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Polybenzimidazole Fiber (PBI): Synthetic Fibre from Benzimidazole

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Abstract: ***Poly [2,2'-(m-phenylen)-5,5'-bisbenzimidazole] or (Polybenzimidazole fibre -PBI) are very stable manufactured fiber with exceptional chemical and thermal stability. It used to fabricate high-performance protective attire such as astronaut space suits, firefighter's gear, high temperature protective gloves, welders' apparel and aircraft wall fabrics., PBI has a very high glass transition temperature (425°C / 800°F) due to the its fully aromatic structure and doesn't exhibits any melting point. Heat deflection temperature of PBI is about 815°F (435°C) at 264 psi (1.8 MPa). Its decomposition temperature is more than 1300°F (> 700°C).***

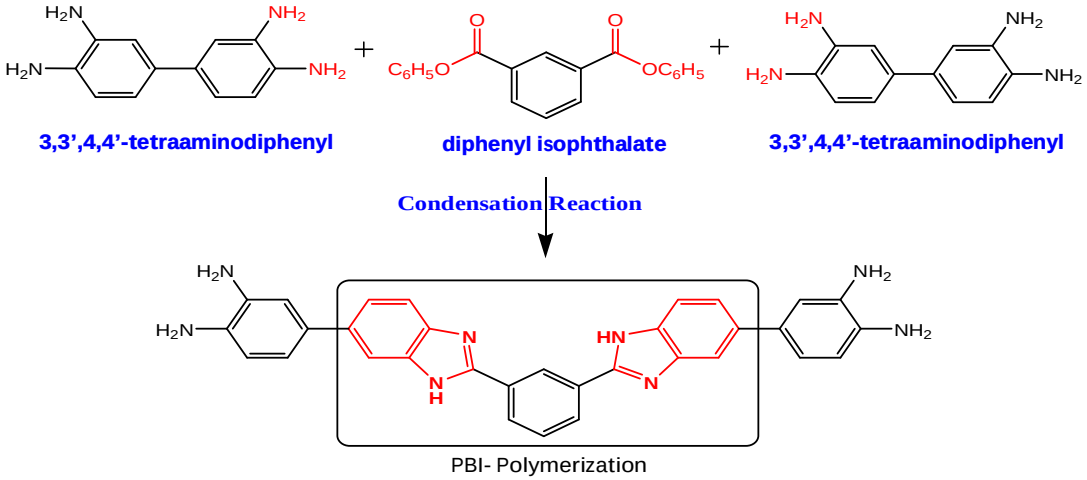
Keywords: PBI; fibre; stability; aromatic structure; glass transition temperature; heat deflection temperature

I. INTRODUCTION

PBI fibers [1] are suitable for a wide range of high temperature applications. PBI was first reported by Brinker and Robinson in 1949.[2] However, the discovery of aromatic polybenzimidazole credited to Carl Shipp Marvel in the 1950s.[3] Some important discovery (and development) timeline of PBI till to commercialization of PBI is as follows:

1) 1961- H. Vogel and C.S. Marvel developed polybenzimidazole.[4]
2) 1963- This considerable work on polybenimidazole sponsored by NASA and the Air Force Materials Lab for for defense and aerospace and applications.
3) 1969- Polybenzimidazole (PBI) was selected by The United States Air Force (USAF) for its extraordinary thermal protective performance.[5]
4) Early1970- USAF laboratories examined PBI for protective clothing.[5]
5) 1970- PBI was continued in use by NASA as part of the clothing of astronauts on Apollo, Skylab and other space shuttle flights.
6) 1980- PBI was introduced to the fire services.
7) PBI Gold fabric (60% Armid fiber + 40% PBI fiber) was developed for fireworks.
8) 1983- PBI fibers become commercially available.
9) 1990-Short-cut PBI fibers were introduced for use in automotive braking systems.
10) 1992- PBI fabrics (of lightweight) were developed for flame-resistant work-wears
11) 1994 – PBI Gold fabric is engineered in black and was specified by FDNY.
12) 2003 – PBI Matrix becomes commercialized.

