Solution-Processable High-Performance Polymers for Optoelectronic Applications

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In nowadays world, life without polymers is unimaginable. Polymers have become major synthetic materials of the 21st century. High-performance polymers (HPPs) are the most desirable materials with a good combination of remarkable mechanical, thermal, electrical, and optical properties accompanied chemical and solvent resistance. Companies of all sizes are involved in various aspects of HPP research, and many academic laboratories have multidisciplinary efforts dedicated to expanding their applications. The synthesis and development of HPPs in the past thirty years have particularly drawn the attention of many polymer scientists and investigators. With the unique features for industrial applications, the development of HPPs with sufficient solubility and processability would be required to further optimize their performance. In fact, HPPs exhibit excellent physical and mechanical properties in a broad temperature range and have exceptionally high radiation resistance and superior semiconductor properties. These characteristics allow HPPs to dominate the applications in many fields.

Therefore, our laboratory developed the synthesis of soluble HPPs (*e.g.*, aromatic polyimides and polyamides) from designed new monomers via facile polymerization methods. An excellent combination of superior properties makes them suitable for a wide range of applications, from engineering plastics in aerospace industries to membrane applications. The functional HPPs having potential applications such as electrochromic,[1] luminescent,[2] memory devices,[3] and high refractive materials[4] were developed and investigated.

Since 2005, our group has reported several arylamine/triphenylamine (TPA) containing electrochromic polymers (ECPs) [Figure 1] with interesting color transitions and good electrochromic reversibility in the visible region or NIR range,[1] which could be differentiated on the method of increasing coloring stages. A first class spans materials polymerized from two electroactive monomers (e.g., polyamides prepared by electroactive diamines and diacids) [Figure 2]. A second class includes the further chemical modification of electroactive units on the end functional groups of electrochromic hyperbranched polymers [Figure 3]. A third class is represented by increasing the electroactive sites into the synthesized monomers by multi-step procedure approaches [Figure 4]. Finally, by random copolymerization of TPA-based diamine monomers, the resulting copolymer could exhibit extensive absorption required for a black electrochromism with multicolor electrochromism [Figure 5], spanning numerous applications including EC windows and displays.

This talk covered a majority of the recent works in our laboratory involving the synthesis and property evaluation of functional HPPs as well as their structural design by using the respective monomers. Solution-processable functional HPPs were well designed and successfully synthesized. Most of the polymers had good solubility in many polar aprotic solvents, and exhibited excellent thin-film-forming ability. Owing to high T_g values, good thermal stability, and mechanical properties, the obtained polymers may be widely applied as electrochromic, luminescent, memory devices, and high refractive materials [Figure 6].

Reference

1. (a) G. S. Liou, S. H. Hsiao, T. X. Su, *J. Mater. Chem.*, **15**, 1812(2005). (c) C. W. Chang, G. S. Liou, *J. Mater. Chem.*, **18**, 5638(2008). (d) C. W. Chang, C. H. Chung, G. S. Liou, *Macromolecules*, **41**, 8441(2008). (e) G. S. Liou, H. Y. Lin and H. J. Yen, *J. Mater. Chem.*, **19**, 7666(2009). (f) G. S. Liou, H. Y. Lin, *Macromolecules*, **42**, 125(2009). (f) H. J. Yen, G. S. Liou *Chem. Mater.,* **21**, 4062(2009). (g) H. J. Yen, H. Y. Lin, G. S. Liou, *Chem. Mater.,* **23**, 1874(2011). (h) H. J. Yen, G. S. Liou, *Polym. Chem.,* **3**, 255(2012).
2. (a) H. J. Yen, G. S. Liou, *J. Polym. Sci. Part A: Polym. Chem.,* **46**, 7354(2008). (b) H. J. Yen, G. S. Liou, *J. Polym. Sci. Part A: Polym. Chem.,* **47**, 1584(2009).
3. (a) C. J. Chen, H. J. Yen, W. C. Chen, G. S. Liou, *J. Mater. Chem.,* **22**, 14085(2012). (b) Y. C. Hu, C. J. Chen, H. J. Yen, K. Y. Lin, J. M. Yeh, W. C. Chen, G. S. Liou, *J. Mater. Chem.,* **22**, 20394(2012).
4. (a) H. J. Yen, G. S. Liou, *J. Mater. Chem.,* **20**, 4080(2010). (b) C. L. Tsai, H. J. Yen, G. S. Liou, *J. Mater. Chem.,* **22**, 17236(2012).

