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RESEARCH PAPER

Landscape on Organosilicon Compounds: Structure, Bonding and Applications

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Abstract: *The organosilicon compound group illustrates exceptional molecules demonstrating multiple structural patterns through unique bond formation capabilities and serving broad spectrums of practical uses throughout various sectors. The abundant bond-forming capabilities of silicon allow for the creation of many different structures in organosilicon compounds through its ability to bond with multiple atomic elements, including carbon in single, double, and triple bonds, oxygen, nitrogen, and sulfur. The synthesis of numerous organosilicon compounds becomes possible through the versatility of silicon because it allows the production of silanes, siloxanes, silanols, silazanes, silsesquioxanes, and other complex compounds. Organic silicon compounds demonstrate valuable properties such as thermal stability, chemical inertness, and flexibility, making them critical components for advanced material design. Various application areas benefit from organosilicon compounds, such as materials science, pharmaceuticals, electronics, and agriculture. The applications of organosilicon compounds in materials science include their use as water-resistant coatings, sealing agents, and adhesive formulations that provide beneficial material modifications. Organosilicon compounds provide three essential functions in pharmaceuticals: they function as drug carriers, image enhancers, and synthetic construction components because of their ability to work well with biological systems and their adjustable chemical characteristics. Semiconductor devices utilize organosilicon compounds both as insulators and dielectric materials while using them as encapsulants. Recent review unveils fresh situations for pioneering modern materials and advanced technologies, which enhance operational efficiency and functional properties.*

Keywords: *Organosilicon, Silanes, VOC, Optically active, Silicon.*

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1. INTRODUCTION

Organosilicon compounds are a class of organometallic compounds with silicon–carbon linkages. The chemistry of organosilicon corresponds to their properties and preparation. Being colorless, combustible, hydrophobic, and stable in air, most organosilicon compounds resemble common organic molecules. One of the synthetic organic chemistry domains with the quickest growth is that of organic silicon compounds. Consequently, it has become one of the most critical areas of research, and the development of new methodology which provides general stereoselective reaction processes continues to be actively investigated [1] Organosilicon compounds, which are silicon-containing hydrocarbons, have a wide range of accepted usage [2]. Examples include silicones like polydimethylsiloxane (PDMS), which is recognised by the European Food Safety Authority (EFSA) as a food additive [3] and is widely used in the field of microfluidics [4]. Simethicone, an over-the-counter medication with a silicone foundation, is a gastrointestinal surfactant to treat infant colic.

Organosilicon compounds are widely used in daily life. Because these substances are not systemically absorbed, several chemicals are commonly used in food, cosmetics, and medicinal products. Some organosilicon compounds, whose interactions with cell membranes and models were studied using various analytical techniques [5]. The results showed that the compounds were maintained in or on the cell membrane.

Hydrocarbons containing silicon, known as organosilicon compounds, are widely used in various applications. Instances comprise silicones such as polydimethylsiloxane (PDMS), which is extensively employed in microfluidics and recognised as a food additive by the European Food Safety Authority (EFSA). Simeticone, an over-the-counter medication with a silicone base, is used as a gastrointestinal surfactant to treat infant colic. A class of compounds known as organosilicons has been used recently to protect wood and other lignocellulosic materials against fungal assault and to increase their water resistance [67]. Organosilicons have been employed as strengthening additives, defoamers, and softening agents in the paper industry [8].

Materials made of organosilicon with Single-bond silicon (Si) bonds are significant functional platforms with a wide range of applications in disciplines including bioscience, energy, and catalysis because of their special optical, electrical, and biocompatibility characteristics. Materials that glow due to the Sissel bond One-off connection Materials with Si bridges have opened up new possibilities for imaging biological processes in living organisms [9]. Consequently, a thorough comprehension of the functions that Si single bond. The role of single-bond Si bonds is useful for developing organosilicon luminous materials in the future.

Organosilicon compounds interest scientists for various reasons, most notably because of several intriguing findings on their biological effects. Five decades ago, the fields of biomaterials and bioengineering emerged, coinciding with the development of modern organosilicon chemistry. It has been reported that some organosilicon compounds affect the collagen biosynthesis in cartilagenous tissue. New approaches based on the organosilicon modification of the biologically active compounds, especially of compounds containing hydrophilic functional groups, offer the possibility to improve their pharmacological properties because of easier penetration of modified compounds through lipophilic barriers inside the body [10-12]. In light of their potential effects on the structure and electronic characteristics of group IV-based electronic materials, the structure and electrical properties of group IV elements containing Si-C, Si-Si, and Ge-Si bonds are fascinating. Modern electronic gadgets heavily rely on Si-Ge atomic layer superlattice materials [13].

2. HISTORY

The Earth's crust contains 25.8% silicon, making it an abundant element in the planet [14]. Bulk and silicon-based atomic models are commonly utilized to comprehend the properties of silicon. Organosilicon compound development started in the 19th century. 1863 Charles Friedal and James Crafts made the first organochlorosilane compound [15]. In the same year, they also reported the synthesis of ethyl and methyl-o-silicic acid using a polysilicic acid ether.

Extensive research in the field of organosilicon compounds was pioneered at the beginning of 20th century by Frederic S.Kipping [16]. He also coined the term "silicone" (resembling ketones) [17-18] about these materials in 1904. In recognition of Kipping's achievements, the Dow Chemical Company established an award in the 1960s for significant contributions to silicon chemistry [19]. Kipping was renowned for his works in which he first created silicone oligomers and polymers and made alkylsilanes and arylsilanes using Grignard reagents. 1945 Eugene G. Rochow contributed significantly to organosilicon chemistry by first describing the Muller-Rochow process [20].

3. PHYSICAL CHARACTERISATION OF ORGANOSILICON COMPLEX

Organosilicon complexes synthesised and characterised for their physical properties, reported in Table 1. To form the complexes in anhydrous circumstances, a solution of the Schiff bases (0.691–1.127 g; 3.385 mmole) in dry methanol (60 mL) was gradually supplemented with ethoxytrimethylsilane (0.47 g; 3.385 mmole) in a 1:1 molar ratio.

After 30 minutes of refluxing the mixture while stirring constantly, a clear solution was obtained; after that, refluxing continued for ten to twelve hours. Following multiple washes with a methanol and n-hexane (1:1 v/v) mixture, surplus solvent was eliminated under lowered pressure, and the mixture was finally vacuum-dried on a rotary evaporator at a bath temperature of 40 ± 5°C.

The crystalline solids were separated and refined using the same solvent by recrystallization. TLC was used to determine the compounds' purity while silica gel-G was used as an adsorbent [21]. Separation of volatile organic compounds (VOCs) from a highly viscous polymer solution was investigated using the rotating packed bed (RPB) technology to minimize the VOC content in the product stream [22].