PBI can be synthesized by condensation mechanism between diphenyl isophthalate and 3,3',4,4'-tetraaminophenyl. Excepting these monomers other monomeric units can be used for synthesis.[1]



A. Applications of PBI fibres

Polybenzimidazole fibres (PBI) are applicable in apparel applications which includes astronaut's suits,[6]firefighter's protective apparel, industrial worker's apparel, aluminized crash rescued gear, and suits for racing car drivers.[7] Extraordinary high decomposition temperature (1300 °F) of PBI which is far exceeding from Nomex/Kevlar blends (Nomex being at 700 °F and Kevlar at 1100 °F) contributing superior break-open and thermal protection. Traditionally, PBI was used semi-permeable membranes for electrodialysis, reverse osmosis or ultrafiltration.[8]

PBI has also established their application in gas separations [9][10] due to its density, very low gas permeability, rigidity in structure, close chain packing and strong hydrogen bonding. PBI usually doped with acids to be proton conductive. Proton conductive power depends on amount of acid doped. But on the same time, doping of acid reduces the mechanical strength of PBI. Thus, the most advantageous doping level of acid into PBI is compromises between these two effects. To solve out this problem, multiple methods such as covalent cross-linking, ionic cross-linking, and composite membranes [11] have been researched and developed. Polybenzimidazole contains imidazole ring which posses basic properties so PBI is able to be complexed by strong acids. Complexation by phosphoric acid makes it a proton conductive material.[12]

PBI resin is molded via a sintering process that was jointly developed by Hoechst Celanese and Alpha Precision Plastics, Inc. [13] Molded PBI resin is an excellent candidate for high strength, low weight material. PBI has compressive strength of 58 ksi, tensile strength of 23 ksi, a flexural strength of 32 ksi, a ductile compressive failure mode and the density of 1.3 g/cm3.[14] Composite Materials Research Group, the University of Wyoming suggests that PBI resin parts preserve considerable tensile properties and compressive strength to 700 °F (371 °C). High dimensional stability and retention of electrical properties at high temperature makes PBI resin's useful as a thermal and electrical insulator.[15] Due to its high-energy conversion efficiency Polymer electrolyte fuel cell (PEFC) is one of the most promising to be power sources for houses and cars. Doped polybenzimidazole (PBI) as high temperature fuel cell electrolyte has so many advantages. It's reported by Wainright, Wang et al. reported that phosphoric acid doped PBI was utilized as a high temperature fuel cell electrolyte.[16] The kinetic rates of the fuel cell reactions increase at elevated temperature. It also can reduce the problem of the catalyst poisoning by adsorbed carbon monoxide and it minimizes problems due to electrode flooding.[17]

PBI/H_3PO_4 is conductive even in relatively low humidity and it allows minimul crossover of the methanol at the same time and this property makes it superior in comparison of some traditional polymer electrolytes such as Nafion. In addition, the system PBI/H_3PO_4 maintains a very good mechanical strength and hardiness.[18] Its modulus has greater magnitudes than that of Nafion[19] which indicates that the thinner films can be used and reducing ohmic loss .

Until that time, only asbestos can well perform in temperature gloves such as for aluminum extrusion, foundries, and metal treatment, while R&D trials on PBI reveals that the PBI system functions adequately as asbestos. Moreover, according to a safety garment manufacturer gloves containing PBI outlasted asbestos two to nine times with an effective cost.[20] PBI fibers containing gloves are softer and suppler than those made of asbestos. nd this softness offering greater mobility, and comfort to workers even if the fabric becomes charred. And one of the most important point that PBI fiber avoids the chronic toxicity problems which is associated with use of asbestos.[21] PBI fibers also can be a good replacement for asbestos in several areas of glass manufacturing.

II. CONCLUSION

Poly(2,2'-m-phenylene-5,5'-bibenzimidazole) is the only commercial available PBI fiber. Hoechst Celanese used Celazole® (U-series) trade name for very first produced PBI articles, which was speedily followed by T-series (PBI-Polyaryleneketone blends). Above discussion on application part of PBI seems promising for further research on making it more useful in various fields.

