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The Significant Properties of Silicate Based Luminescent Nanomaterials in Various Fields of Applications: A Review

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Abstract — Silicate-based luminescent nanomaterials have various applications such as biomaterials, biomedical, public health, tissue engineering, bone materials, plasma display panels (PDPs) and drug delivery, orthopedic as well as dental implants. Their remarkable scope in scientific research performs significant role in useful optical modules to fulfill the demands of our societies, arise marketing and lighten industries that have inspired by the green nature of environment. It helps in forming a balanced industrial framework that increases potentiality, makes better use of natural nanomaterial resources, and also keeps our atmosphere green. The primary goal of this review paper is to provide updates on silicate-based luminescent nanomaterial applications, also to discuss the benefits, unique properties and their future research scopes.

Keywords — Biomaterials, Tissue engineering, Bone materials, Plasma display panels (PDPs).

I. INTRODUCTION

Various compositional silicate biomaterials are being used in orthopedic and dental implants for global and commercial vision. Apart from this, it is in great demand in the wide areas of applications such as plasma display panels, drug delivery systems, cancer therapy as well as bone tissue engineering. In this way, we will not be an exaggeration to say that silicate biomaterial is playing its leading role in the field of medical research as compared to other materials, which is particularly visible in the present scenario.

"Nanomaterial Diversity" has made our green ecosystem human friendly, which provides complementary innovations for human consumption. Research has shown that the silicate-based bio-ceramics have emerged as promising candidates for biomaterials which are used as a living organism's bio-active molecule *in vitro* as well as *in vivo* that is proven for tissue engineering applications. Silicates with akermanite structure such as $Ca_2MgSi_2O_7$ and $Sr_2MgSi_2O_7$ phosphors have been reported to improve bioactivity [1]. They are mainly applied in the basic principles of understanding of material analysis and their characterization. Such a way, it is imperative to evolve bio-compatible, bio-active, bio-resorbable (i.e. biodegradable) and sustainable materials for orthopedic and dental implants [2], biomedical, drug delivery [3] applications. These are proven to be able to withstand high stresses and weights, which invites positive cellular and genetic reactance in our human body with a view to the rapid restoration, betterment, regeneration and protection of the damaged tissues. Silicate structure-based bio ceramics with a broad variety of compositions are included, such as silicate bio-glass, $Ca_2MgSi_2O_7$ [*Akermanite*] [4], and $Ca_3MgSi_2O_8$ [*Merwinite*] [5], $Ca_2MgSi_2O_6$ [*Diopside*] [6, 7]. All of these ceramics have been transcendent apatite fabricating capabilities in excited body liquids [8]. Akermanite [$Ca_2MgSi_2O_7$] and Wollastonite [$CaSiO_3$]; both the predominantly silicate structures have also been found to be amenable for drug delivery applications under investigation [9]. Silicate with akermanite structure may be a possible and attractive bio ceramics for tissue engineering applications [10-13]. The primary aim of this paper is to review; various silicate-structure-based luminescent materials/biomaterials applications and their benefits as well as unique properties which can provide sustainable environment to future generation.

II. APPLICATION OF BIOMATERIALS

[a] Bone Replacement

As bone substitutes, bio silicates play a vital role in bone tissue engineering. Bone replacement has emerged as an advanced therapy for the restoration of damaged and epidemical tissues rather than their expulsion or implants. This is how we see that it has been shown to be useful in reducing the effects of negative immune responses and organ damage from the human body. The unprecedented revolution in tissue substitution coincided with the evolution of synthetic biomaterials [14].

[b] Tissue Engineering

Tissue engineering applications have contributed in development of science and technology, especially in biomedical sector. It contributes for repair, restoration as well as maintenance of damaged tissues or the entire organ. It helps to boost functional capability of tissues via joining scaffolds, cells and bio-active molecules. Initially it was considered to be a sub-domain of biomaterials, but it is a broad area that has emerged in itself [15].