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Table 1. Analytical and physical data of the $Me_3Si(IV)$ complex

C. No	Products and Colour	M.P. °C	Yield (%)	Elemental Analysis, Found (Calcd.)					Mol. Wt. Found (Calcd.)
				%Si	**%C**	**%H**	**%N**	**%S**	
Me_3SiL_1	$C_{13}H_{16}N_2O_3Si$ reddish	104	69.55	10.01 (10.16)	56.45 (56.50)	5.82 (5.84)	10.19 (10.14)	—	270.65 (276.36)
Me_3SiL_2	$C_{14}H_{18}N_2O_3Si$ reddish	138	65.36	9.50 (9.67)	57.84 (57.90)	6.27 (6.25)	9.60 (9.65)	—	281.98 (290.39)
Me_3SiL_3	$C1_6H_{22}N_2O_3SSi$ reddish	116	69.80	8.15 (8.01)	54.75 (54.83)	6.30 (6.33)	7.92 (7.99)	9.01 (9.15)	356.12 (350.51)
Me_3SiL_4	$C_{20}H_{22}N_2O_3Si$ reddish	82	79.59	7.56 (7.66)	65.63 (65.55)	6.02 (6.05)	7.65 (7.64)	—	357.83 (366.49)
Me_3SiL_5	$C_{22}H_{23}N_3O_3Si$ brown	160	73.43	6.85 (6.93)	65.02 (65.16)	5.69 (5.72)	10.30 (10.36)	—	413.11 (405.52)
Me_3SiL_6	$C_{17}H_{20}N_4O_3Si$ brown	132	90.30	7.93 (7.88)	57.19 (57.28)	5.60 (5.66)	15.75 (15.72)	—	350.94 (356.45)
Me_3SiL_7	$C_{16}H_{21}ClN_2O_3SSi$ reddish	122	56.09	7.18 (7.30)	49.83 (49.92)	5.45 (5.50)	7.21 (7.28)	8.30 (8.33)	380.32 (384.95)
Me_3SiL_8	$C_{17}H_{19}ClN_4O_3Si$ brown	130	76.65	7.06 (7.18)	52.33 (52.23)	4.88 (4.90)	14.23 (14.33)	—	383.56 (390.90)
Source: Singh, H. L., Singh, J., & Mukherjee, A. Bioinorg Chem Appl [21]									

Polysiloxane was isolated from low-molecular-weight cyclic siloxane components (LMWSCS) and the volatile organic compound (VOC) xylene at 140°C from the mixtures under investigation. Figure 1. Due to its ability to process viscous liquids countercurrently in high-specific-surface-area packings—something that is not achievable with traditional equipment like thin-film evaporators—RPB technology has great promise as an extremely effective instrument for the purification of highly viscous liquid combinations.

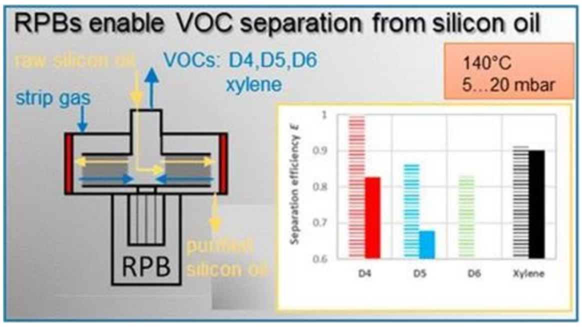

Fig. 1. Separation of VOC by RPB Technology

4. CHEMICAL STRUCTURE AND BONDING In ORGANOSILICON COMPOUNDS

4.1. Tetrahedral Compounds

Most compounds containing tetracoordinate silicon and tetracoordinate carbon atoms exhibit the structural chemistry of the SiC single bond. The SiC bond's structural chemistry in molecules where the carbon coordination state exists. So, organosilicon compounds have a tetrahedral geometry, mostly due to the sp3 hybridised orbitals of silicon. The organosilicon compounds contain bonds between the silicon and carbon atoms. Optically active silanes are also possible when central chirality exists, like carbon. A series of monofunctional optically active silanes can be prepared and used for the stereochemical studies. The SiC bond is markedly polarized, and the bond ionicity increases by attaching different substituents to the silicon or the carbon atoms, which may affect its length [23].

4.2. Penta- and Hexacoordination

Silicon can form penta- or hexa-coordinated compounds, in contrast to carbon. Incorporating d orbitals to generate either sp_3d or sp_3d_2 is commonly used to explain the synthesis of such highly coordinated silicon compounds. Nonetheless, the bonding can be described by a three-centre and four-electron bond. For stable complexes, both models call for electronegative substituents. In fact, electronegative substituents like Cl, F, NR_2, and RO are used to create highly coordinated silicon compounds. In order to develop a dative link, electronegative atoms following silicon would contract their d orbitals and transfer electrons.

This concept is called pπ-dπ or (p-d)π bonding (see pπ–dπ Bonding) and has been used to explain several unique structural features such as shorter

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experimental bond lengths than calculated for Si–O and Si–F, planarity about nitrogen of $(H_3Si)_3N$, and the wider bond angle of disilazanethan dimethylamine [24]. On the other hand, there is disagreement over the theoretical predictions of (p-d)π bonding. One possible explanation for the shorter silicon bond lengths to electronegative elements could be a greater contribution from ionic structures like R3Si+ X−. Therefore, the conjugation of σ*–π may significantly influence (Figure 2) [25].

4.3. Bond Energies and Lengths

Table 2 [26] shows the selected tetracoordinated silicon-element and the corresponding carbon-element bonds and their bond length. The bond lengths are shorter for silicon bonded to more electronegative elements than carbon. The compound's coordination number can also somewhat affect silicon's bond lengths. Although bond lengths of silicon compounds are longer than those of the corresponding carbon compounds, silicon forms stronger bonds than carbon [27].

5. SYNTHESIS METHODS FOR ORGANO-SILICON COMPOUNDS

5.1. The Rochow Process (Direct Synthesis)

In the presence of a catalyst, the reaction of aryl chloride or alkyl chloride with silicon is an example of direct synthesis. Mostly, methyl chloride is subjected to the reaction at 250–350ºC in a fluid bed with fine particles of silicon mixed with a copper catalyst [28].

Cu

$MeCl + Si = Me_nSiCl_{4-n}$ ➤

For dichlorodimethylsilane, Me_2SiCl_2, conditions are usually optimised, as it is required for methyl silicones production, and the mixtures of chlorosilanes are always obtained and given in Table 3 [26]. According to the table, the boiling points are very close. In the silicone industry, an extensive fractionating system separates these chlorosilanes.

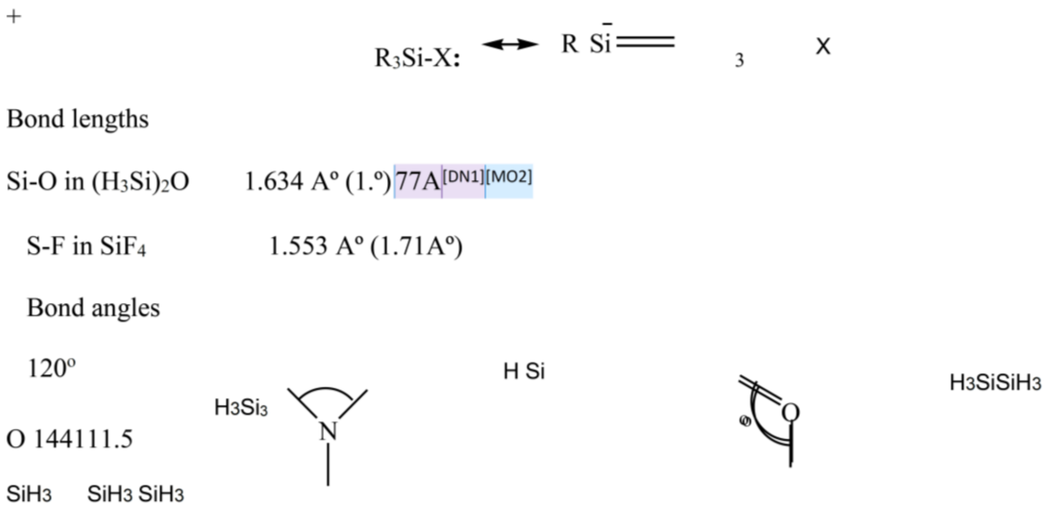

Fig. 2. Examples of anomalous bond angles and bond lengths [25]

