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(Review Article)

Progress in the development of organic molecules as a blue light emitter in India

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Abstract

We provide a brief overview of the work done to date by Indian researchers on the synthesis of luminogenic molecules for the creation and assessment of organic light-emitting devices. Furthermore, our attention has only been on the "next generation" of blue emitters. Since 1987, blue OLED technology has been developed. As a result, we can observe the feathers growing in OLED technology every year. The current state of blue light emitting material design, which includes different emission molecules based on TADF, HLCT, phosphorescence, and fluorescence, is discussed in this work. Numerous research teams in India are focusing on blue-emitting materials to develop the most effective molecules for OLEDs. Here, we tried to cover all the blue light-emitting molecules that have been reported in India thus far by compiling data on the molecular structures of the materials that have already been published.

Keywords: Blue light emitters; Light emitting diodes; OLED; Progress in OLED; Synthesis of luminogenic molecules

1. Introduction

Although a great deal of research has been done in the field of OLEDs in recent years, our nation has not focused on particular molecules or developed device architectures to produce highly efficient OLED emitters. A few Indian research groups are developing luminogenic molecule synthesis for the creation and evaluation of organic light-emitting devices at the University of Delhi, IISE Bangalore, NISER Bhubaneshwar, Annamalai University, and NIT Rourkela. We talked about the state of OLEDs both domestically and globally and how India falls short of other countries in some areas when it comes to development. Less knowledge about OLED technology, poor facilities, a communication gap between academia and business, and—above all—a lack of investment capital are the causes of this. Thus, let us now quickly review the progress that has been made in the synthesis of molecular frameworks as OLEDs thus far. Our goal is to provide an overview of OLEDs in order to raise awareness and bridge the communication gap between academia and industry. Here, we only provide details on the published works that the academic and industrial communities have produced thus far in order to provide a clear picture of their ongoing light technology research projects. Apart from this, we have only concentrated on the advancement of the so-called "next generation" of blue emitters. Since 1987, blue OLED technology has been developed. As a result, we can observe the feathers growing in OLED technology every year. The current state of blue light emitting material design, which includes different emission molecules based on TADF, HLCT, phosphorescence, and fluorescence, is discussed in this work. In an effort to develop the most effective molecules that can produce the best OLEDs, several teams are working on blue-emitting materials. Here, we tried to cover all the blue light-emitting molecules that have been reported in India thus far by compiling data on the molecular structures of the materials that have already been published.

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2. Development in the synthesis of luminogenic molecules by the Indian researchers

Karthik et al. [1] published their work on triplet–triplet fluorescence (TTF) pyrene-benzimidazole based deep blue emitting dopants (PyPIC1–PyPIC5) with different π linkers, for example, phenyl, thiophene, and triphenylamine (**Figure 1**).

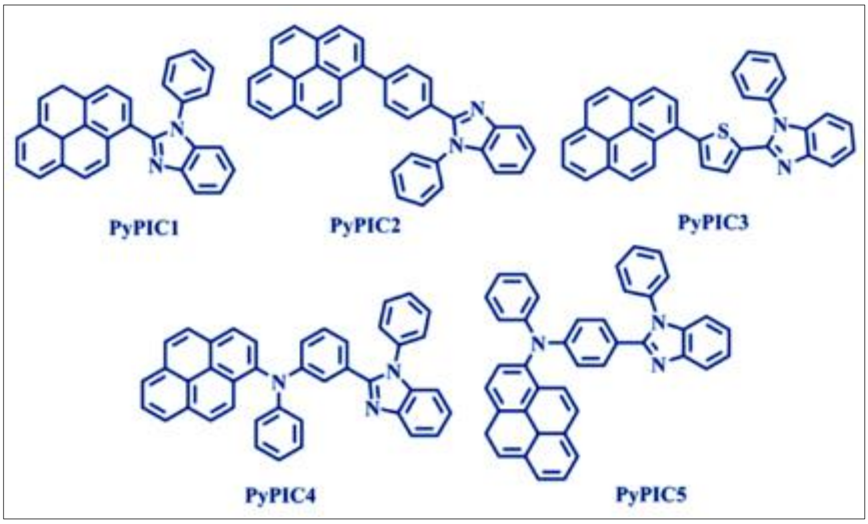

Figure 1 Structure of pyrene-benzimidazole based molecules

Kumar and Patil [2] reported a synthesis of fluoranthene-based two-electron transporting blue emitting materials such as TPFDPSO2 and TPFDBTO2 (**Figure 2**).

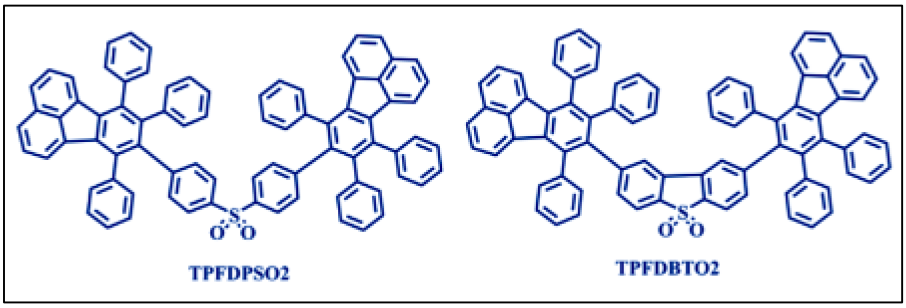

Figure 2 Structure of fluoranthene-based molecules

Dahule et al. [3] synthesized Quinoline based phosphor a DPQ (2,4-diphenylquinoline)-substituted blue light-emitting organic moieties such as Ome-DPQ, M-DPQ, and Br-DPQ (**Figure 3**).

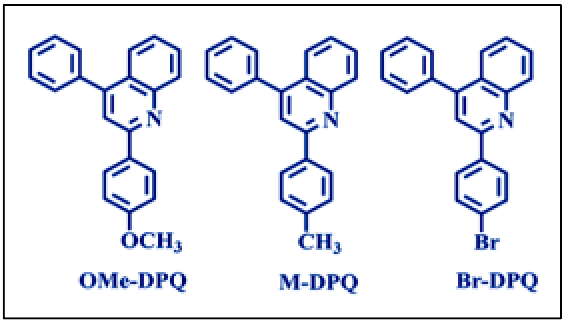

Figure 3 Structure of Quinoline based phosphor molecules

Kumar et al. [4] gave their devotion to develop TPFDPS and TPFDBT fluoranthene molecules (**Figure 4**).

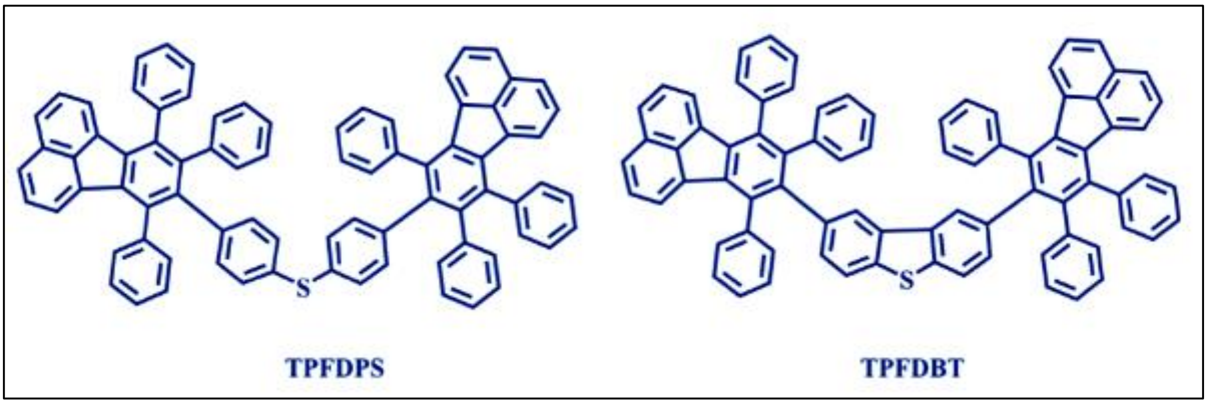

Figure 4 Structure of fluoranthene molecules

Nishal et al. [5] created five Schiff bases in addition to Zinc-based complexes: Zn(salen), Zn(salpen), Zn(salbutene), Zn(salhexene), and Zn(salheptene) (**Figure 5**).

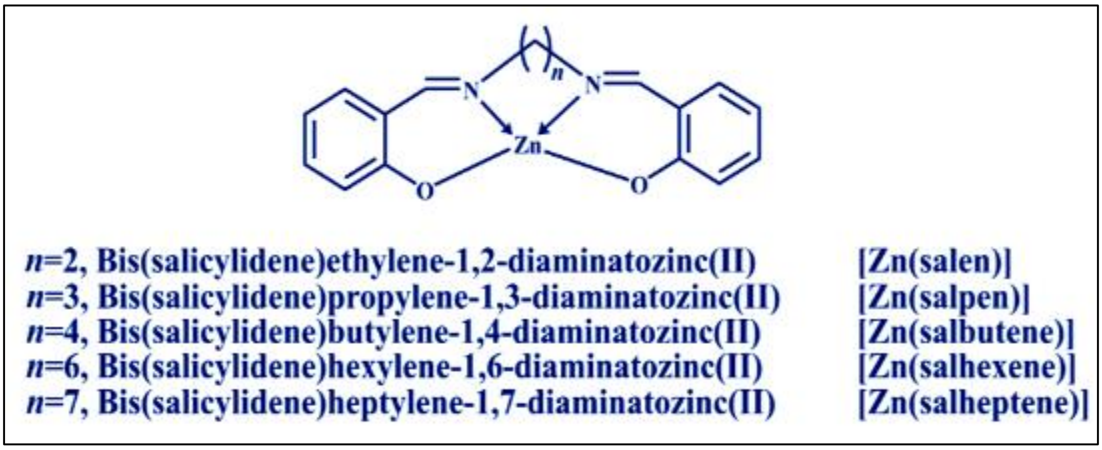

Figure 5 Structure of Zinc-based complexes of Schiff bases molecules

Lakshmanan et al. [6] synthesized substituted bipyridine based three fluorophores named ELC1, ELC2 and ELC3 (**Figure 6**).

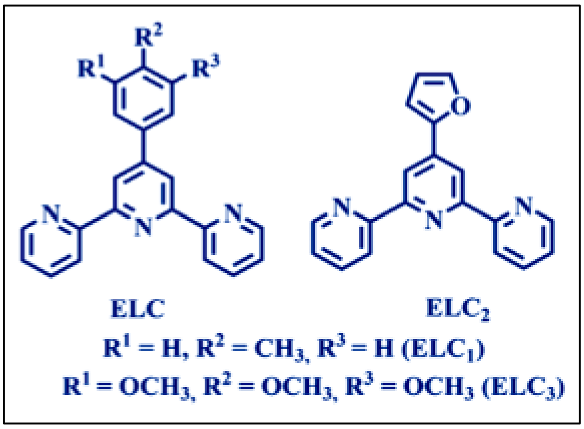

Figure 6 Structure of substituted bipyridine based molecules

Jadhav et al. [7] successfully synthesized a novel phenanthroimidazole (PI)-substituted (**Figure 7**) derivative.