III. Essential Criteria of Biomaterial

The most essential criterion in the integration of biomaterials that it must be biodegradable, biocompatible, and capable of maximizing the purpose of attaching as well as growing cells. Natural materials are often already designed to meet these needs. Hence, they prove to be good candidates from the point of view of human use [16]. Biomaterials including Calcium (Ca), Magnesium (Mg), and Silicon (Si) have very low degression rate, which have been demonstrated to be the prominent mechanical power in approaches comparable to traditional biomaterials like calcium phosphates [HAP] and Wollastonite ($CaSiO_3$) structures [17]. Mellite is given by the common formula $\mathbf{M_2T^1T^2{}_2O_7}$, which is a large exclusive group of compounds (where M= Sr, Ca, Ba and T^1= Mn, Co, Cu, Mg, Zn as well as T^2= Si, Ge). These have been extensively studied as optical materials [18].

IV. Traditional Techniques

The better use of various traditional techniques for the formation of silicate bio-ceramics (especially akermanite structure) including combustion method [19], sintering and crystallization method [20], sol–gel procedure [21], as well as container less processing technique [22]. Nowadays, the spray pyrolysis method is also being utilized. However, all of these methods are suitable for the formation of bio-ceramic structures. Generally, the most applicable synthesis techniques for the formation of luminescent materials [especially silicates] to better utilize are conventional solid-state reaction technique, which demands very high-temperature thermal treatment. High temperature treatment is very important for the structure formation of any nanomaterial, because it has chemical structure formation layer by layer. Therefore, at present all nanophosphors are being prepared by this technique. In this way, this technique is easier than other technique. Akermanite structured ceramics prepared through sintering akermanite powder compacts at 1370^0C high temperature for 6 hours [23].

V. Role of Fluxs in Structure Formation

Fluxes play a significant role in the crystal structure formation of any nano and micro phosphors. These fluxes increase the rate of any formation. As a result, phosphors with actual chemical structures are obtained. Some special fluxes such as potassium chloride (KCl), lithium fluoride (LiF), calcium chloride ($CaCl_2$) as well as boric acid (H_3BO_3) for assembled to improve crystal structure formation [24].

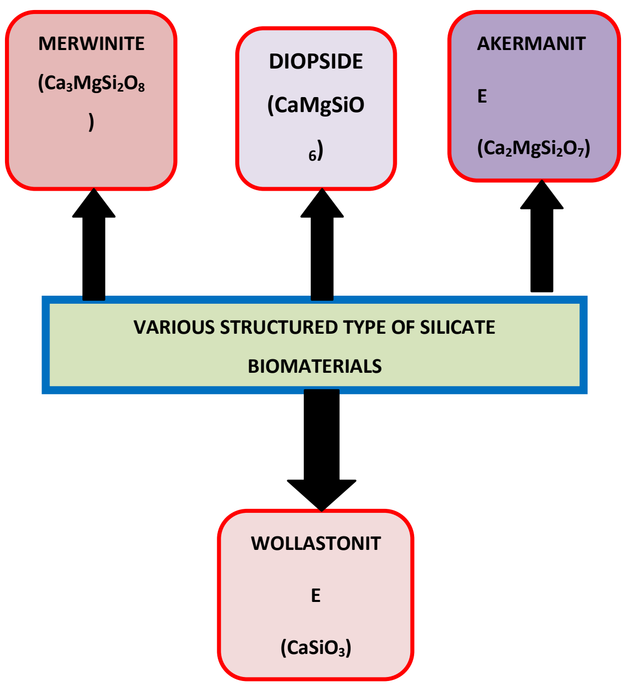

FIGURE: 1. TYPE OF SILICATE BIOMATERIALS

Various literature reports suggest that the in-vitro HAP formation capability of the akermanite structure is possible only because of the silicon rich layer, which greatly accelerates the composition of HAP on its plane and also be regulates the precipitation dynamics of bone such as apatite deposition, when it was dipped in simulated body fluids [25-26]. When tested for in-vivo trial, it is found that akermanite helps to a great extent in promoting cell expansion and osteogenic discrimination [27–30].