Table 2. Some selected lengths of bond for C–X and Si–X

Bond	Bond length (A°)	Bond	Bond length (A°)
D_3Si-H	1.48	D_3C-H	1.09
H_3Si-CH_3	1.87	H_3C-CH_3	1.53
H_3Si-$N(SiH_3)_2$	1.74	H_3C-NH_2	1.47
H_3Si-$OSiH_3$	1.63	H_3C-OH	1.41
H_3Si-F	1.59	H_3C-F	1.38
H_3Si-SiH_3	2.33	H_3C-SiH_3	1.87
H_3Si-PH_2	2.25	H_3C-PH_2	1.86
H_3Si-$SSiH_3$	2.14	H_3C-SH	1.82
H_3Si-Cl	2.05	H_3C-Cl	1.78
H_3Si-Br	2.21	H_3C-Br	1.94
H_3Si-I	2.44	H_3C-I	2.14

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Table 3. The directsynthesis products of monomer composition

Compound	%Composition*	Boiling Point (°C)
$(CH_3)SiHCl_2$	1.0–6,0	41.0
$(CH_3)SiCl_3$	3.0–10.0	66.0
$(CH_3)_2SiCl_2$	75.0–93.0	70.0
$(CH_3)_3SiCl$	1,0–5.0	58.0
$(CH_3)_4Si$	0.01–0.5	26.6
* Composition of the products depends on operating conditions		

5.2. Reaction with Grignard Reagents

The preparation of particular organosilicon compounds with an appropriate chlorosilane and a Grignard reagent is the most important laboratory method. Various types of methyl-chlorosilanes, $SiCl_4$, $SiHCl_3$, and are used in the reaction. Stepwise reaction occurs when more than two chlorine atoms are present in silicon carries.

$R_3SiCl + R'MgBr$ ➤ R_3SiR'

5.3. Alkylation (or Arylation) Reaction with Grignard Reagents

The alkylation (or arylation) reaction [29] occurs under carefully controlled conditions but, for that purpose, alkoxysilanes can conveniently be used because the reactivity of the last alkoxy group toward Grignard reagents is very low. In the following order of complexes Si–CN >SiCl >SiOR >Si–OSi >SiH shown the relative reactivity of SiX toward Grignard reagent.

$MeSi(OEt)_3 + 2RMgBr$ ➤ MeR_2SiOEt

5.4. Reaction of SiX toward Grignard Reagent

The reagents of Poly-Grignard from X–$(CH_2)n$–x when n is larger than 4 then give normal products. For the preparation of silanes, organolithium compounds can also be used conveniently. In the case of n=1, in this Grignard reactions can be utilized.

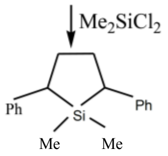
Li(in situ)

$Me_3SiCl + CH_2Cl_2$ _T_H_F_ $(Me_3Si)_2CH_2$ ➤

5.5. Reactivity of the Lithium Reagents

Alkenes like styrene and 1,1-diphenylethylene are important, and dilithium reagents are derived by reductive coupling reaction to prepare ring compounds.

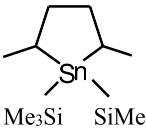
$2PhC = CH_2 + 2Li \rightarrow PhCHLiCH_2CH_2CHLiPh$



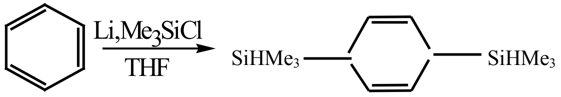
A similar dilithium reagent derived from 1,1-bis(trimethylsilyl) has been used for the protecting ligand of the first monomeric stannylene [30].

(i) Li =

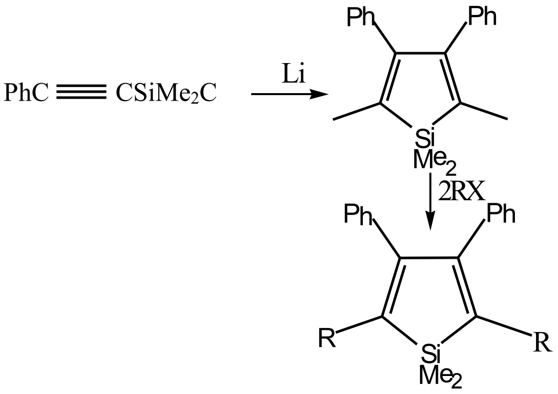
$2Me_3SiCHCH_2$ (ii) $SnCl_2$ $Me_3SiSiMe_3$ →



Closely related to the Birch reduction, benzene, and other aromatic compounds afforded reduction-silylation products [31].



Electron-transfer reactions of bis(phenylethynyl) dimethylsilane gives 2,5-dianion of 3,4- diphenylsilole [DN5][MO6] that is a useful intermediate to variously substituted siloles [32-35].



5.6. Silylmetals Reactions

Since most of the silicon compounds are polarize as Si+-X− because silicon is a positive element and covalent bonded compounds. However, silicon can form bonds with alkaline earth metals and alkaline to give silylmetals [36] in which silicon compounds polarize as Si−-M+. Silyl anions were produced by silylmetalswhich are react with haloalkanes to give the corresponding organosilanes.

DMI$Me_3SiC_5H_{11}$

$Me_3SiNa + C_5H_{11}Cl$ ➤

The transmetalation reaction between silylmercury and Li may also prepare silyllithium compounds. The requisite silylmercury may be prepared from chlorosilane or hydrosilane [37-38].

$2Li2Me_3SiSiMe_2Li(Me_3SiSiMe_2)_2Hg$ ⟶

Diethylamino-substituted silyllithium was successfully prepared and used to prepare silicon-functional compounds [39].

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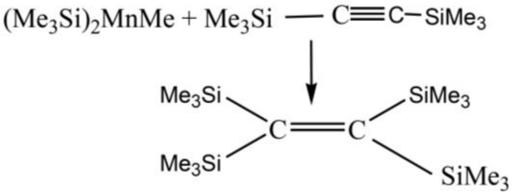
Li (dispersion) $Ph_2Si(NMe_2)Cl$ → THF, 0ºC
$Ph^2Si(NMe^2)Li$ ↓
Ph_2SiCl_2
$Ph_2SiSiMe_2SiPh_2$
NMe_2 NMe_2

A combination of MeMgBr, a manganese salt and trimethylsilyllithium is an interesting reaction that is reported to be equivalent to $(Me_3Si)_2MnMe$.



5.7. Addition of Hydrosilane with Alkenes and Alkynes (Hydrosilation)

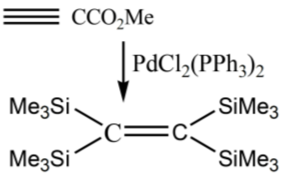
Addition reactions of hydro silanes to alkenes shown in the following general scheme are one of the most frequently utilized reactions for the preparation of organosilanes [40].

$R_3SiH + R'CH = CH_2 \rightarrow R_3SiCH_2CH_2R'$

Alkenes with a variety of substituents such as acetal, amine, amide, carbamate, ester, ether, isocyanate, ketone, oxirane, and sulfide can be hydrosilated, usually without affecting the functional group [41]. It is not so remarkable in the case of radical hydrosilation, but reactivity is high for hydrosilane, which has an electronegative group in the case of transition metal catalyzed hydrosilation [42-43].