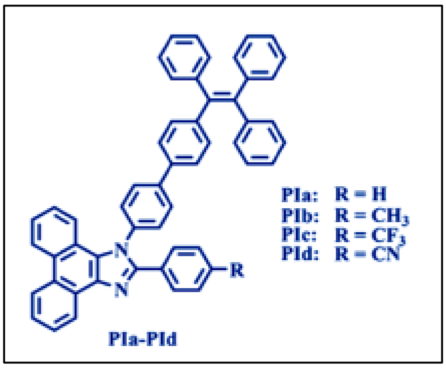

Figure 7 Structure of phenanthroimidazole molecules

Jhulki et al. [8] designed three substituted benzophenone moiety based novel hosts: BP2, BP3, and BP4 (**Figure 8**).

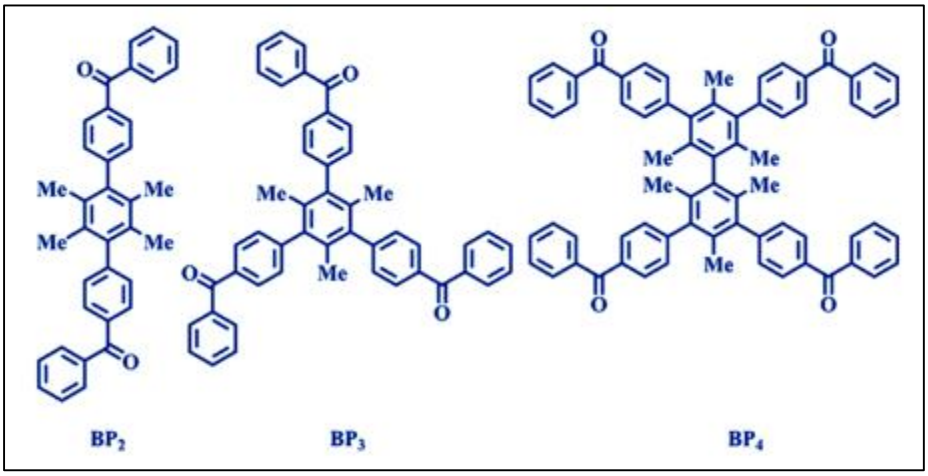

Figure 8 Structure of substituted benzophenone molecules

Gandeepan et al. [9] successfully produced benzopyridine moiety based blue TADF fluorescence emitters such as BpypC, BpypTC, Bpyp2C, and Bpyp3C (**Figure 9**).

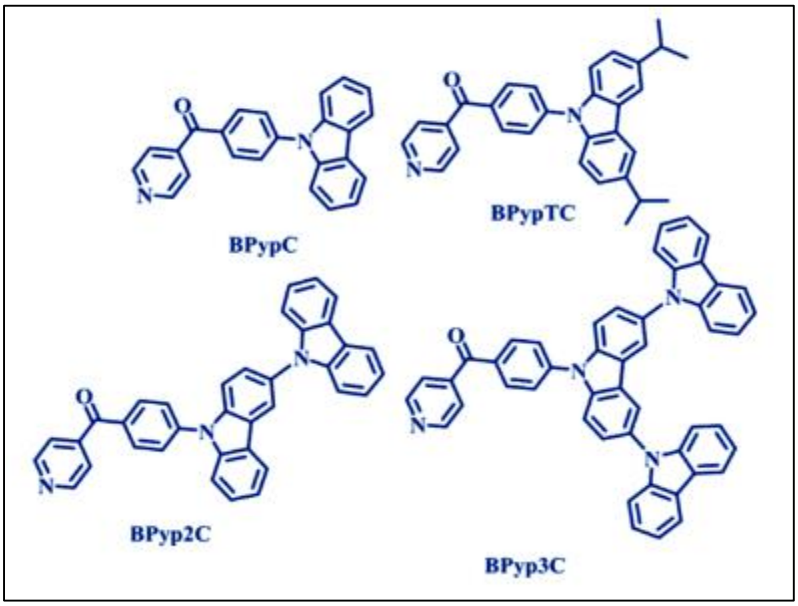

Figure 9 Structure of benzopyridine molecules

Kumar et al. [10] reported symmetrical and non-symmetrical fluoranthene derivatives with different donor and acceptor moieties (**Figure 10**).

Figure 10 Structure of fluoranthene molecules

Gupta et al. [11] also introduced a new concept of D–π–A for blue emitters by synthesizing multi alkynyl benzene bridged triphenylene-based molecules through incorporation of spacers (**Figure 11**).

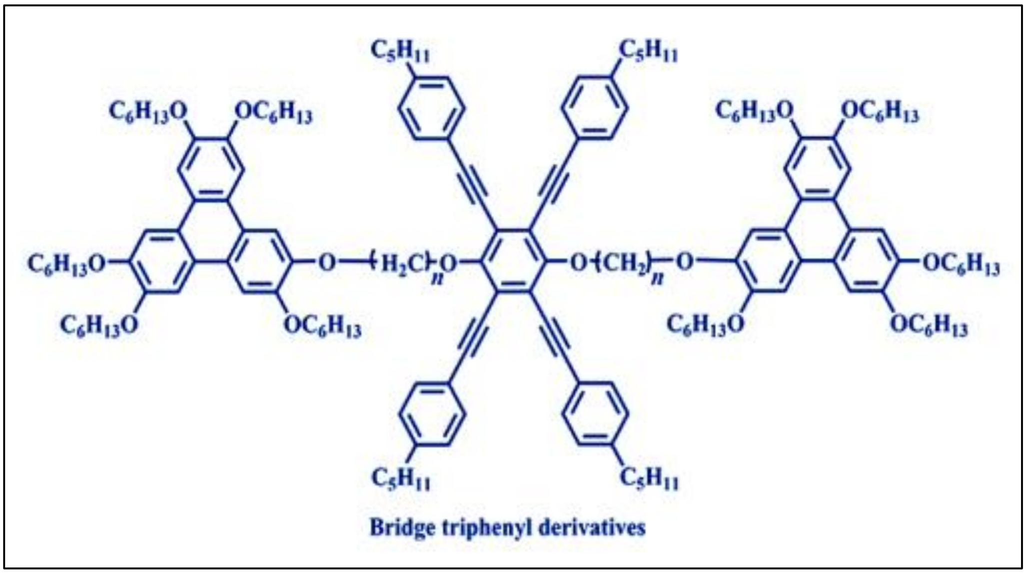

Figure 11 Structure of substituted alkynyl benzene bridged triphenylene-based molecules

Rajamalli et al. [12] synthesized two benzopyridine carbazole based fluorescence molecules DCBPy and DTCBPy made up of carbazole and 4-(t-butyl) carbazolyl groups, respectively (**Figure 12**).

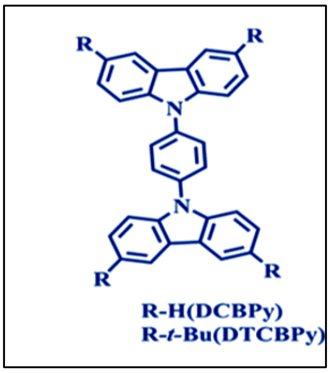

Figure 12 Structure of benzopyridine carbazole based molecules

Pathak et al. [13] introduced a series of five-ring polycatenars (a–d) in which p-substituted moiety showed a columnar hexagonal phase, whereas the m-substituted one exhibited a reduced tendency to stabilize the mesophase (**Figure 13**).

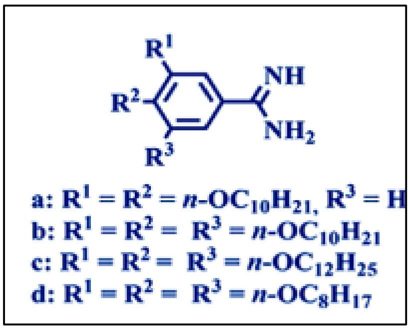

Figure 13 Structure of polycatenars molecules

Pathak's group [14-15] came up with a new concept and they developed stilbene-based derivatives (a– e) in a star shape by linking dialkoxy styrene with benzene at the third and fifth positions and a single amide linkage at the first position of the central benzene ring (**Figure 14**).

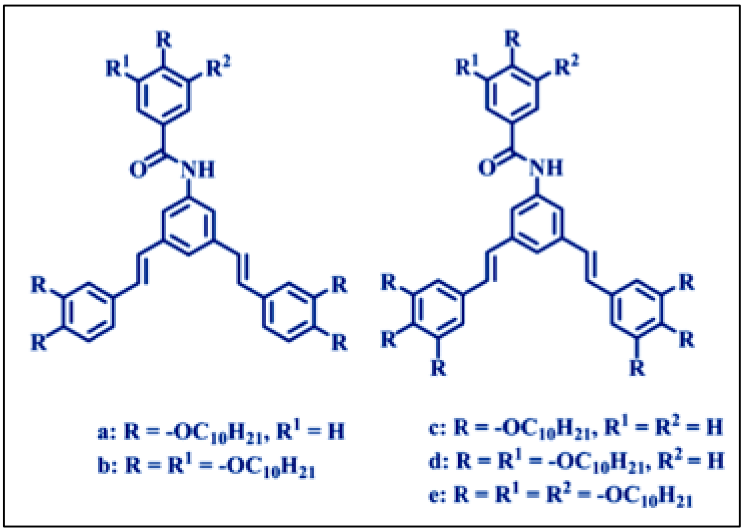

Figure 14 Structure of substituted stilbene-based molecules

Thanikachalam et al. [16] synthesized fused benzimidazole and triphenyl amine-based compounds composed of donor-linker acceptors with phenyl and styryl as spacers (**Figure 15**).

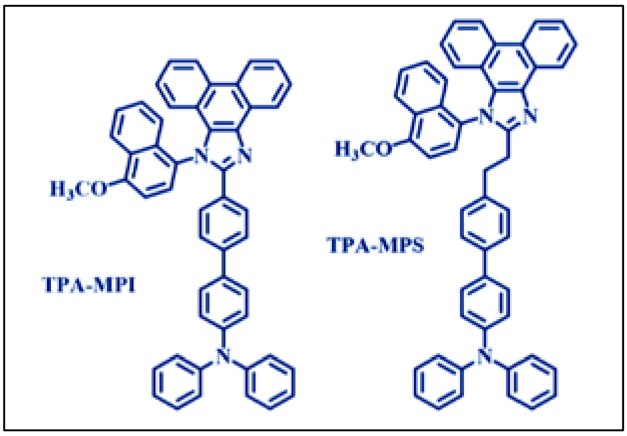

Figure 15 Structure of fused benzimidazole and triphenyl amine-based molecules

Urinda et al. [17] synthesized Ir (II)-based metal complexes by fitting the pyridine-tetrazole as an ancillary ligand (**Figure 16**).