VI. Silicate Based Luminescent Materials

These alkaline earth metal such as ***(Calcium, Strontium, Barium)*** rare-earth doped silicates develop as luminescence phosphors continuously over a long duration of time, also called as ***long persistent luminescence phosphors (LPL)***, which are being studied extensively. Because of these specific features, their applications such as traffic signs, decoration and textile printing etc, are continuously increasing in the growing market. Compared with the sulphide materials utilized in the past, silicate phosphors yields have superior features such as longtime duration and brighter luminescence emission, abundant [24], facile preparation and cheaper [31-34].

Light exhibits a tremendous practical approach in the exclusive area of material science and nanotechnology applications. Therefore, its ever-increasing steps in globalization have widely interconnected to the whole world. In particular, it has emerged as an interdisciplinary approach to clean energy in nanotechnology science. We see that in recent years, there are many categories in the emerging field of optical display devices, lamp phosphors and white light production in rare earths [RE] doped inorganic systems. The significant role of RE^{3+} ion has been great attraction of efficient phosphors [35].

The most expressive studied of silicates-based phosphors exhibit attractable features, like high stability to heat and chemical, water resistance, quantum yield (~70%) as well as large light intensity [36]. The silicate phosphor-based devices have been designed using more eco-friendly, more co-compatible and more energy economized [37, 38].

The luminescent features of CMS-based phosphors arise due to being co-doped accompanied various rare-earth ions [39]. For LLP and PDPs applications, CMS has been broadly studied as a host. LLP can be persisting for a long-time in the darkness after the stimulation is removed. This process has fascinated a lot of attention. For this reason, it is being applied in several areas, like emergency lights, safety indicators, road signal, glossy paints, graphic art pieces etc. Blue, green and red-colored LLPs as well as white LLP are also required for full colour exposure [40].

Akermanite is also demonstrated as a possible bone material, due to its good biocompatibility and bioactivities [41,42]. Luminescent biosensors have fascinated consideration because of their possible assumptions in real time, in situ biomedical monitoring [43,44] as well as human disease detection [45,46].

VII. Properties of Silicate Based Phosphors

Application of silicate based luminescent material is one of the most advanced innovative potential applications of various research areas. These applications of phosphor converted white LEDs due to its very unique significant characteristics such as operated long lifetime, energy saving, long brightness, higher luminescent efficiency, chemical stability, compactness and Environment friendly behavior [47] as well as extreme chemical resistance and visual light transparency, thermal stability, excellent water resistance and strong absorption in the near ultra violet region [48,49].

In the 19th century, after the discovery of this phosphor, the LLPs have been substantially developed. In particular, the invention of Eu^{2+} and Dy^{3+} co-doped silicates led to unprecedented and improved results, whose luminescent brightness, LLP features and stability were clearly better than those of sulphide series products. Basically, observation of the Europium and Dysprosium ion co-doped phosphors reveals that the Europium ion is an activator and the Dysprosium ion generate certain traps either for electrons or for holes [50]. Dysprosium (Dy^{3+}) is one of the most significant RE ions that gives a greater contribution in the production of several kinds of light emitting phosphors (LEPs) [24].