$HSiCl_3 + CH_2 = CHCH_2Cl \ \underline{H^{2PtCl6}} \ Cl_3Si(CH_2)_3 + CH_2 = CHCH3$

An addition reaction [2σ + 2π] of acetylenes and disilaneswas closely related to hydrosilation. The prototype of the reaction is shown in example the cis addition is established similar to hydrosilation [44-45].



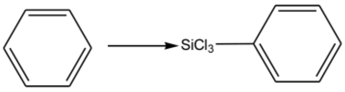
$Me_3SiSiMe_3 + MeO_2CC$

To add trichlorosilane to acrylonitrile, base-catalysts like t-amines and phosphines are used as catalysts, which are almost limited.

$$HSiCl_3 + CH_2 = CHCN \xrightarrow{\text{Base}} Cl_3SiCH_2CH_2CN$$

5.8. Hydrosilanes Condensation by Halogenated Hydrocarbons and Hydrocarbons

In the presence of vapor phase at 400–500ºC benzene reacts with trichlorosilane to give trichlorophenylsilane. Reaction temperature falls to 270–350ºC and yield improves by adding a catalyst such as BF_3 and BCl_3 [46].



$HSiCl_3$ ++ H_2

Dehydrochlorinative coupling of hydrosilane with aryl or alkenyl chloride is utilized in the industrial synthesis of trichlorophenylsilane, methyldichlorophenylsilane, trichlorovinylsilane, and dichloromethylvinylsilane [45]. At high temperature in the presence of vapor phase these reactions are usually carried out and accompanied by side reactions like reduction and redistribution.

$$HSiCl_3 + CH_2 = CHCl \xrightarrow{500-600℃} CH_2 = CHSiCl_3 + HCl$$

$$HSiCl_3 + CH_2 = CHCl \xrightarrow{500-600℃} CH_2 = CHSiCl_3 + HCl$$

The reaction of 2-chloropropene, trichlorosilane, and amine in the presence of a catalytic amount of copper (1) chloride proceeds smoothly under mild conditions to give allyltrichlorosilane in high yield [48].

$$HSiCl_3 + CH_2 = CHCH_2Cl \xrightarrow{RC_3uNCl} CH_2 = CH_2CHSiCl_3$$

5.9. Other Reactions

New Si–C bonds are generated in a variety of reactions, although most of them are not utilized in the systematic synthesis of compounds of organosilicon. An Interesting representative examples are given in the following.

At low temperature the reaction of tetrachlorosilane with diazomethane in the presence of ether gives (Chloromethyl)trichlorosilane with 60% yield.

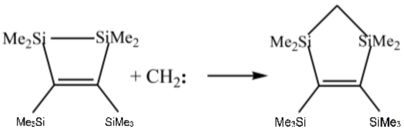
$SiCl_4 + CH_2N_2 \rightarrow Cl_3SiCH_2Cl + N_2$

Methylenations Second and third are possible but with lots of difficulty. The methylenation product are given by a Simmons-Smith reagent and reaction of trialkylsilane. The reactivity of tri-n-butylsilane was much higher than cyclohexene toward iodomethylzinc iodide. Actually, good trapping reagents were trialkytsilanes for species of divalent like silyleneand carbene.

$Et_3SiH + ICH_2ZnIEt_3SiCH_3 + ZnI$ ⟶

$Me_2Si: + Et_3Si\text{-}HEt_3Si\text{-}SiMe_2\text{-}H$ ⟶

For a reactive Si–Si bond, Methylene insertion is also possible. Insertion also occurs on the same substrate in the reactions of divalent silicon species, silylene. A new Si–C bond with different types of substrates is formed by Silylene, which will be explained later.

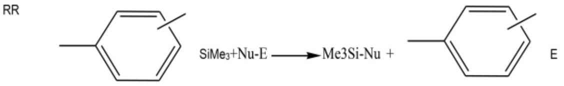


5.10. Synthesis of Silane by Si-C Bond Cleavage

By the action of different types of reagents and other electronegative groups, like halogen and alkoxy, the Si–C bonds are cleaved. Therefore, for the introduction of functionality into the silicon part, these reactions are utilised. With electrophilic reagents, cleavage of the Ar–Si bonds is simple. For the preparation of chlorosilanes, halodesilation is important.

$Ph_3SiLi + Me_3SiCl \rightarrow Ph_3SiSiMe_3 \rightarrow HCl/AlCl^3$ $Cl_3SiSiMe_3$

Reaction is useful for the preparation of both silicon-functionalized silanes and aryl derivatives by the electrophilic attack with E–Nu to give $Nu–SiR_3$ and Ar–E, and for the above reaction Arylsilanes undergo ipso-desilylation.



Nu–E=D–Cl, $CH_3CO–Cl/AlCl_3$, Br–Br, t-Bu–Cl/$AlCl_3$, $NO_2–OH/Ac_2O$, etc in the laboratory, it is a standard procedure for the preparation of chlorosilanesthe chlorodemethylation reaction with a 1:1 mixture of acetyl chloride and aluminium chloride.

$CH_3COCl/AlCl_3$
$Me_3SiSiMe_2Cl$
$2CH_3COCl/AlCl_3$
$Me_3SiSiMe_3$
$ClMe_2SiSiMe_2Cl$

In the presence of a catalytic amount of hydrogen chloride, aluminum chloride, or trimethylchlorosilane is an example of redistribution reaction also undergoes cleavage of the Si–C bond. Facile cleavage of the allyl-silicon bond has been utilized for the preparation of iodotrimethylsilane [49].

$Me_3SiSiMe_3 + Me_3SiCl \xrightarrow{AlCl_3} Me_3SiSiMe_2Cl + Me_4Si$

$CH_2 = HCH_2SiMe_3 + I^2 \rightarrow CH_2 = CHCH_2I + Me_3SiI$

The source of carbon nucleophiles gives the corresponding carbanions which may be used in the synthesis and give the Si–C bond can also be cleaved by strong nucleophiles.

$(Me_3Si)_2CH_2 + NaOMe \xrightarrow{HMPA} {}^{-}Na^{+} + Me_3SiOMe$ Me_3SiCH_2

$CH_2 = CHCH_2SiMe_3 + F^{-} \rightarrow CH_4 = CHCH_2^{-} + Me_3SiF$

6. APPLICATIONS Of ORGANOSILICON COMPOUNDS

6.1. Organosilicon Compounds in Polymer Science and Materials

One of the most potential solutions to the issues with traditional halogenated fire retardants' availability, safety, and health effects is the use of organosilicon compounds as fire retardants in polymers. There are currently many different kinds of organosilicon compounds with varying levels of oxidation on the market, such as silanes, polysiloxanes, and polysilsesquioxanes, as well as structures like polycarbosilane and polysilazanes that have heteroatoms in the main chain. When such compounds are dispersed into organic polymers, a condensed phase action may occur that influences the behaviour of the polymers in the event of a fire, creating a ceramic phase that is thermally stable and protective during the initial stages of burning. Basically, there are two types of compounds that are employed as fire retardants: (1) low molecular weight compounds and (2) macromolecular compounds. It is possible to think of low molecular weight organosilicon compounds as the end product of organic radicals replacing hydrogen atoms in silane (SiH_4). The majority of commonly used macromolecular organosilicon compounds are based on the Si-O bond, also known as siloxane, which can undergo polymerization to create polysiloxanes with various geometric configurations. Silane is the silicon equivalent of methane, wherein an organic functional group like vinyl, amino, chloro, epoxy, mercapto, alkoxy, etc. takes the place of a hydrogen atom. A hydrolytically sensitive centre, such as -OR, is typically present in silanes, and it can react with the hydroxyls of inorganic substrates to generate stable covalent bonds.