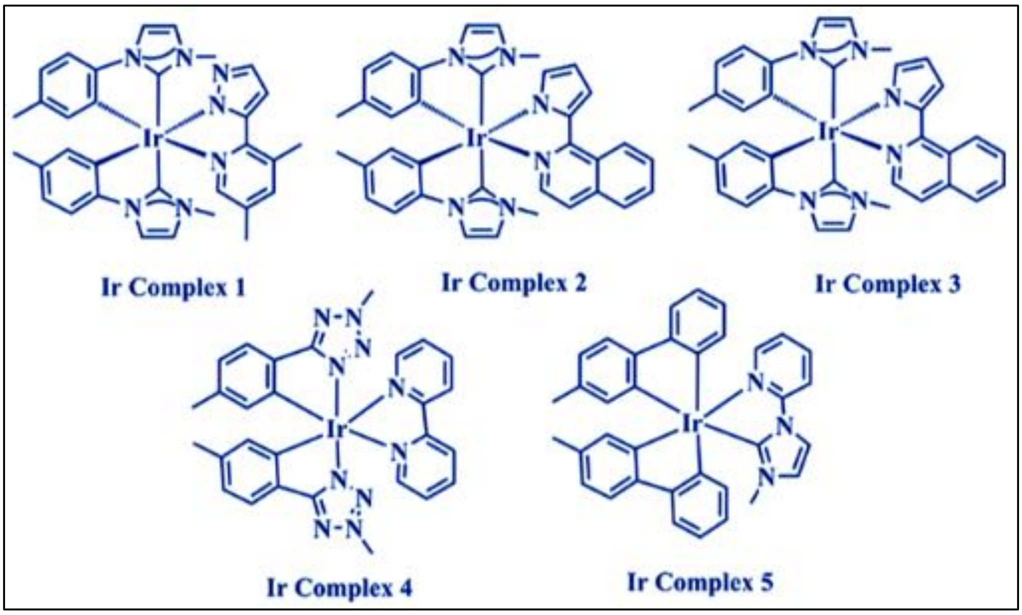

Figure 16 Structure of Ir (II) metal complex based molecules

Valsange et al. [18] demonstrated a simple pyrene core based small organic molecule named PY-II as a blue light emitter (**Figure 17**).

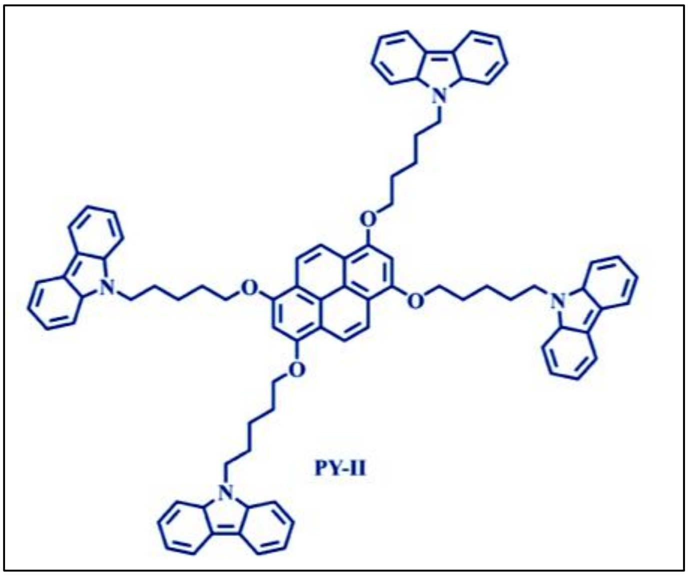

Figure 17 Structure of pyrene core-based molecule

Bishnoi et al. [19] reported novel non-planar **phenothiazine- 5-oxides based** on the donor, acceptor, and spacer concept compounds 2a–I (**Figure 18**).

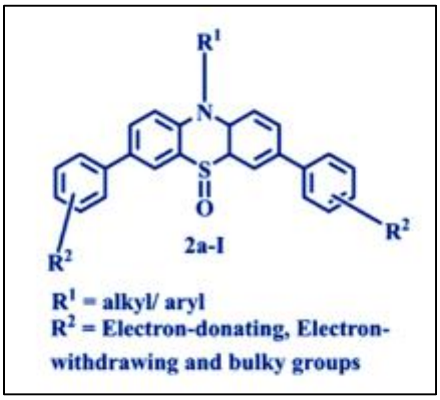

Figure 18 Structure of phenothiazine- 5-oxides based molecules

Gopikrishna et al. [20] developed a imide groups containing naphthalimide compounds (a–f) as a acceptor molecules (**Figure 19**).

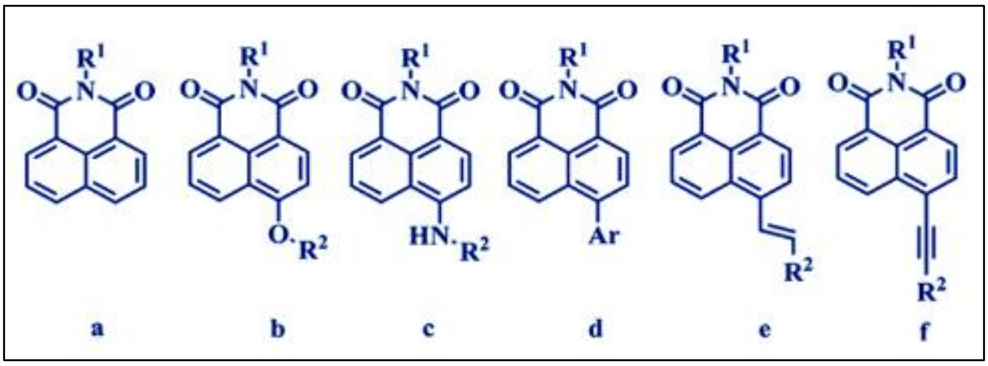

Figure 19 Structure of naphthalimide molecules

Jayabharathi et al. [21] reported carbazole (Dibenzopyrrole) and tertiary amine based new efficient deep blue emitting (**Figure 20**).

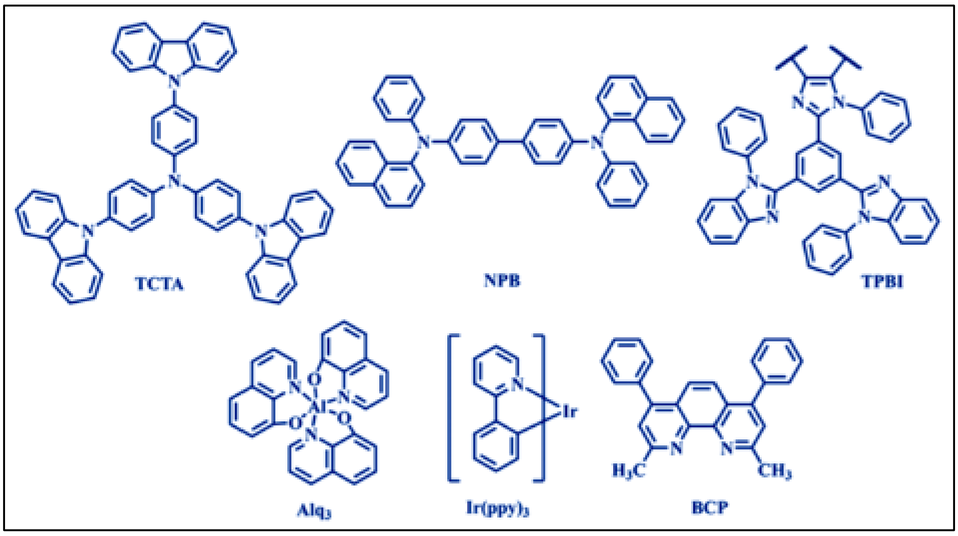

Figure 20 Structure of carbazole (Dibenzopyrrole) and tertiary amine-based molecules

Joseph et al. [22] reported compound containing carbazole with triphenylamine & fluorene units in which a cyano group was added to increase EL properties of moieties (**Figure 21**).

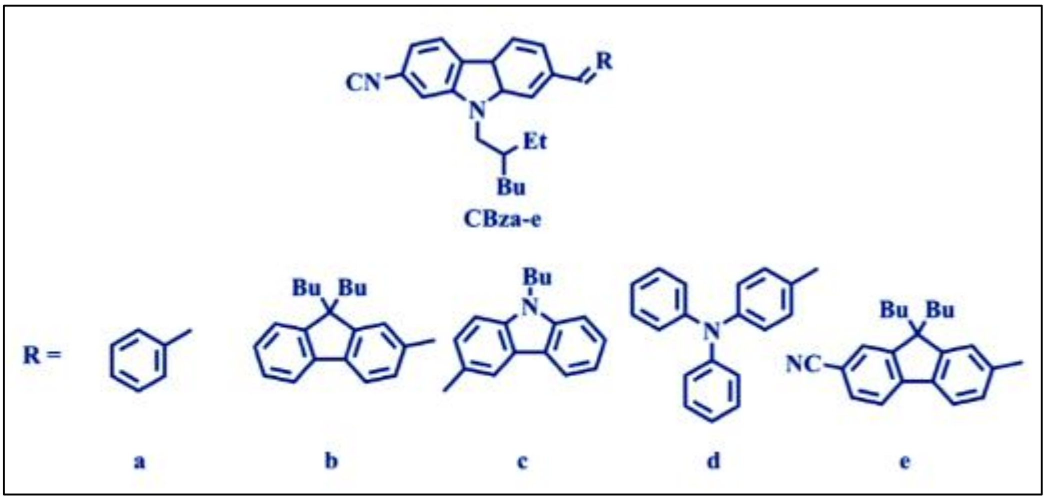

Figure 21 Structure of carbazole with triphenylamine & fluorene molecules

Konidena et al. [23] succeeded in the synthesis of cyano carbazole-triphenyl amine based a modified hybridized local and charge transfer (HLCT) fluorescent TPA-based emitter (**Figure 22**).

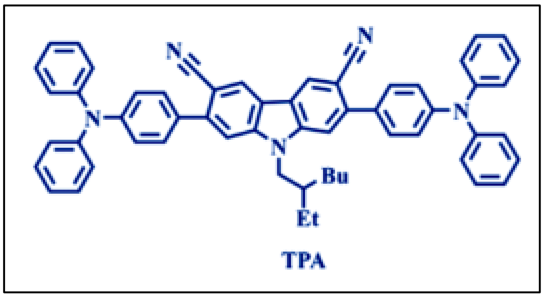

Figure 22 Structure of cyano carbazole-triphenyl amine-based molecule

Thanikachalam et al. [24] synthesized substituted fused imidazole-based molecules and conducted optical study to investigate nondoped OLEDs (**Figure 23**).

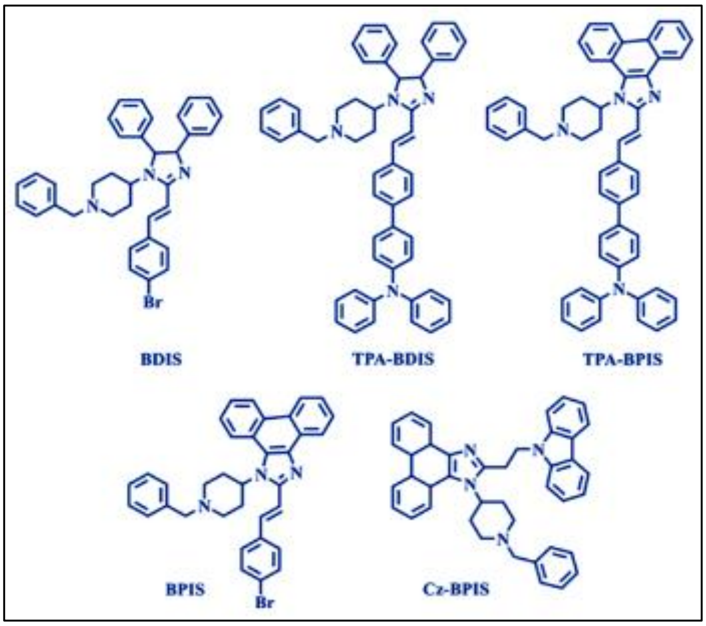

Figure 23 Structure of substituted fused imidazole based molecules

Bala et al. [25-26] developed a one-pot four-component methodology to synthesize s-heptazine based coumarin-linked triazolyl framework. (**Figure 24**).