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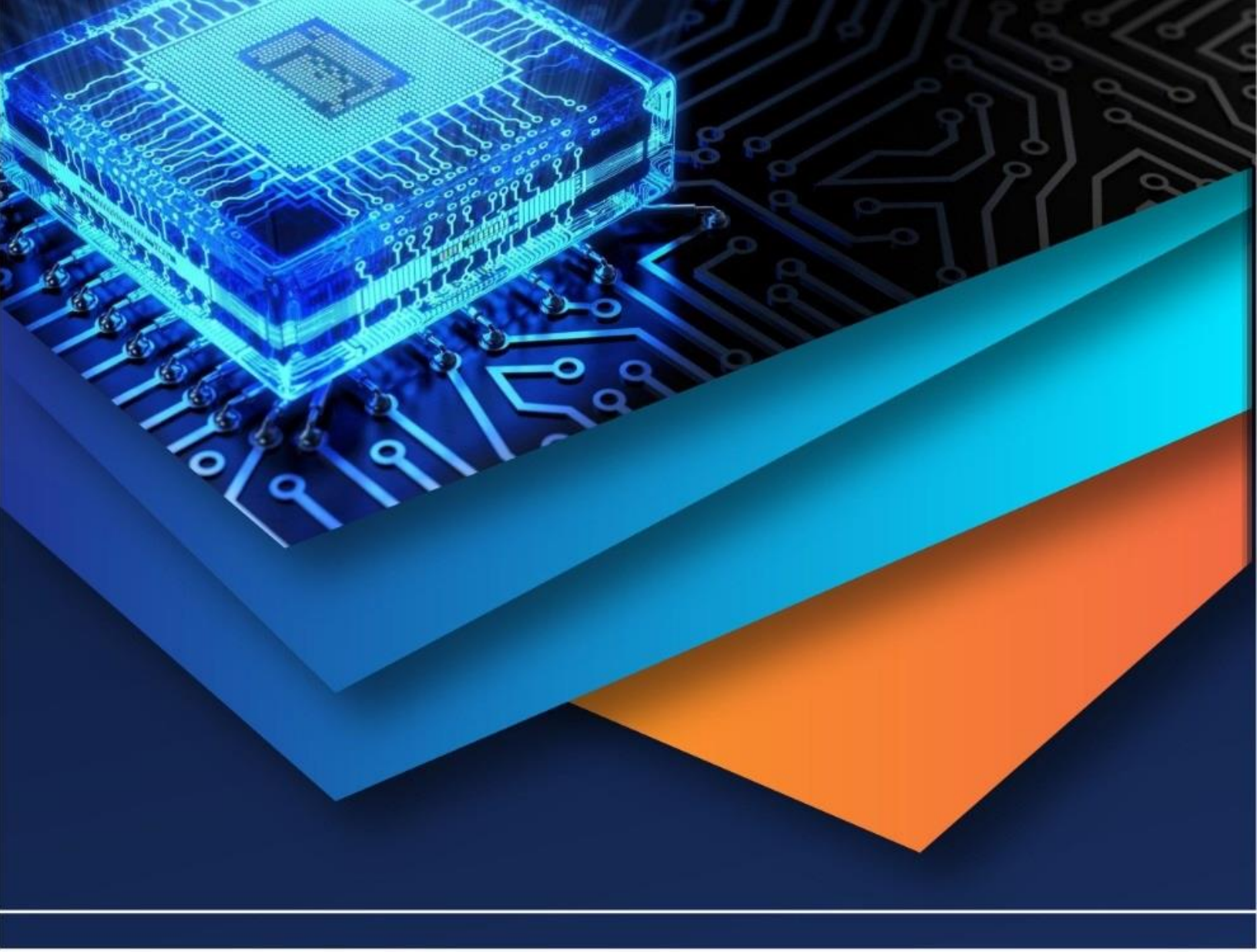

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