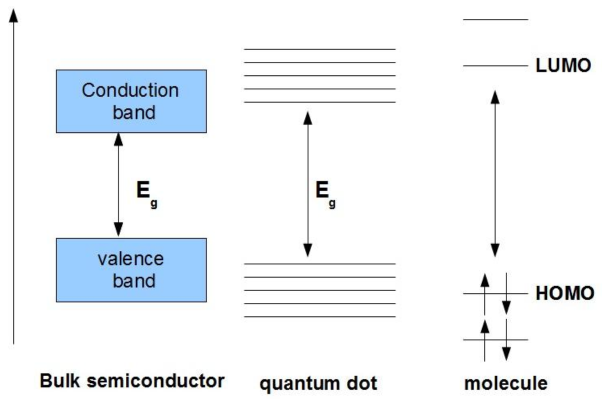

Fig. 2. Energy diagram of a semiconductor photocatalyst interface.

$$LiNbO_3 + h\nu \rightarrow h^+ + e^- \quad (1)$$

Therefore, the creation of electron hole pairs is through a ligand to metal charge transfer of an electron from the UV on oxygen to the conduction band on Niobium.

The reaction rate of the photocatalyst is surface area dependent, as its electron- hole transfer takes place on the surface [12]. Therefore, the photocatalyst morphology is an important property in determining the effectiveness of the photocatalyst [13]. The ability of a semiconductor to undergo photo induced electron transfer to adsorbed particles is governed by the band energy positions of the semiconductor and the redox potentials of the adsorbents [14].

IV. Experimental

Acidic phase i.e. decrease of pH enhances corrosion on the surface of the reinforcement. For sustainable construction the photocatalysts should maintain a higher pH value.

pH Determination of cementations materials in presence of photocatalyst.

At first 1N solution of $LiNbO_3$ and 1N solution of TiO_2 were prepared separately. Thereafter, pH of individual solution was measured using BUTECH-810 pH meter. To determine the pH of cementations materials in presence of photocatalyst cement solution was made first by mixing 16mg cement into 100ml distilled water for maintaining catalyst to cement ratio 1:100. Thereafter, 2 ml 1N $LiNbO_3$ were added to the 4ml cement solution (taken from the instant mixture of cement solution) for obtaining solution of cementations material in presence of photocatalyst. pH of this solution was measured instantly using the pH meter. pH value of cementations material in presence of TiO_2 photocatalyst was also measured using the same pH meter. The pH values obtained from this study are given in Table I.

TABLE I: pH of Photocatalyst in Presence of Cement

Component	pH	Component	pH
1N $LiNbO_3$	10.47	Cement+ $LiNbO_3$	10.42
1N TiO_2	10.33	Cement+ TiO_2	10.16

From Table I it is seen that the mixture of 1N $LiNbO_3$ with cement solution gives the higher pH (10.42) value than that of 1N TiO_2 (pH 10.16) with cement solution. Higher pH value of cementations materials in presence of photocatalyst $LiNbO_3$ reduces the corrosion problem of RC materials.

V. Role of Photocatalyst in Construction Material

Photocatalyst is needed for a cleaner environment and a better quality of life that leads to thoughts of a more eco-compatible use of light. In this context photochemistry applied to construction materials that could provide a very interesting solution [15]. It could become an integral part of the strategies adopted for reducing environmental pollution through the use of construction materials containing photocatalysts.

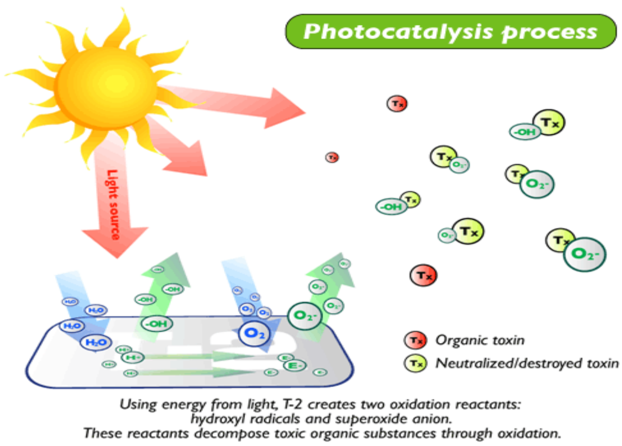

Fig. 3. Photocatalysis process.

Photocatalysts induce the formation of strongly oxidizing reagents [16], [17] which can decompose some organic and inorganic substances present in the atmosphere [18]. Photocatalysis is, therefore, an accelerator for oxidization processes that already exist in nature [19].

Indeed, it promotes faster decomposition of pollutants and prevents them from accumulating on the surfaces [20], [21]. We proposed that the use of $LiNbO_3$ in construction purpose could make an effective contribution to improve air quality by reducing pollutants [2] and reducing corrosion problem of reinforcement.

VI. CURRENT AND FURTHER DEVELOPMENTS

In practice, carbon dioxide (CO_2) initiates reinforcement corrosion, when the concrete cover in contact with this steel is carbonated and rather wet (even in a non-permanent way). Chlorides which induce metal corrosion, are ions dissolved in the pore solution ("free chlorides"). The presence of $LiNbO_3$ in concrete increased the pH value and higher pH value increased the photocatalytic property, which reduce the corrosion problem of RC materials.

We should consider employing many of the options that might improve the sustainability of this material, and continue to gain knowledge and expertise in this area.

ACKNOWLEDGMENT

The work is financed by Zamalah/Institutional scholarship provided from the Universiti Kebangsaan Malaysia and the Ministry of Higher Education of Malaysia. The first author expresses honest appreciation to CUET, Chittagong, Bangladesh for providing leave for this research.

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