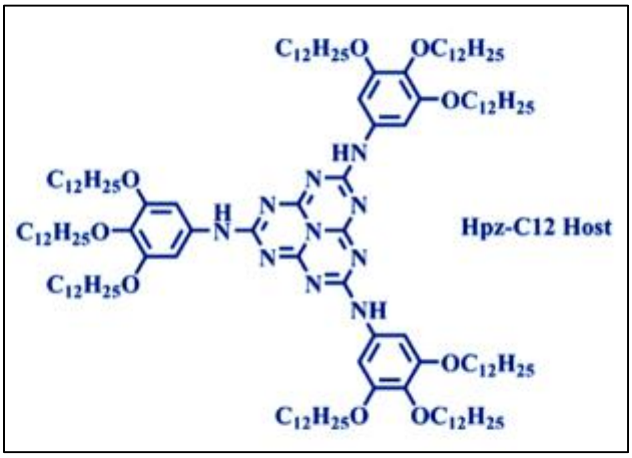

Figure 24 Structure of s-heptazine based coumarin-linked triazole molecules

Ghate et al. [27] published a work on Quinoline based organic phosphor Oet- DPQ (ethoxy) using an acid-catalyzed process (**Figure 25**).

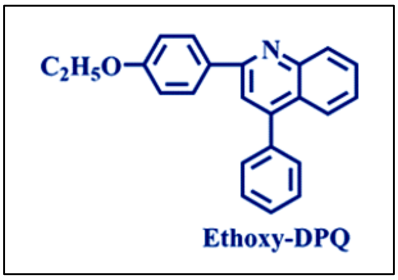

Figure 25 Structure of Quinoline based molecules

Gupta et al. [28] reported a star-shaped triazine–perylene conjugate molecules as a blue light emitter (**Figure 26**).

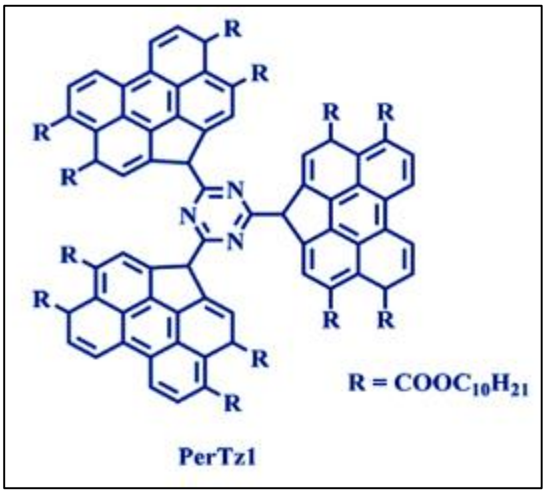

Figure 26 Structure of triazine–perylene based molecules

Sharma et al. [29] synthesized star-shaped TPE (Tx1) and TPAN (Tx2, Tx3) truxene molecules using Suzuki and Sonogashira reactions (**Figure 27**).

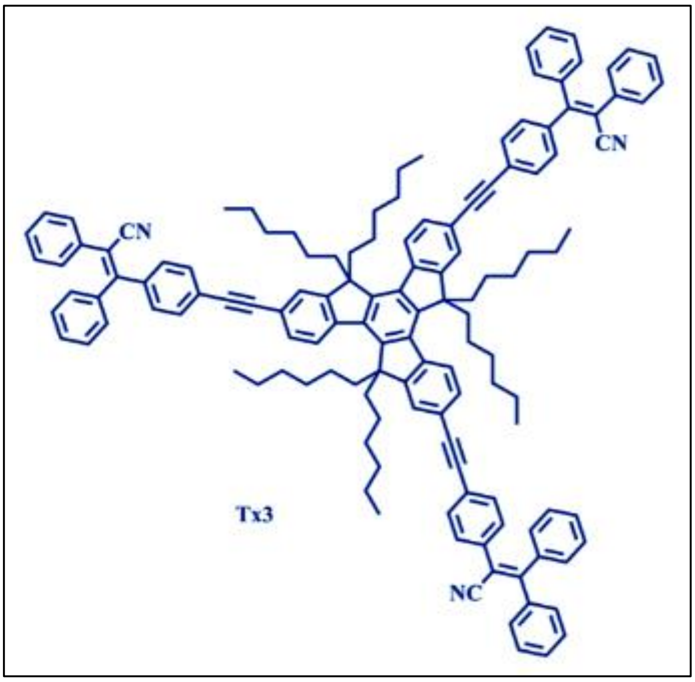

Figure 27 Structure of substituted truxene molecule

Siddiqui et al. [30] introduced poly-vinyl carbazole based a donor–acceptor derivative where acridone acts as an acceptor and carbazole acts as a donor (**Figure 28**).

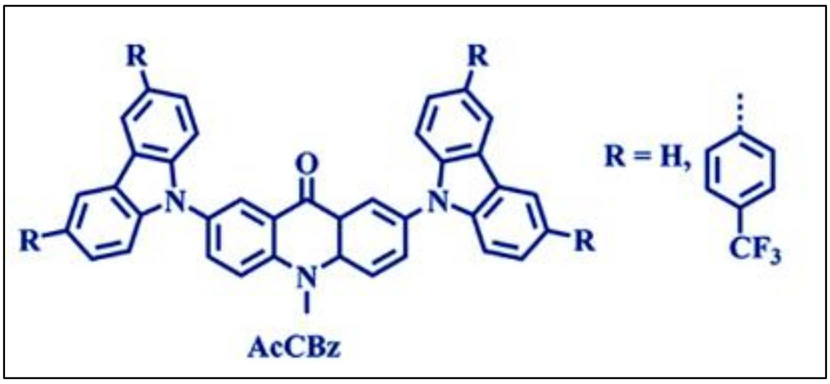

Figure 28 Structure of poly-vinyl carbazole-acridone based molecules

Tagare et al. [31] reported two-star-shaped fluorescent PI fluorophores containing fused benzimidazole and triphenyl amine framework (**Figure 29**).

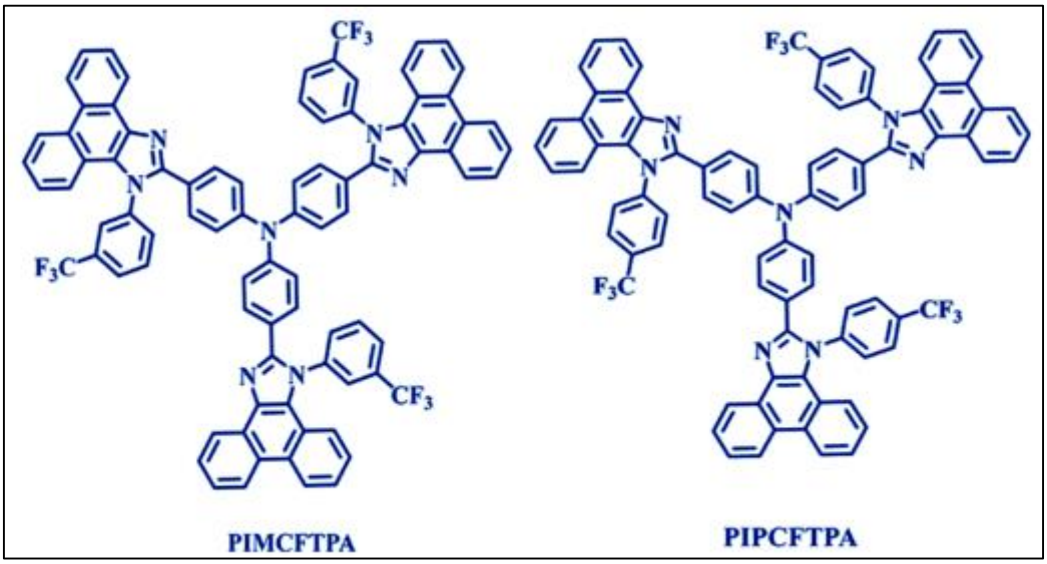

Figure 29 Structure of fused benzimidazole and triphenyl amine-based molecules

Venkatramaiah et al. [32] introduced three carbazole-phthalimide based molecules with the D–π–A structure (**Figure 30**).

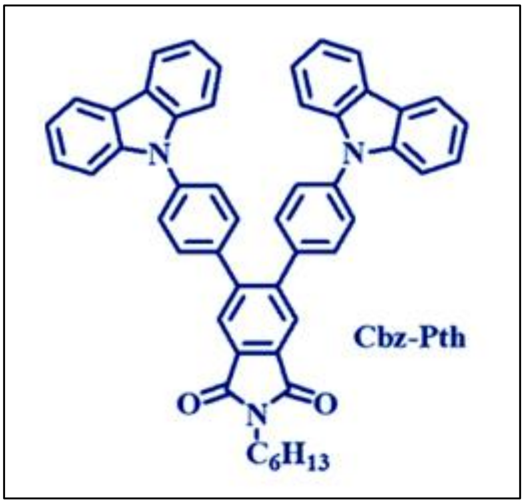

Figure 30 Structure of carbazole-phthalimide based molecules

Manohara et al. [33] reported the fluorophores BznCY, BZnCYBR, and BZnCYVY based on cyanopyridine frameworks which were obtained via Williamson ether synthesis followed by reaction with chalcone via an aldol condensation reaction (**Figure 31**).

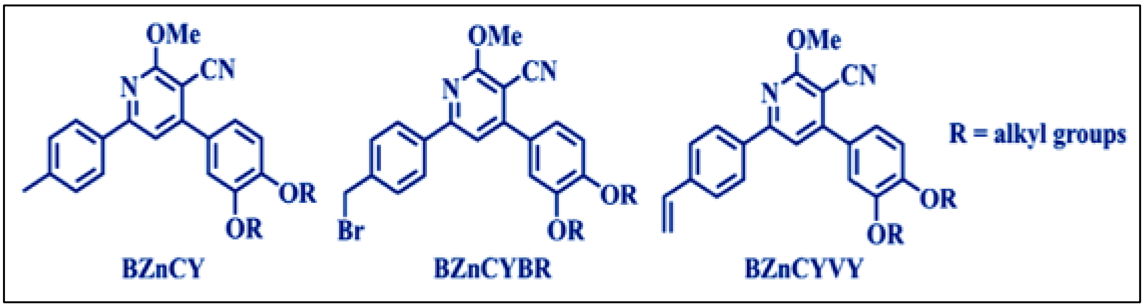

Figure 31 Structure of cyanopyridine based molecules

Kadam et al. [34] introduced substituted fused carbazole-indole derivatives Cbz-a and Cbz-b as a potential candidate for blue light emitting applications (**Figure 32**).