One type of organosilicon chemical is siloxane, which is made up of –Si-O-Si-O- backbones with side chains R connected to the silicon atoms (R_2SiO), where R can be an organic radical or a hydrogen atom that may include functional groups. Silicones are polymers made of siloxanes, including polydimethylsiloxane (PDMS), the

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most common polymer in the silicone sector. A variety of siloxanes and polysiloxanes have been synthesised with the intention of using them as fire retardants.

A family of organic-inorganic hybrid compounds known as silesquioxanes has the generic formula ($RSiO_{1.5}$), where R is an organic group. The process of hydrolytic condensation of trifunctional monomers $RSiX_3$, where X is a highly reactive substituent like Cl or alkoxy, yields polysilsesquioxanes $(RSiO_{1.5})_n$.

6.2. Pharmaceuticals and Biomedical Applications of Organosilicon Compounds

Unique prospects for medical applications are provided by the inclusion of silicon and the creation of tiny molecules made of organosilicon. Organosilicon small molecules have unique chemical characteristics that can lead to increased potency and improved pharmacological qualities, making the biological exploration of these compounds extremely intriguing. There are diverse applications of organosilicone compounds in pharmaceutical and biomedical domain.

6.2.1. Silicon-containing amino acids and analogues

Amino acids with silicon can be used to create peptides with better physiochemical characteristics and in vivo activity. There are various intriguing reports on the use of siliconcontaining therapeutically important chemicals and unnatural amino acids, as well as an increasing number of systematic comparisons. It has been demonstrated that adding a silyl group improves lipophilicity increases resistance to proteolytic degradation, and boosts cellular absorption. There are a number of known amino acids that contain silicon that are unnatural, including-(dimethylsila)-proline (sila-proline, Sip), β-TMS(Trimethylsilyl)-alanine, and β-TMS-phenylalanine. Based on the lipophilicity, TMS-alanine offers a straightforward isosteric substitute for tert-leucine, as observed for renin inhibitory peptides with just a slight decrease in activity [1, 50].

6.2.2. Silyl ethers and drug delivery strategies related to silicon

In the case of silyl linkers or silicon-based nanoparticles, the ability to regulate the hydrolysis rate of a silyl ether can be crucial for medical applications involving drug release and administration [51, 52, 53]. The reactivity of N- and O-silylated compounds has been used to investigate acid-sensitive prodrugs [54, 55]. For instance, antiulcer prostaglandins coupled to polybutadiene in silyl ether prodrugs have been engineered to break down in the stomach's acidic environment [56]. Using a bifunctional silyl ether (CO-Si-OC) method for a prodrug linkage, Desimone and colleagues have revealed regulated drug delivery from biocompatible nanoparticles [57]. Each prodrug-nanoparticle conjugate [58], which has near-quantitative encapsulation, is produced from a bifunctional dialkylsilane electrophile [59] and a therapeutic molecule that contains hydroxyl [60], resulting in a polymerizable monomer [61].

By changing the size of the alkyl substituents on the silyl linker [59] (Et, i- Pr, or t-Bu), the pace of drug release can be regulated over the period of hours, days, or months. The authors employed HPLC analysis to show that the therapeutic drug lost all silyl ether activity after release under acidic circumstances.

6.2.3. Organosilicon-based fluoride acceptors for imaging

Because organosilanes have effective fluoride-accepting capabilities that can be used to get around the problem of employing unstable 18F (Fluorine-18) isotopes, organosilicon compounds hold promise for the creation of novel biological imaging agents. There are many applications beyond the small molecule therapeutics where organosilicon molecules have applications for PET (Positron emission tomography) imaging, new controlled drug release strategies, and structural probes for the direct detection of drug-protein binding interactions. There are growing area in medicinal chemistry, the incorporation of silicon will continue to provide a new source of chemical diversity and the inspiration to solve a range of problems related to drug design [62].

Following are the scope of organosilicon-based fluoride acceptors for imaging:

- **18F-labeled silicon-based fluoride acceptors:** Radiopharmaceutical chemistry has witnessed innovative approaches to introduce fluorine-18 (18F) into radiotracers for positron emission tomography (PET).
- Traditionally, fluorine-18 is bonded to aliphatic or aromatic carbon atoms. However, unconventional methods based on silicon, boron, and aluminum chemistry have emerged.

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- The silicon-fluoride-acceptor isotopic exchange (SiFA-IE) approach challenges a longstanding dogma in radiochemistry: the inability to obtain radiopharmaceuticals of high specific activity (SA) via simple IE.
- SiFA-IE chemistry occurs in dipolar aprotic solvents at room temperature, avoiding radioactive side product formation.
- SiFA species range from small prosthetic groups to labeled peptides and affibody molecules.

These nonclassical labeling methodologies based on silicon chemistry provide exciting opportunities for advancing radiochemistry and improving the specificity and efficiency of radiopharmaceuticals used in positron emission tomography (PET) imaging. They represent a promising avenue for future research in this field [63].

Researchers have developed a novel theranostics ligand called LuFL that is labeled with both fluorine-18 (18F) and lutetium-177 (177Lu). This ligand targets fibroblast activation protein (FAP), which plays a crucial role in cancer diagnosis and therapy [64] LuFL contains two essential components:

- Organosilicon-based fluoride acceptor (SiFA): This allows for efficient labeling with fluorine-18.

DOTAGA [DN7]

- Chelator: This enables coordination with lutetium-177 for radionuclide therapy.

The labeling procedure for LuFL is simple and highly efficient, making it suitable for cancer theranostics.

Cellular assays confirmed that LuFL has excellent binding affinity towards FAP, outperforming existing FAP tracers like FAPI-04. In vitro studies demonstrated high specific uptake and internalization of 18F-/177Lu-labeled LuFL in FAP-expressing cells.PET imaging, SPECT (Single-photon emission computed tomography) imaging, and biodistribution studies in tumor-bearing mice revealed higher tumor uptake and longer retention for LuFL compared to other tracers. Radionuclide therapy experiments showed significantly greater inhibition of tumor growth with 177Lu-labeled LuFL compared to control groups and 177Lu-labeled FAPI04 [65].

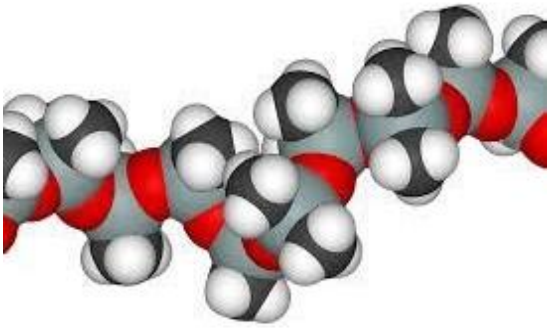
In summary, LuFL represents a promising radiopharmaceutical for cancer theranostics, combining efficient labeling, excellent binding affinity, and enhanced tumor uptake and retention.