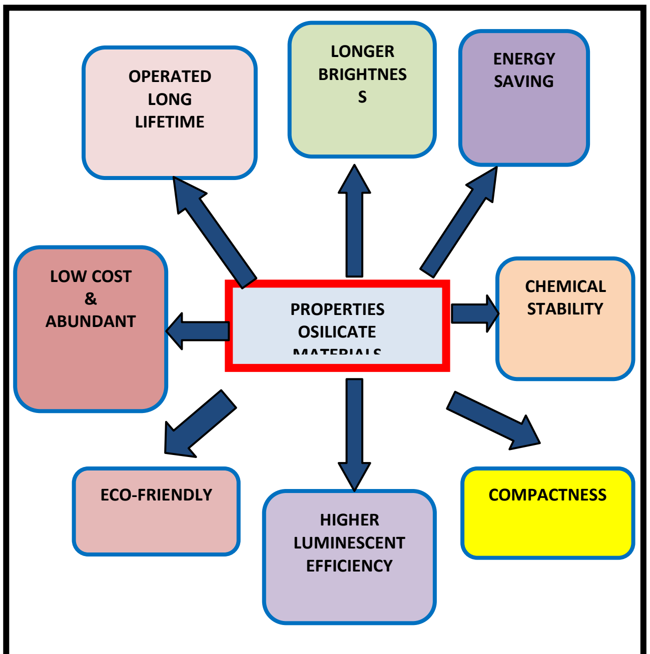

FIGURE: 2. PROPERTIES OF SILICATE MATERIAIS

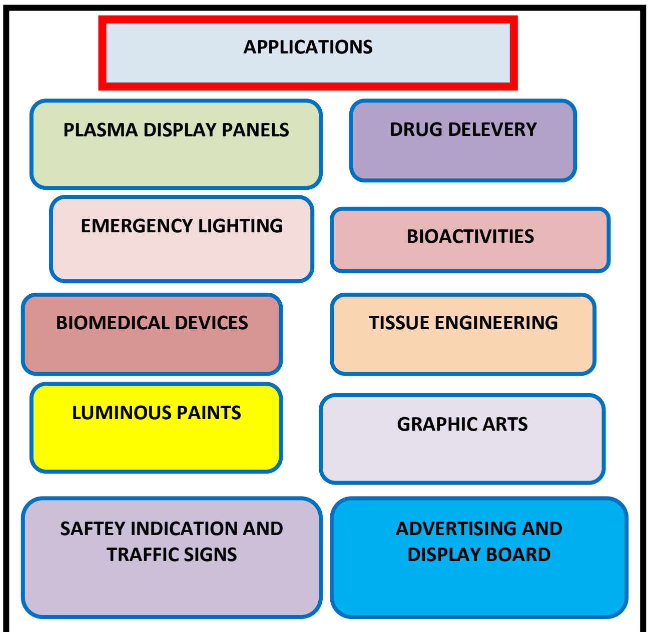

FIGURE: 3. APPLICATIONS OF SILICATE MATERIAlS

VIII. Environment And Nanomaterial Diversity

The relationship between environment and nanomaterial diversity exhibits complementary parts to each other. It refers to the sum total of the variety of human life and its kinetic interactions. It is essential part for the sustainable green nature of mankind. It performs some very crucial ecological roles with respect to eco friendly system, climate change, adapting to environmental changes and favorable it to human life. A multi advanced technology-based concept to empower the quality of the services of physical optical devices in a very smart and effective way by using nano sensors and similarly sensory data receptors. The diversity of nanomaterials has completely changed the lighting market today. That's why we need that the nanomaterials created should be in every possible way friendly to the environment and our human life. Nanomaterials made from rare earth utilized for doping are the lifeblood of any optical devices. Therefore, it becomes necessary to conduct such rare earth doping, which is responsive to high ideal values of environment and human life along with better results.

IX. CONCLUSION AND FUTURE SCOPE

Silicate has proved itself as a promising candidate in not only a single field but in several areas of research as well as of mankind applications. Its role as substitute of bone is a remarkable finding. Also, its role in repairing/ restoring the damaged tissue as substitute of living tissue can bring revolution in biomedical field. Silicate exhibits better results than other materials due to its various characteristic properties, which has been playing an important role in terms of globalization. Silicates nanomaterials with co-doped europium and dysprosium rare earths are generating very remarkable results, which are being used globally to make optical LED devices. These devices demonstrate their commitment towards being highly energy saving thus eco-friendly. Both rare earths europium and dysprosium have presented evidence of enhanced luminescence features. Through this present review paper, I have tried to mention the various characteristic properties of silicate phosphor in a better way. My main goal is to specifically study its different significant features by generating akermanite structured silicate phosphor with other rare earth erbium (Er^{3+}), which can fully demonstrate its favorable behavior towards the environment and human life. I hope that silicate with erbium doped akermanite structure will also give promising results, which we will be able to use successfully in different applications.

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