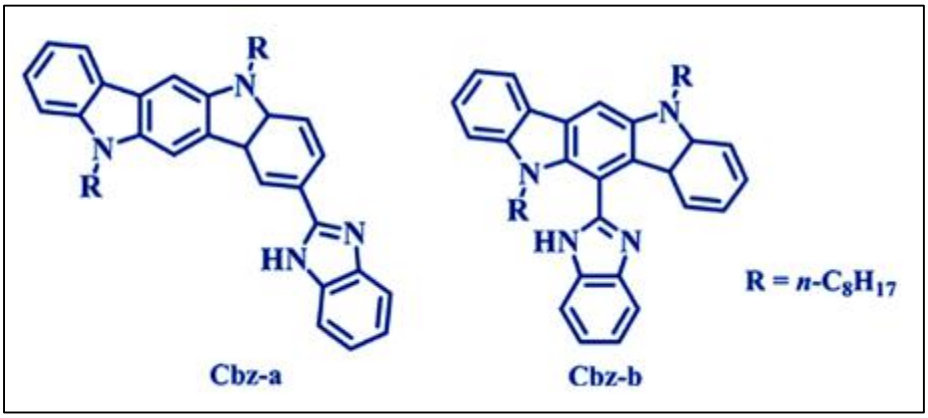

Figure 32 Structure of fused carbazole-indole based molecules

Tagare et al. [35] developed two new blue PI-based luminophores containing ether linkage between fused benzimidazole molecules (**Figure 33**).

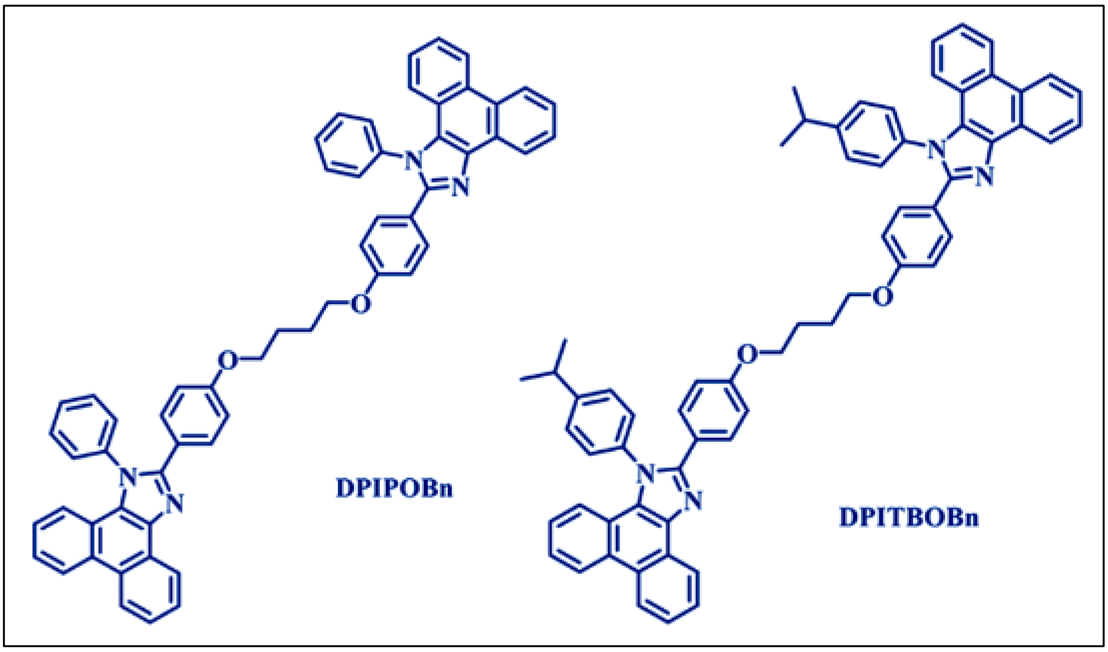

Figure 33 Structure of ether linked fused benzimidazole molecules

Kajjam et al. [36] successfully synthesized tetraphenyl substituted imidazole based novel TPI-based luminophores TP 1–TP 4 (**Figure 34**).

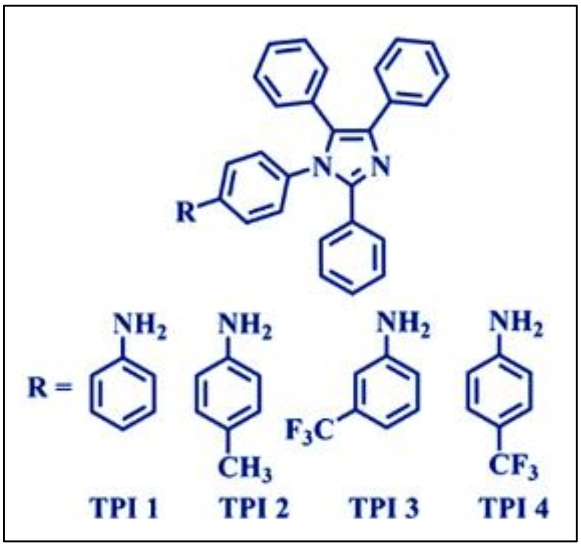

Figure 34 Structure of tetraphenyl substituted imidazole-based molecules

Jayabharthi et al. [37] developed fused benzimidazole-thiophene-carbazole based new blue-emitting bis-PI derivatives such as NPIBN, CNPIBP, and CNPIBN (**Figure 35**).

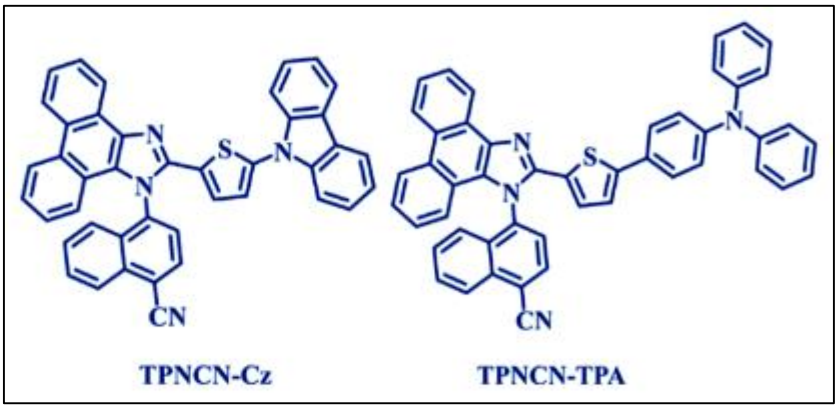

Figure 35 Structure of fused benzimidazole-thiophene-carbazole based molecule

Bala et al. [38] introduced novel **triazole linked** poly**phenylenes phenyl acetylene based** new compounds (**Figure 36**).

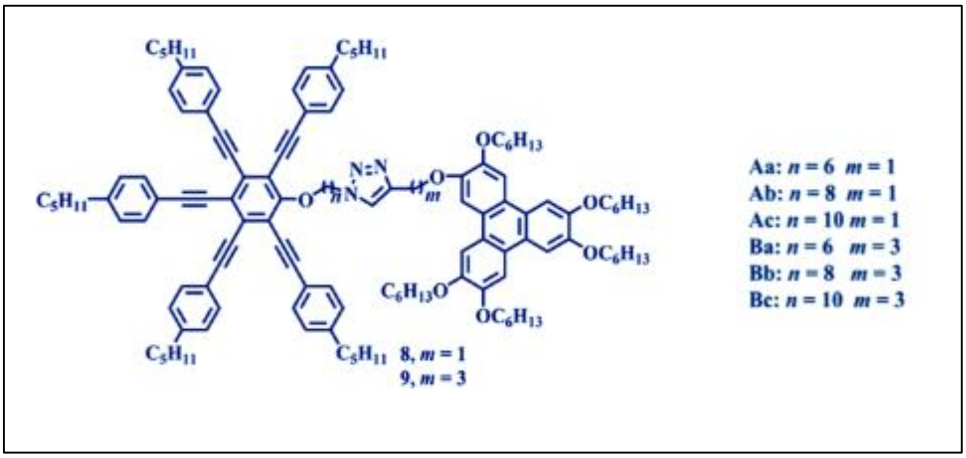

Figure 36 Structure of triazole linked polyphenylene phenyl acetylene-based molecules

Awasthi et al. [39] synthesized an acridone-dinaphthylamine derivative (AcNpH) to investigate its property as a blue TADF material (**Figure 37**).

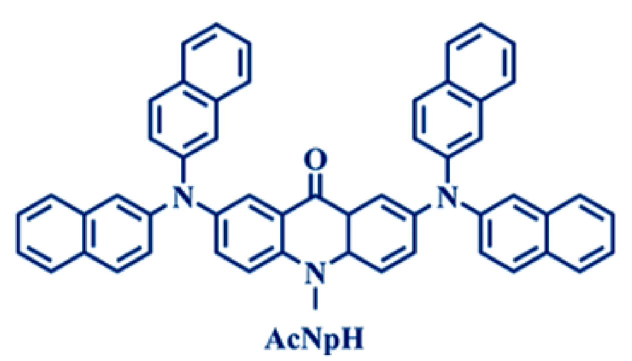

Figure 37 Structure of acridone-dinaphthylamine molecules

Das et al. [40] developed fused **benzimidazole based** four deep blue emitter compounds PNSPI, ANSPI, PSPINC and ASPINC (Figure 38).

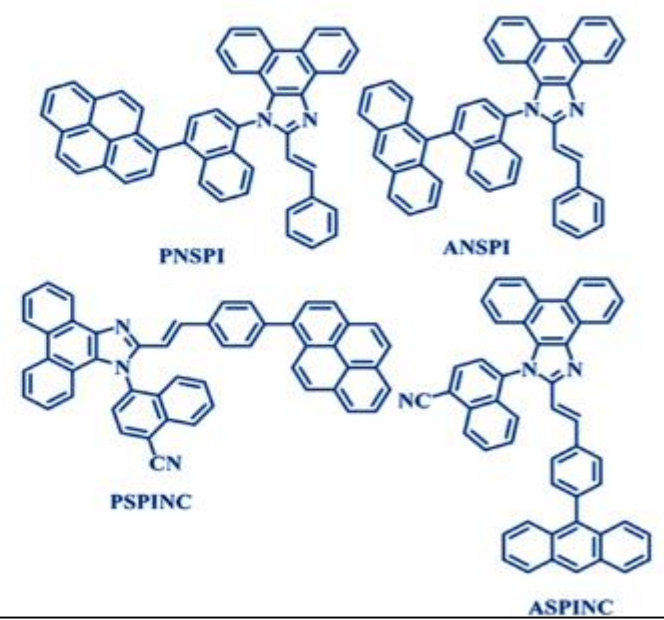

Figure 38 Structure of fused benzimidazole based molecules

Mahadik et al. [41] designed a series of substituted quinoxaline-thiophene based derivatives. They synthesized nine 2,3-di(thiophene-2-yl) quinoxaline-based amine derivatives and characterized them by standard spectroscopic techniques (**Figure 39**).