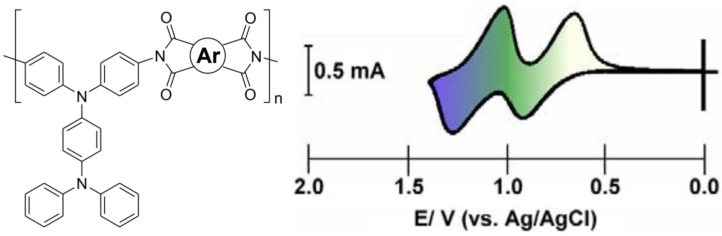

Figure 1. The first EC polyimide with its cyclic voltammetric diagram and electrochromic behavior.

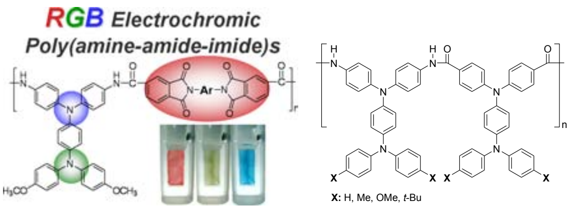

Figure 2. Chemical structure of RGB and multi-color EC materials polymerized from two electroactive monomers and their electrochromic behaviors.

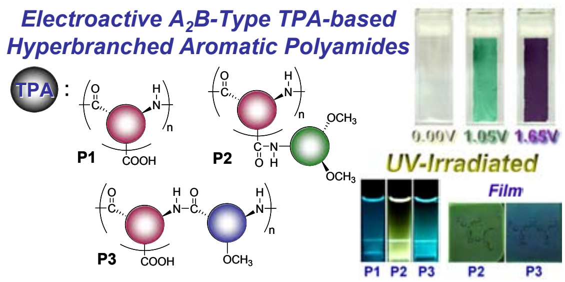

Figure 3. Electrochromic and luminescent behaviors of the TPA-based hyperbranched polyamides

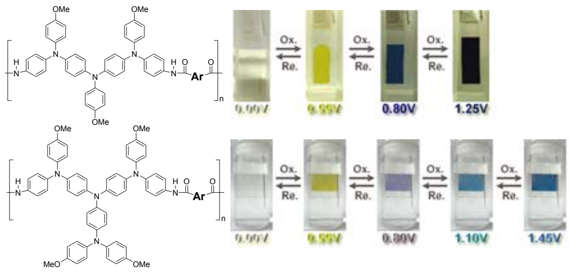

Figure 4. Chemical structure of the polyamides and their multi-electrochromism at the different applied potential.

Figure 5. Chemical structure of the copolyamide and its electrochromism at the different applied potential.

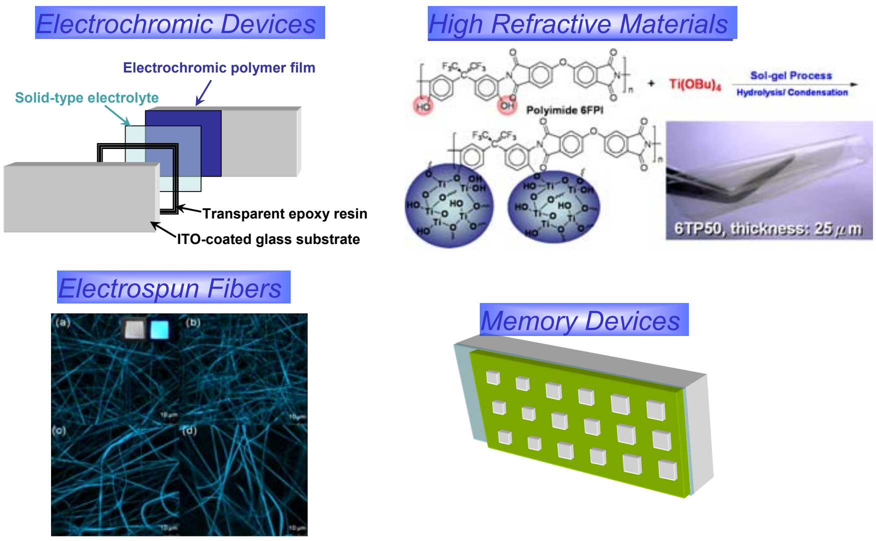

Figure 6. Summary of pratical applications for the prepared functional HPPs, such as electrochromic devices, light-emitting electrospun nanofibers, high refractive materials, and memory devices.