6.2.4. *Organosilicone compound* silsesquioxanes [DN8] *nanocomposite for cardiovascular interventional devices*

Using polyhedral oligomeric, a promising nanoscale silica particle with special use in cardiovascular interventional devices, a new generation of silica nanocomposites has been created. Silsesquioxanes (SQS) are nanostructures that resemble ladders or cages. The trifunctional monomers of these three-dimensional organosilicon oligomers, Si_4O_6, are completely hydrolyzed to create them. These silica nanocomposites are even more resistant to degradation due to the high intermolecular interactions between their constituent molecules and neighbours as well as their robust framework with their shorter bond lengths [66].

6.2.5. *olysiloxane in bioimaging*

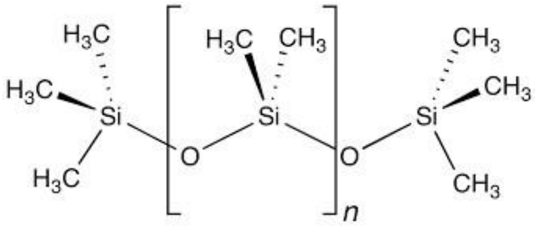
Polysiloxane-based film, elastomers [DN9] sometimes known as "silicon rubbers", are one type of polymer-based material that is appealing for use in chemical or biological applications because they have unique thermal, chemical, mechanical, and biocompatible characteristics [67]. Elastomers made of polysiloxane are now often utilised in bioimaging. The polysiloxane matrix provided the particular cells with an ideal environment for incubation. Boccaccini et al. saw the creation of a brand-new polysiloxane/bioactive glass film in 2016. The polysiloxane composite films' surface is covered in MG-63 cells [67]. According to the findings, composite films made of polysiloxane and bioactive glass (BG) have exceptional cytocompatibility from 260°C to 500°C and display very little toxicity to MG-63 cells. The polysiloxane-based film showed promise for use in the field of medical implants.



Model Structure of Polysiloxane
(Source: Wikipedia)

6.2.6. *Cross-linked organosilicon polymers*

Cross-linked organosilicon polymers [DN11] are frequently utilised as components in composites, coatings, biomedical materials, and other products. Due to their distinctive qualities, such as physiological inertness, low toxicity, and flexibility that is comparable to soft biological tissues, these polymers are intriguing as materials for biomedical applications. The use of biodegradable cross-linked polysiloxanes in bioengineering appears promising [68].



Model Structure of Cross-Linked Organosilicon Polymers (Source: Wikipedia)

6.2.7. *Orthopedic implants*

As polysiloxanes provide the ability to create materials with regulated structure for the development of bioactive ceramic-based materials that can be useful in orthopedic applications, implant materials consisting of organosilicon precursors and active/passive fillers have been thoroughly explored. Numerous variables, including as the pyrolysis temperature, type of fillers, processing conditions, composition, and structure of the preceramic precursors, influence the properties of ceramics generated from polysiloxane [69].

6.2.8. *Ophthalmic implants*

In medicine, silicone-based synthetic materials are used for a wide range of purposes, including the complete replacement of tissues or organs (such as the replacement of joints in the finger or foot, breast implants, ophthalmological implants, etc.), repair, corrective, diagnostic devices (such as catheters, pacemakers, heart valves, tubing, etc.), and drug delivery systems. Ophthalmology is a field of medicine that focuses on the identification, physiology, and management of eye conditions. For a variety of ophthalmic implant applications, including contact lenses and intraocular lenses, silicone polymers are suitable [69].

6.2.9. *Wound dressing*

Healthcare workers have special obstacles while treating skin wounds or injuries. Alkoxysilane functional precursor that underwent hydrolysis and condensation in a sol-gel process is converted into a thermoresponsive polymeric network via functionalization with a poly (Nisopropyl acrylamide) copolymer to create polyurethane/siloxane dressing membrane. To increase the dressing membranes' affinity and adhesion to the fibroblast cells, the surface of the polyurethane/siloxane membranes was modified using a biodegradable and biocompatible gelatin. The authors demonstrated that compared to various commercial dressings (0.9-1.7 MPa), the dressing membrane had a higher tensile strength (4.5 MPa). This made it possible to regulate the dressing membrane's properties in order to shield wound tissues from shock and outside pressures as well as to keep their form while being applied [69].

6.2.10. *Antibacterial activity*

The utilization of Quaternary ammonium silane (QAS) and antimicrobial peptides has been found to be effective in reducing bacterial adhesion and biofilm formation both in vivo and in vitro. These substances interact with bacterial membranes, leading to cell lysis and death, and exhibit a good degree of performance. Quaternary ammonium compounds (R_4N^+) are particularly promising as antibacterial contact-killing coatings due to their cationic organic nitrogen composition, low toxicity for the food and health care industries, and antimicrobial activity against fungi, yeasts, and both gram-positive and gram-negative bacteria. The longlasting biocidal activity of quaternary ammonium salt-containing polymers has generated significant interest, with polysiloxane being a particularly attractive carrier due to its amphiphilic nature and high flexible/free rotatable chain in solution. The high flexibility of polysiloxane allows it to form polysiloxane bearing QAS groups that interact with bacterial membranes. Silicone, which is commonly used in medical applications such as ventricular shunts, cardiac pacemakers, syringes, artificial joints, and implantable contraceptives, is an example of a material that can benefit from the incorporation of these substances [69]. [DN12]

6.3. Organosilicone Compound Catalysis and Chemical Reactions [DN13]

Organosilicon compounds are a class of organometallic compounds that contain carbon-silicon bonds (Fig. 3). They have various

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applications in consumer products, such as water repellents, lubricants, sealants, and personal care products. Organosilicon compounds can also be used as catalysts in chemical reactions, due to their unique properties, such as thermal stability, hydrophobicity, and reactivity.

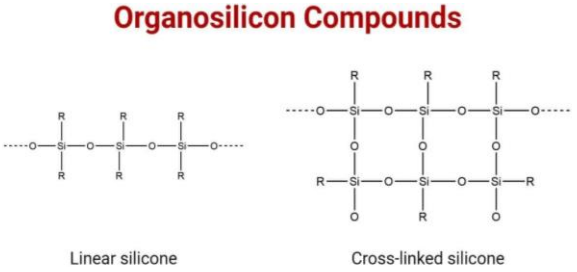

Fig. 3. Organosilicon Compounds

The catalytic activity of these compounds are influenced by their structure, functional groups, and coordination with other metal or non-metal atoms. Some of the catalytic reactions that organosilicon compounds are discussed below:

Hydrosilylation: In such type of reactions, a silicon-hydrogen bond and an unsaturated organic compound are involved, for instance an alkene or alkyne. These reactions are catalyzed by a metal complex of an organosilicon compound, like platinum, rhodium, or palladium. Hydrosilylation is generally exploited to synthesize silicones, silanes, and other organosilicon compounds [70].

Cross-coupling: Coupling reaction can be understood as a reaction between two different organic compounds, like an aryl halide and an organosilicon compound, to form a new carbon-carbon bond. The reaction is catalyzed by a metal complex of an organosilicon compound, such as nickel, copper, or palladium. Cross-coupling is used to synthesize various organic molecules, such as pharmaceuticals, agrochemicals, and materials [71].

Ring-opening polymerization: This is a reaction between a cyclic organic compound, such as a lactone or a cyclic ether, and an organosilicon compound, such as a silanol or a siloxane. The reaction is catalyzed by an organosilicon compound, such as a silanol or a siloxane. Ringopening polymerization is used to produce various polymers, such as polyesters, polycarbonates, and polyethers [72].