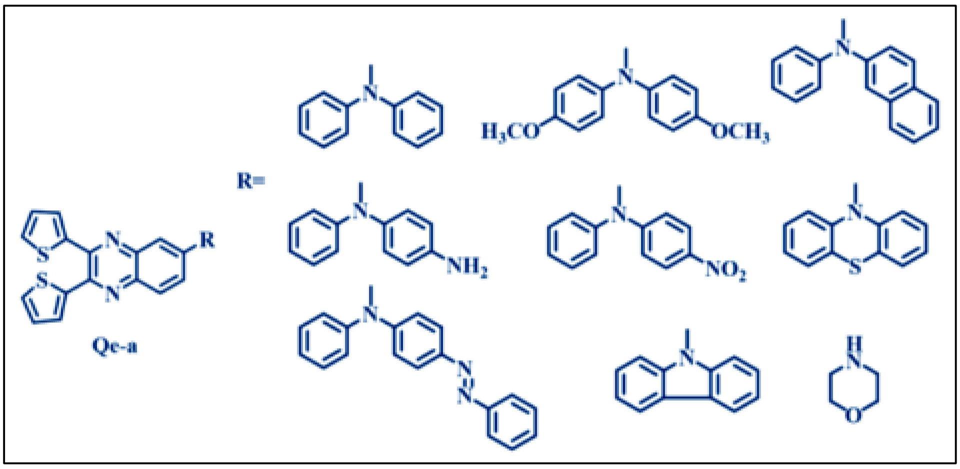

Figure 39 Structure of quinoxaline-thiophene based molecules

Najare et al. [42] developed a new molecule with proper hole and electron transfer based on pyrene-substituted oxadiazole moiety (**Figure 40**).

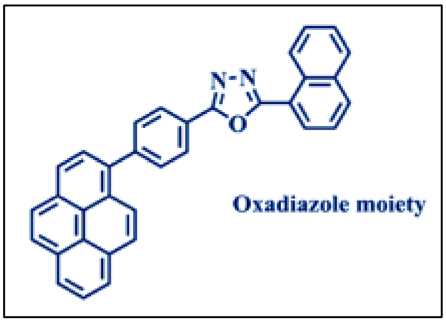

Figure 40 Structure of pyrene-substituted oxadiazole molecules

Ravindra et al. [43] reported an AIE-based novel substituted tetra phenyl containing imidazole molecule (**Figure 41**).

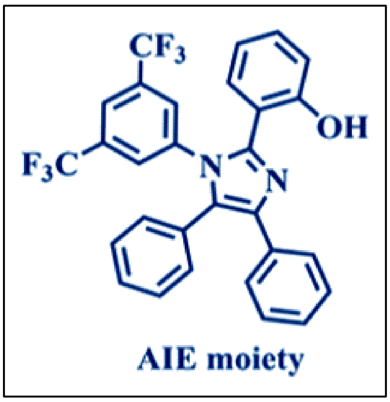

Figure 41 Structure of substituted tetra phenyl containing imidazole molecule

Tagare et al. [44-45] reported triphenyl amine-imidazole based three bright blue color bipolar fluorophores BIMTRA, DBIPTPA, DBIPTPA, and TBIMTPA. (**Figure 42**).

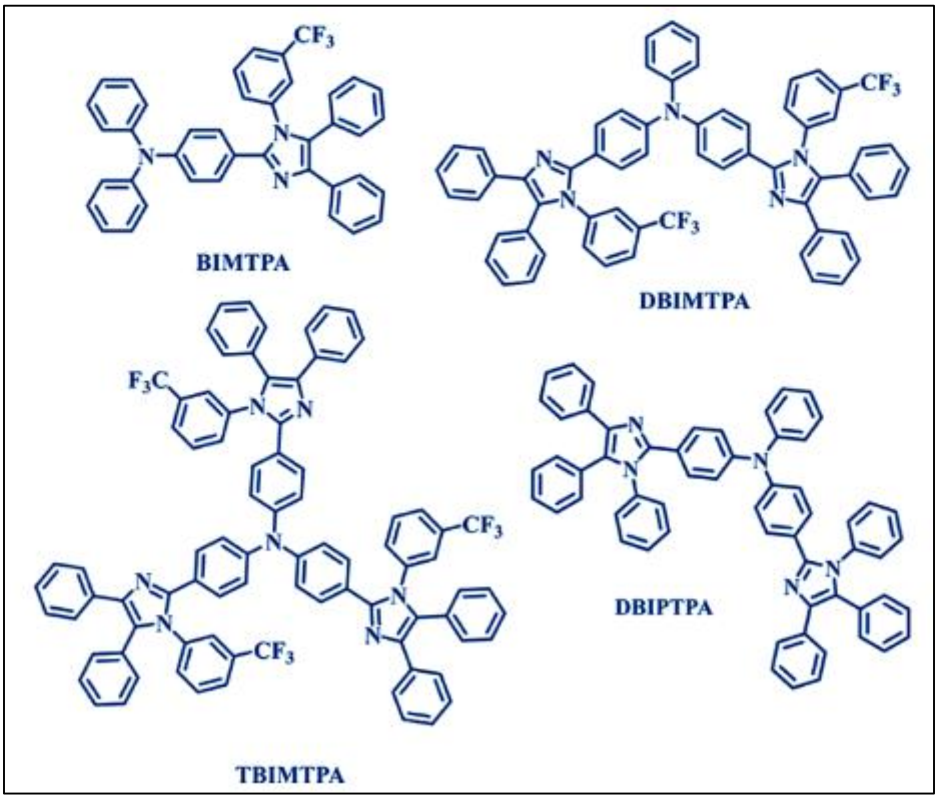

Figure 42 Structure of triphenyl amine-imidazole based molecules

Patil et al. [46] published their work on a synthesis of a novel fused triphenyl amine TADF-based IDFL molecule (**Figure 43**).

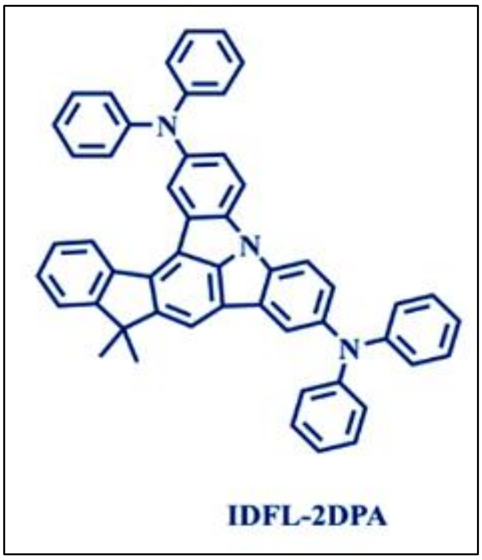

Figure 43 Structure of fused triphenyl amine molecules

Karuppusamy et al. [47] developed novel pyrazoline skeleton donor–acceptor molecules PP-OCH3 and PP-Br (**Figure 44**).

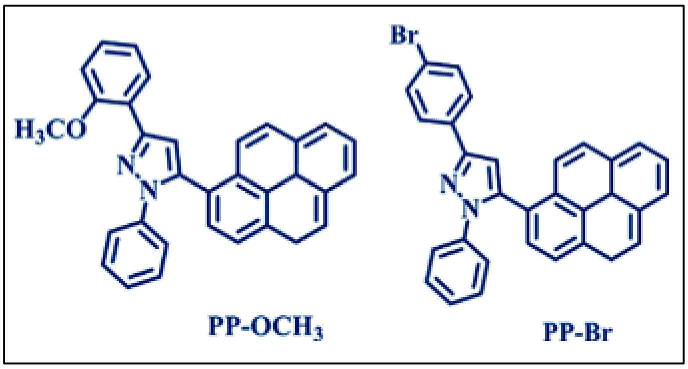

Figure 44 Structure of pyrazoline skeleton molecules

Jayabharathi et al. [48] reported two new blue emissive materials based on fused benzimidazole framework (**Figure 45**).

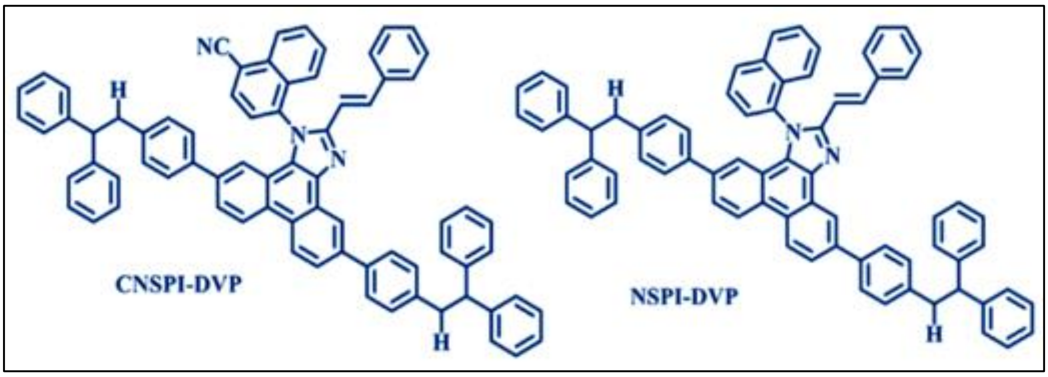

Figure 45 Structure of fused benzimidazole molecules

Dixit et al. [49] came up with a huge stroke by developing seven different bipolar PI derivatives PI1–6 based on fused benzimidazole framework containing different heterocycles (**Figure 46**).

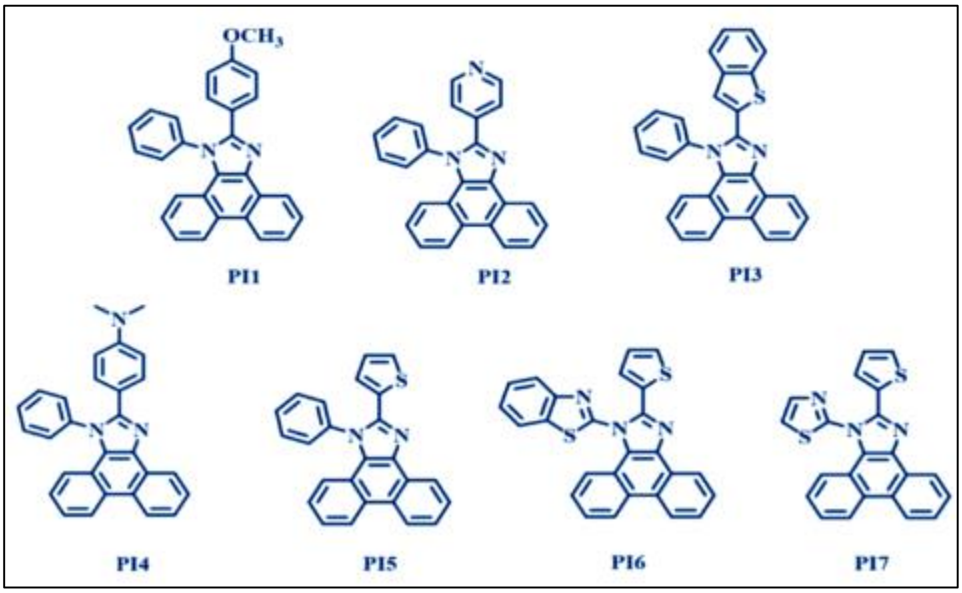

Figure 46 Structure of fused benzimidazole with different heterocyclic molecules

Sharma et al. [50] designed fused benzimidazole-Carbazole based molecular frameworks MIPCN and DPICN as a blue light emitter (**Figure 47**).

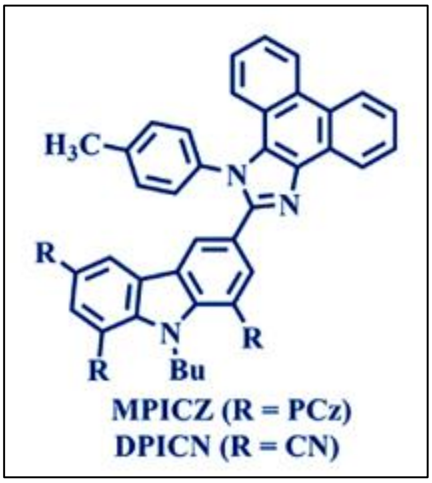

Figure 47 Structure of fused benzimidazole-Carbazole based molecules

Tagare et al. [51] developed imidazole-Carbazole based derivatives BIPOCz, in which tetra phenyl substituted imidazole molecule was attached to carbazole framework by ether linkage (**Figure 48**).

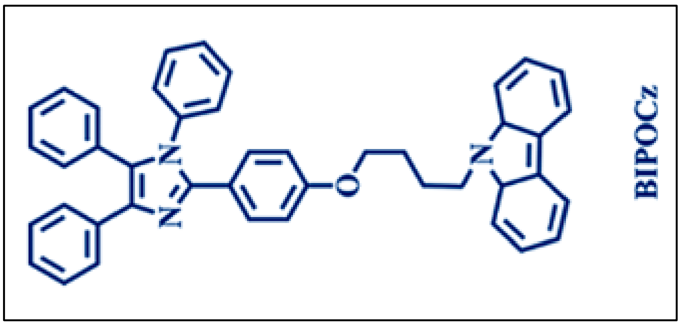

Figure 48 Structure of imidazole-Carbazole based molecules

Vasylieva et al. [52] synthesized novel acridinone based conjugated organic TADF molecules with a D–A–D structure (**Figure 49**).

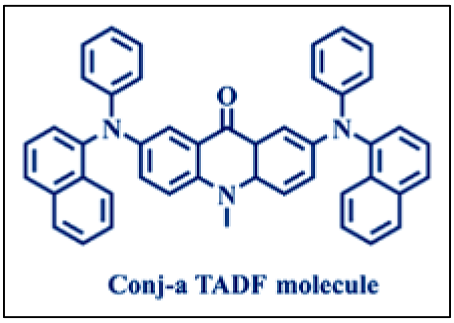

Figure 49 Structure of acridinone based molecules

Najare et al. [53] synthesized three oxadiazole-imine based conjugated framework containing molecules (**Figure 50**).

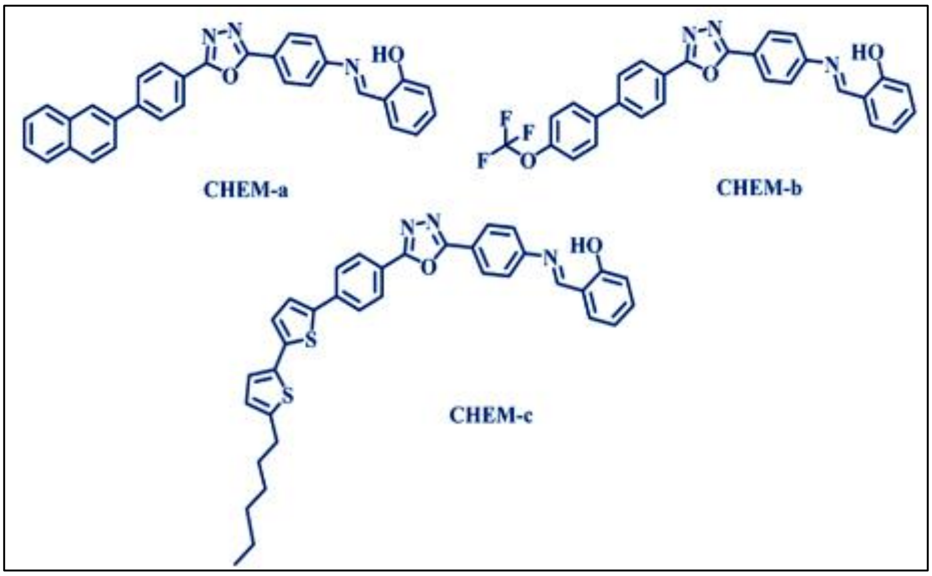

Figure 50 Structure of oxadiazole-imine based molecules

Kumar et al. [54] synthesized fluorescent derivatives based on a core called coumarin-thiophene fluorescent tags (CTFTs) (**Figure 51**).

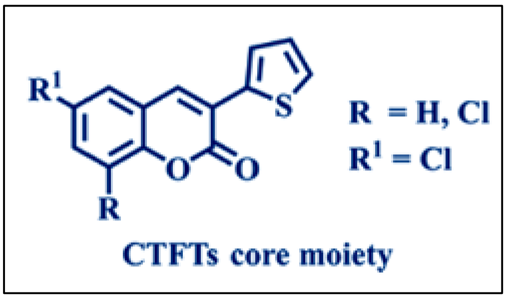

Figure 51 Structure of coumarin-thiophene based molecules

Bahadur et al. [55] demonstrated carbazole-benzophenone based two potential isomers Bpy-pDTC and Bpy-Mdtc (**Figure 52**).

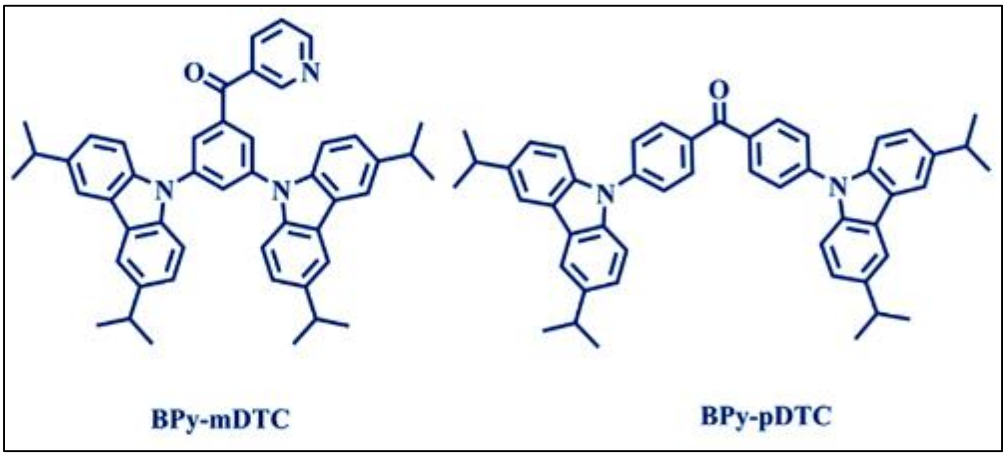

Figure 52 Structure of carbazole-benzophenone based molecules

Girase et al. [56] group developed two new tetra phenyls substituted imidazole-triphenyl amine based bipolar molecules 4-PIMCFTPA and 4-BICFTPA (**Figure 53**).

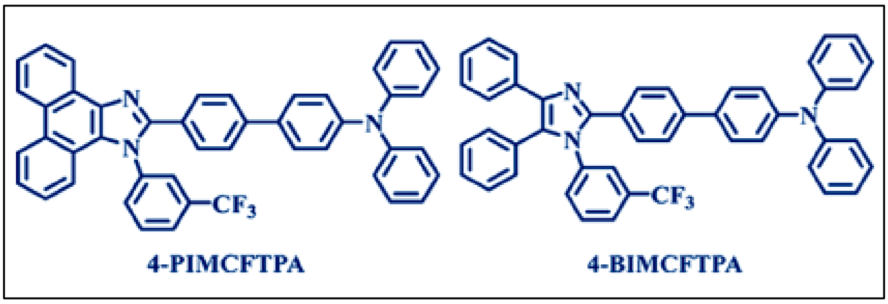

Figure 53 Structure of tetra phenyl substituted imidazole-triphenyl amine-based molecules

Thomas et al. [57] designed an imidazopyridine and fused benzimidazole based molecule that can balance the intramolecular charge between molecules (**Figure 54**).

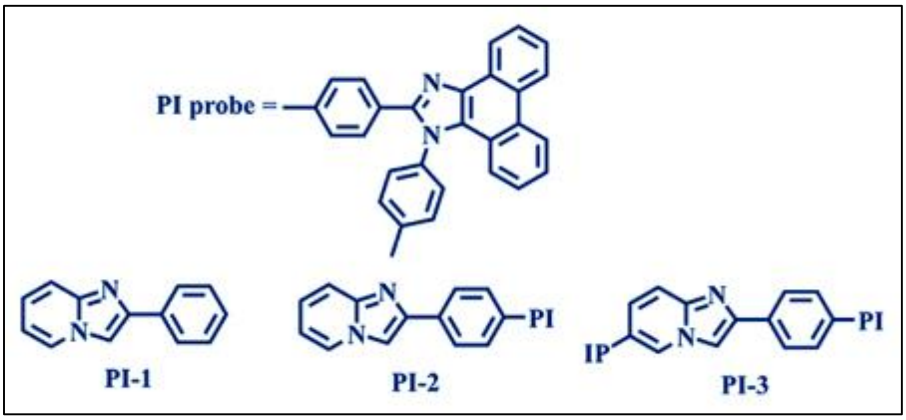

Figure 54 Structure of imidazopyridine and fused benzimidazole based molecules

Girase at al. [58] has synthesized tetra phenyl substituted imidazole-Benzothiazole based three core acceptors PHBISN, PTBISN, and m-CFBISN (**Figure 55**).

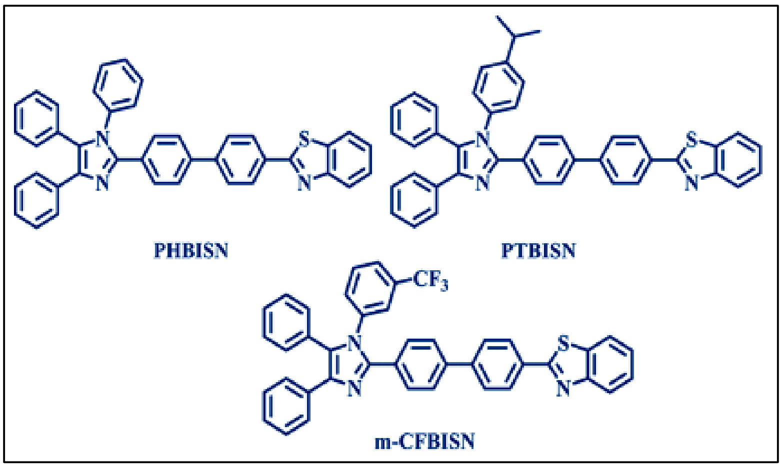

Figure 55 Structure of tetra phenyl substituted imidazole-Benzothiazole based molecules

3. Conclusions

In summary, blue OLED development has been ongoing since 1987. As a result, we can observe the feathers growing in OLED technology every year. The current state of blue light emitting material design, which includes different emission molecules based on TADF, HLCT, phosphorescence, and fluorescence, is discussed in this work. When compared to the red and green devices, most blue materials are experiencing problems with their lifetime. However, the TTF and hyperfluorescence-based molecules are extracted to stop the blue materials' efficiency from building up. For blue emitters, the addition of the aforementioned phenomenon to TADF and HLCT represents a significant advancement. Furthermore, the phosphorescence and TADF-based materials exhibit a satisfactory efficiency and electroluminance spectrum, while the TTF-based blue materials are less efficient. Ph-OLEDs can be the best blue OLED material for device fabrication if appropriate materials are selected for the device design. Here, we have compiled all the data from previously published materials in an attempt to cover all the blue light-emitting molecules that have been reported in India to date. In an effort to develop the most effective molecules that can produce the best OLEDs, several teams are working on blue-emitting materials. It is anticipated that it might lower daily energy consumption in human life. India is still lagging somewhat, though, when it comes to increasing OLED production and collaborating both domestically and internationally with business and academia. Current research has shown that devices designed to improve efficiency are not too dissimilar from blue OLED devices that are produced internationally. Furthermore, it will expedite the adoption of ultra-efficient blue lighting equipment to elevate India to the forefront and will directly impact India's economic expansion.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Karthik, D.; Thomas, K. R. J.; Jou, J.-H.; Kumar, S.; Chen, Y.-L.; Jou, Y.-C. RSC Adv. 2015, 5, 8727.