Oxidation: This is a reaction between an organic compound and an oxidizing agent, such as hydrogen peroxide or oxygen. The reaction is catalyzed by an organosilicon compound, such as a silanol or a siloxane. One of the applications of oxidation reactions is the synthesis of various organic compounds, such as alcohols, ketones, and acids. These compounds have important roles in the chemical industry, as well as in biological processes. Organosilicon compounds are another class of organic compounds that have interesting properties and uses. They can act as ligands in coordination chemistry, meaning that they can bind to metal ions and form stable complexes. These complexes can be used as catalysts in homogeneous catalysis, which is a type of catalysis where the catalyst and the reactants are in the same phase. Some examples of homogeneous catalysis involving organosilicon compounds are hydroformylation, carbonylation, and polymerization reactions.

6.4. Electronics and Optoelectronics

Organosilicon compounds with Si-centered chirality have a long history, and a lot has changed since Kipping's groundbreaking research. 1. A deeper comprehension of the processes involving chirality at silicon has been made possible by the use of homochiral silanes as mechanistic probes. However, the use of silicon-centered chirality in functional polymers and optoelectronic materials is still in its infancy and should grow in the not too distant future. From a synthetic perspective, current techniques for creating silicon-stereogenic silanes have mostly focused on using transition metal catalysis, such as C–H activation, to desymmetrize dihydrosilanes.

Some applications of organosilicon compounds in electronics and optoelectronics are:

- **Organic light-emitting diodes (OLEDs):** These are devices that produce light when a current passes through them. They are used for screens, lamps, and other purposes. Organosilicon compounds can act as materials that transport holes, electrons, or host other molecules in OLEDs [73]. Silicone-based polymers, which have special qualities because of their simple chemistry, environmental resilience, and ease of production. The applications of these polymers in sectors like organic field-effect transistors, organic solar cells, and organic lightemitting diodes (OLEDs) are particularly intriguing. Composites that combine organic polymers and inorganic components (silicon) have better thermal stability and are extremely electrically conductive. Table 4 represents use of polymers

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containing silicon in their structure for the construction of OSCs (construction of organic semiconductors). PCE: the power conversion efficiency; V_{oc}: the open-circuit voltage. Table 5 shows Examples of the use of polymers containing silicon in their structure for the construction of OLED.

- Solar cells: These are devices that turn sunlight into electricity. They are used for power generation, mobile devices, and other purposes. Organosilicon compounds can act as materials that accept electrons, donate electrons, or transport holes in solar cells [74].
- **Field-effect transistors (FETs):** These are devices that control the current in a circuit. They are used for amplifiers, switches, and other purposes. Organosilicon compounds can act as materials that insulate gates, dielectrics, or semiconductors in FETs [75].
- **Optical fibers:** These are fibers that carry light signals over long distances. They are used for communication, data transfer, and other purposes. Organosilicon compounds can act as materials that cover, fill, or modify optical fibers [76].

6.5. Coatings and Surface Modifications

Organosilicone compounds are organic-inorganic hybrid materials that have Si-C bonds and can form various structures such as linear, cyclic, or cross-linked polymers. They have many applications in coatings and surface modifications due to their unique properties, such as:

Water repellence: Organosilicone compounds have potential to create the hydrophobic layers on variety of substrates, like textiles, metals, glass, and ceramics. Mechanism of such attributes lie on their ability to react with surface hydroxyl groups or forming self-assembled monolayers. These layers can protect the substrates from moisture, corrosion, and staining [77-78].

Lubricity: Organosilicone compounds have ability to diminish the friction and wear of surfaces by forming smooth and flexible films. These films are characterized by their low surface energy and high thermal stability and can also act as dispersants and stabilizers for pigments and fillers in coatings [77, 79].

Adhesion: Organosilicone compounds have property to augment the adhesion of coatings to substrates by developing the covalent bonds or intermolecular interactions with both organic and inorganic components. They can also improve the compatibility and durability of coatings by reducing the interfacial tension and stress [77, 80].

Functionalization: Organosilicone compounds have the capability to add functional groups like hydroxyl amino epoxy and vinyl to surface materials thereby facilitating other chemical connection possibilities or molecular interactions. The coatings benefit from specific properties including electrical conductivity along with optical transparency and biocompatibility because of organosilicone compounds [77].

Table 4. Polymers containing silicon in their structure for the construction of OSCs. PCE: the power conversion efficiency; V_{oc}: the open-circuit voltage

Donor	Acceptor	V_{oc} (V)	PCE (%)
DINTTDTS/DINDTS [DN14]	IDT-C8	0.89	4.52
dithieno[3,2-b:2′,3′-d]silole	thieno[3,4c]pyrrole-4,6-dione	0.63	2.65
dithieno[3,2-b:2′,3′-d]silole	naphtho[2,3-c]thiophene-4,9dione	0.90	5.21
DTS	BDT	1.01	2.66
DTC/DTS	3-ethyl-rhodanine	0.82	8.0
DINDTS/DINCNDTS	IN/INCN	0.94	6.79

Table 5. Use of polymers containing silicon in their structure for the construction of OLED

OLED		Turn on Voltage (V)	Maximum Luminance (cd m^{-2})	Current (cd A^{-1})	Power (lmW^{-1})	External Efficiencies (%)
Carbazole-substituted dithienosilol	es	5.3	91,920	17.59	12.55	5.63
MFMPS		3.2	31,900	16.00	13.50	4.80
$(PBI)_2DMT$	PS	2.5	14,155	13.30	14.51	4.25
DMTPS-DP	A	3.1	13,405	8.28	7.88	2.42
PyDMS		3.5	49,000	9.10	7.10	3.00

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The modifiable surface characteristics of various substrates and coatings receive benefits from organosilicone compounds due to their functionality as versatile materials. Such compounds develop hydrophobic surfaces, lubricious coatings, adhesive films and functional applications which boost coating performance throughout multiple applications.

6.6. Functionalization and Modification Strategies

The article [86] reviews current functionalization and modification approaches which include the following:

Electro-click reaction: The electro-click reaction allows easy electrode and sensing film modifications through a chemical process that does not use substances like Cu(I)-catalyzed azide–alkyne cycloaddition (CuAAC). Scientists consider this reaction the prototypical click reaction before it became essential in synthetic chemistry.

This functionalization technique allows the biosensing interface to become ready for use in a fast, selective, and clean manner [87].

Surface-grafted polymerisation: Surface-grafted polymerisation enables efficient attachment of polymer chains to surfaces, thus improving properties such as adhesion, as well as bio-compatibility and wettability. Various methods such as redox reactions and plasma treatment and UV irradiation trigger the polymerization process [88].

Self-assembled monolayers: Creating functionalized ordered monolayers on surfaces becomes achievable by using a simple method of self-assembled monolayers that allows precise control over surface topology and chemistry. The different mechanisms to create monolayers include electro-static forces, physisorption, and chemisorption interactions [89]. The assembly of different materials into composite structures represents a promising method to unite the advantages of inorganic or organic components within a single system.

Composite materials: Composite materials combine features which produce exclusive characteristics that include optical transparency together with mechanical strength and thermal stability [90].

6.7. Emerging Trends and Future Prospects

Organosilicon chemistry is a rapidly evolving field that aims to create novel organosilicon polymers with well-defined structures and functions. To achieve this goal, researchers have developed new synthetic methods using organosilicon reagents, catalysts, and reactions [9192]. These methods enable the fine-tuning of the polymer properties and functions.