[2] Kumar, S.; Patil, S. J. Phys. Chem. C 2015, 119, 19297.

[3] Dahule, H. K.; Thejokalyani, N.; Dhoble, S. J. Luminescence 2015, 30, 405.

[4] Kumar, S.; Patil, S. New J. Chem. 2015, 39, 6351.

[5] Nishal, V.; Singh, D.; Saini, R. K.; Tanwar, V.; Kadyan, S.; Srivastava, R.; Kadyan, P. S. Cogent Chem. 2015, 1, 1079291.

[6] Gupta, N.; Grover, R.; Mehta, D.S.; Saxena, K. Displays, 39, 104.

[7] Lakshmanan, R.; Shivaprakash, N. C.; Nair, S. S. J. Lumin. 2015,168, 145.

[8] Jadhav, T.; Choi, J. M.; Dhokale, B.; Mobin, S. M.; Lee, J. Y.; Misra, R. J. Phys. Chem. C 2016, 120, 18487.

[9] Jhulki, S.; Seth, S.; Ghosh, A.; Chow, T. J.; Moorthy, J. N. ACS Appl. Mater. Interfaces 2016, 8, 1527.

[10] Rajamalli, P.; Senthilkumar, N.; Gandeepan, P.; Ren-Wu, C. C.; Lin, H.W.; Cheng, C. H. ACS Appl. Mater. Interfaces 2016, 8, 27026.

[11] Kumar, S.; Kumar, D.; Patil, Y.; Patil, S. J. Mater. Chem. C 2016, 4, 193.

[12] Gupta, M.; Pal, S. K. Langmuir 2016, 32, 1120.

[13] Rajamalli, P.; Senthilkumar, N.; Gandeepan, P.; Huang, P. Y.; Huang, M. J.; Ren-Wu, C. Z.; Yang, C. Y.; Chiu, M. J.; Chu, L. K.; Lin, H. W. J. Am. Chem. Soc. 2016, 138, 628.

[14] Pathak, S. K.; Pradhan, B.; Gupta, M.; Pal, S. K.; Sudhakar, A. A. Langmuir 2016, 32, 9301.

[15] Pathak, S. K.; Gupta, M.; Pal, S. K.; Achalkumar, A. S. ChemistrySelect 2016, 1, 5107.

[16] Thanikachalam, V.; Jeeva, P.; Jayabharathi, J.; Ramanathan, P.; Prabhakaran, A.; Saroj Purani, E. Ind. Eng. Chem. Res. 2016, 55, 9639.

[17] Urinda, S.; Das, G.; Pramanik, A.; Sarkar, P. Comput. Theor. Chem. 2016, 1092, 32.

[18] Valsange, N. G.; Wong, F. L.; Shinde, D.; Lee, C. S.; Roy, V. A. L.; Manzhos, S.; Feron, K.; Chang, S.; Katoh, R.; Sonar, P. A. New J. Chem. 2017, 41, 11383.

[19] Chaudhary, S.; Mukherjee, M.; Paul, T. K.; Bishnoi, S.; Taraphder, S.; Milton, M. D. ChemistrySelect 2018, 3, 5073.

[20] Gopikrishna, P.; Meher, N.; Iyer, P. K. ACS Appl. Mater. Interfaces 2017, 10, 12081.

[21] Jayabharathi, J.; Sujatha, P.; Thanikachalam, V.; Jeeva, P.; Nethaji, P. RSC Adv. 2017, 7, 54078.

[22] Joseph, V.; Thomas, K. R. J.; Singh, M.; Sahoo, S.; Jou, J. Eur. J. Org. Chem. 2017, 2017, 6660.

[23] Konidena, R. K.; Thomas, K. R. J.; Dubey, D. K.; Sahoo, S.; Jou, J. H. Chem. Commun. 2017, 53, 11802.

[24] Thanikachalam, V.; Sarojpurani, E.; Jayabharathi, J.; Jeeva, P. New J. Chem. 2017, 41, 2443.

[25] Matta, A.; Gupta, M.; Kumar, Y.; Taniike, T.; Van der Eycken, J.; Singh, B. K. ChemistrySelect 2018, 3, 10815.

[26] Bala, I.; Ming, L.; Yadav, R. A. K.; De, J.; Dubey, D. K.; Kumar, S.; Singh, H.; Jou, J.; Kailasam, K.; Pal, S. K. ChemistrySelect 2018, 3, 7771.

[27] Ghate, M.; Kalyani, N. T.; Dhoble, S. J. Luminescence 2018, 33, 999.

[28] Gupta, R. K.; Ulla, H.; Satyanarayan, M. N.; Sudhakar, A. A. Eur. J. Org. Chem. 2018, 2018, 1608.

[29] Sharma, R.; Volyniuk, D.; Popli, C.; Bezvikonnyi, O.; Grazulevicius, J. V; Misra, R. J. Phys. Chem. C 2018, 122, 15614.

[30] Siddiqui, Q. T.; Awasthi, A. A.; Bhui, P.; Muneer, M.; Chandrakumar, K. R. S.; Bose, S.; Agarwal, N. J. Phys. Chem. C 2018, 123, 1003.

[31] Tagare, J.; Ulla, H.; Satyanarayan, M. N.; Vaidyanathan, S. J. Photochem. Photobiol., A 2018, 353, 53.

[32] Venkatramaiah, N.; Kumar, G. D.; Chandrasekaran, Y.; Ganduri, R.; Patil, S. ACS Appl. Mater. Interfaces 2018, 10, 3838.

[33] Manohara, H. M.; Devaiah, C. T.; Hemavathi, B.; Ahipa, T. N. J. Lumin. 2019, 206, 284.

[34] Kadam, V. S.; Bhatt, P. A.; Karmakar, H. S.; Zade, S. S.; Patel, A. L. ChemistrySelect 2019, 4, 3948.

[35] Tagare, J.; Dubey, D. K.; Jou, J.; Vaidyanathan, S. ChemistrySelect 2019, 4, 6458.

[36] Kajjam, A. B.; Dubey, D. K.; Yadav, R. A. K.; Jou, J. H.; Sivakumar, V. Mater. Today Chem. 2019, 14, 100201.

[37] Jayabharathi, J.; Nethaji, P.; Thanikachalam, V.; Ramya, R. ACS Omega 2019, 4, 4553.

[38] Bala, I.; Yang,W.-Y.; Gupta, S. P.; De, J.; Yadav, R. A. K.; Singh, D. P.; Dubey, D. K.; Jou, J.-H.; Douali, R.; Pal, S. K. J. Mater. Chem. C 2019, 7, 5724.

[39] Awasthi, A. A.; Gupta, N.; Siddiqui, Q. T.; Parab, P.; Palit, D. K.; Bose, S.; Agarwal, N. J. Chem. Sci. 2019, 131, 1.

[40] Das, S.; Okamura, N.; Yagi, S.; Ajayaghosh, A. J. Am. Chem. Soc. 2019, 141, 5635.

[41] Mahadik, S. S.; Chacko, S.; Kamble, R. M. ChemistrySelect 2019, 4, 10021.

[42] Najare, M. S.; Patil, M. K.; Nadaf, A. A.; Mantur, S.; Inamdar, S. R.; Khazi, I. A. M. Opt. Mater. (Amst). 2019, 88, 256.

[43] Ravindra, M. K.; Mahadevan, K. M.; Basavaraj, R. B.; Darshan, G. P.; Sharma, S. C.; Raju, M. S.; Vijayakumar, G. R.; Manjappa, K. B.; Yang, D. Y.; Nagabhushana, H. Mater. Sci. Eng., C 2019, 101, 564.

[44] Tagare, J.; Dubey, D. K.; Jou, J. H.; Vaidyanathan, S. Dyes Pigm. 2019, 160, 944.

[45] Tagare, J.; Dubey, D. K.; Yadav, R. A. K.; Jou, J. H.; Vaidyanathan, S. Mater. Adv. 2020, 1, 666.

[46] Patil, V. V.; Lee, K. H.; Lee, J. Y. Chem. Eng. J. 2020, 395, 125125.

[47] Karuppusamy, A.; Kannan, P. Chem. Phys. Lett. 2020, 745, 137241.

[48] Jayabharathi, J.; Sivaraj, S.; Thanikachalam, V.; Anudeebhana, J. Mater. Adv. 2021, 2, 6388.

[49] Dixit, S. J. N.; Gupta, C.; Tadavi, T. H.; Chandrakumar, K. R. S.; Bose, S.; Agarwal, N. New J. Chem. 2021, 45, 16238.

[50] Sharma, A.; Balasaravanan, R.; Thomas, K. R. J.; Ram, M.; Dubey, D. K.; Yadav, R. A. K.; Jou, J. H. Dyes Pigm. 2021, 184, 108830.

[51] Tagare, J.; Boddula, R.; Yadav, R. A. K.; Dubey, D. K.; Jou, J. H.; Patel, S.; Vaidyanathan, S. Dyes Pigm. 2021, 185, 108853.

[52] Vasylieva, M.; Pander, P.; Sharma, B. K.; Shaikh, A. M.; Kamble, R. M.; Dias, F. B.; Czichy, M.; Data, P. Electrochim. Acta 2021, 384, 138347.

[53] Najare,M. S.; Patil,M. K.; Garbhagudi,M.; Yaseen,M.; Inamdar, S. R.; Khazi, I. A.M. J. Mol. Liq. 2021, 328, 115443.

[54] Kumar, N.; Alghamdi, A. A.; Mahadevan, K. M.; Nagaraju, G. J. Mol. Struct. 2021, 1223, 129208.

[55] Bahadur. S. K.; Ravindran, E.; Deori, U.; Yadav, N.; Nanda, G. P.; Rajamalli, P. J. Mater. Chem. C 2022, 10, 4886.

[56] Girase, J. D; Rani Nayak, S.; Tagare, J.; Shahnawaz; Ram Nagar,M.; Jou, J. H.; Vaidyanathan, S. J. Inf. Disp. 2022, 23, 53.

[57] Thomas, K. R. J.; Nagar, M. R.; Jou, J.-H. J. Photochem. Photobiol., A 2022, 423, 113600.

[58] Girase, J. D.; Nagar, M. R.; Jayakumar, J.; Jou, J. H.; Vaidyanathan, S. J. Lumin. 2022, 248, 118992.