Some of the emerging trends and future prospects in organosilicon chemistry are summarized in a recent review article [91] such as:

Electrochemistry: This is a novel synthetic strategy that uses electricity to drive or catalyze the formation of organosilicon compounds. Electrochemistry has not been widely used in organosilicon chemistry, but recent advances in electrified organic synthesis have opened new possibilities and challenges [91].

Functionalization and modification strategies: These are novel approaches to modify electrodes, sensing films, and surfaces with organosilicon compounds. These approaches include click chemistry, surface-initiated polymerization, self-assembly monolayers, and hybrid materials [91].

Applications in energy and environmental fields: Organosilicon compounds have potential applications in energy storage, conversion, and harvesting, such as in lithium-ion batteries, fuel cells, and solar cells. They can also be used in environmental remediation, such as in the removal of heavy metals and organic pollutants from water and soil [92].

Applications in biomedicine and nanotechnology: Organosilicon compounds have potential applications in biomedicine and nanotechnology, such as in drug delivery, tissue engineering, and biosensors. They can also be used in nanofabrication, such as in lithography, etching, and patterning [93].

7. ENVIRONMENTAL And TOXICOLOGICAL ASPECTS OF ORGANOSILICONE COMPOUNDS

Organosilicones are synthetic substances that consists of silicon and oxygen along with carbon atoms. Consumer products use organosilicones as water repellents while also including their use in lubricants and sealants and cosmetics and personal care products. Organosilicones present possible health hazards to people together with environmental problems because their release happens through multiple pathways into air, water, and soil systems. It becomes essential to conduct systematic environmental monitoring of

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organosilicone quantity alongside source tracking and effect evaluation. Some of the topics that environmental studies can explore regarding organosilicones are:

- Methods for detection and analysis of organosilicones in different environmental matrices, such as air, water, soil, sediment, biota, and consumer products. For example, one study [78] developed a method for characterizing organosilicone surfactants and their effects on herbicide activity using various physico-chemical measurements.
- Sources and pathways of organosilicone emissions and releases into the environment, such as industrial processes, wastewater treatment plants, landfill leachates, and consumer product use and disposal. For example, one study [94] surveyed the occurrence and concentration of organosilicones in personal care and household products, which can be potential sources of human and environmental exposure.
- Fate and transport of organosilicones in the environment, such as degradation, transformation, sorption, volatilization, and bioaccumulation. For example, one study [95] investigated the degradation of organosilicones in anaerobic digesters and their impact on biogas production and quality.
- Effects and risks of organosilicones on human health and the environment, such as toxicity, endocrine disruption, ecotoxicity, and bioavailability. For example, one study [96] evaluated the toxicity of organosilicones to aquatic organisms and their potential to act as endocrine disruptors.

Organosilicon compounds have a variety of industrial uses, such as water repellents, lubricants, and sealants. They can form stable oxo-bridged structures, such as $(CH_3)_3Si—O—Si(CH_3)_3$, unaffected by moisture and air.

Organosilicon molecules are also used as surfactants in pesticides to enhance their efficacy, but they also exhibit pesticidal activity themselves. However, the toxicity of organosilicon surfactants is generally low.

Some organosilicone compounds may pose toxicological risks to humans and the environment, depending on their structure, exposure, and biodegradation. Here are some key points about the toxicity of organosilicone compounds:

- Organosilicone compounds can be classified into two main groups: linear and cyclic. Linear organosilicone compounds have a chain-like structure, while cyclic organosilicone compounds have a ring-like structure. The toxicity of organosilicone compounds is influenced by the number and type of organic groups attached to the silicon atoms, as well as the shape and size of the molecule.
- Organosilicone compounds can enter the human body through inhalation, ingestion, or dermal absorption. They can also be released into the environment through industrial processes, agricultural applications, or consumer products. The fate and transport of organosilicone compounds in the environment depend on their physicochemical properties, such as water solubility, vapor pressure, and partition coefficients.
- Organosilicone compounds can undergo biodegradation by microorganisms or abiotic processes, such as hydrolysis or photolysis. Biodegradation can reduce the toxicity of organosilicone compounds by breaking them down into less harmful or more readily excreted products. However, biodegradation can also increase the toxicity of organosilicone compounds by generating more toxic or persistent metabolites.
- Organosilicone compounds can cause adverse effects on various biological systems, such as the nervous system, the endocrine system, the immune system, the reproductive system, and the developmental system. The mechanisms of toxicity of organosilicone compounds are not fully understood, but they may involve oxidative stress, DNA damage, hormone disruption, inflammation, or apoptosis.
- The toxicity of organosilicone compounds is assessed by various methods, such as in vitro assays, animal studies, epidemiological studies, and risk assessment models. The toxicity data of organosilicone compounds are limited and inconsistent, due to the diversity and complexity of these chemicals. Therefore, more research is needed to evaluate the potential health and environmental impacts of organosilicone compounds.

Growers have access to the most powerful adjuvants and super-penetrants in the form of organosilicone surfactants. They have inherent

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pesticidal qualities, but they also boost the effectiveness and off-target effects of pesticides. They may be connected to losses in honey bee populations since they are poisonous to bees and other useful organisms. Additionally, they can add to the chemical environment that humans and pollinators are exposed to. They can be found in medication and personal care items. Organosilicone surfactants may not be safe when used as agrochemical spray adjuvants due to toxicological risks.

Food and drink items containing silicone, such bakeware and nipples, may include organosilicone compounds. The kind and concentration of siloxanes, the temperature and duration of interaction, and the composition of the food matrix all affect migration. Although the consequences of ingested siloxanes on health are little understood, some research points to the possibility of hepatotoxic, neurotoxic, and endocrine disruption effects. Indoor dust contains chemicals known to contain organosilicones, which can collect and present a concern for ingesting or inhalation. Dust contains different amounts of organosilicone compounds depending on the nation, the area, and the kind of building. Cookware, building materials, personal hygiene products, and domestic sanitation items are the sources of organosilicone chemicals found in dust. Although the harmful consequences of dust-borne organosilicone compounds have not been thoroughly investigated, there is some evidence to suggest that they may cause immunotoxicity, respiratory irritation, and allergy sensitization.

8. CONCLUSION: CURRENT STATUS AND OUTLOOK FOR ORGANOSILICONE COMPOUNDS

Organosilicon compounds are a class of compounds that contain silicon-carbon bonds. They have many applications in various fields, such as water repellents, lubricants, sealants, fungicides, and hybrid materials. Here are some key points about the current status and outlook for organosilicon compounds:

New synthetic methods: Researchers have developed new ways to create organosilicon polymers of well-defined structures, using organosilicon reagents, catalytic systems, and novel reactions. These methods allow for more control over the properties and functions of the polymers [78].

Oxo-bridged organosilicon compounds: These compounds have flexible and moistureresistant structures, due to the delocalization of the lone pairs on the oxygen atoms into the vacant orbitals of silicon. They are used to make silicone elastomers, which can remain rubberlike at very low temperatures [78].

Polyorganosilsesquioxanes: These are hyper-branched structures and nanogels that can transform from macromolecules to colloidal particles, depending on the reaction conditions. They can be used as molecular nanofluids, nanoscale fillers, and transparent aerogels [97].

Hybrid organ element structures: These are organosilicon compounds that contain other elements, such as boron, carbon, or metal. They can form complex molecular composites with unique properties, such as thermal stability, optical activity, and biological activity [97, 98].

9. AUTHORS' CONTRIBUTIONS

Contribution of all authors are equal and the order of the authors have been approved by all the authors.

All authors read and approved the final manuscript.

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