Chapter

Introductory Chapter: Dyes and Pigments - Past, Present, and Future

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1. Introduction

Dyes and pigments have been playing an undoubtedly important role in human life since the ancient years. Today their mass production is well established, and a vast number of dyes and pigments are globally produced. Currently, the industrial interest for new dyes and pigments with special properties is constantly growing. This has triggered significant research attempts all over the world and new multifunctional dyes and pigments suitable for novel, hi-tech applications have been proposed/created. The steady growth of the global dyes and pigments market signifies a vibrant future for research in the corresponding, wide research field.

2. Historical background

Dyes and pigments are narrowly connected to human culture and different types of them have been used from people since the ancient years in order decorate various types of materials including textiles, ceramics, wood etc. [1] It is well documented that more than 2000 years ago, in ancient China, Egypt, Rome and Greece natural dyes and pigments obtained from plant roots, animals or mineral sources were used. [1, 2] They were mostly used for decorative applications but also as protective layers against wear and corrosion of various objects. [2]

The big revolution in the field occurred in the beginning of 19th century when Sir William Henry Perkin produced the first synthetic organic dye, the so-called *mauveine*, using aniline as a starting compound. [1, 3] *Mauveine* proved to be a suitable dyestuff for various types of textiles predominantly silk, and mass production of the *aniline purple* (the original industrial name of *Mauveine*) commenced. Industrial revolution made the production of many more synthetic dyes feasible, and the expansion of synthetic dyes industry became enormous in later years. In fact, the majority of the currently known classes of dyes and pigments were invented during 19th century. [4]

3. Contemporary trends and the future of dyes and pigments

Today, the classes of dyes and pigments have been enriched with numerous entries. The scope of this field extends to and aims at novel high-tech applications such as laser dyes, [5] dyes and pigments for bio-labelling, [6] intravital microscopy applications, [7] and smart sensing devices responding to various external stimuli [8].

It comes as no surprise that the global dyes and pigments market for the year 2020 was determined to be as large as $ 32.9 billion with an estimated growing rate of about 5% for the next few years. [9] The largest shares of the global production of dyes and pigments are the ones pertaining to textile-dyes and leather-dyes covering together nearly 75% of the global production. Furthermore, printing inks and paper dyes industry hold important shares.

All the above information indicates that the use of dyes and pigments is well-established in everyday life. They appear in our lives dying objects made out of various materials e.g. plastic, wood, metals, ceramics, leather, textiles etc. (see **Figure 1**) and are either applied by the manufacturers of the products or can be used by the end-user in order to protect, modify or decorate variety of objects and materials. The variety of paints depending on use and target-surface is enormous and most of the dyes and pigments are readily available to the user. This indicates a vitally tight connection between production and everyday life. Some examples of dyes and pigments used in everyday life are depicted in **Figure 1**. Their versatility is huge, and their applications are massive.

Yet, science is constantly pushing the limits of the corresponding research field and attempts to obtain novel dyes with special functions are unceasingly being made. (Multi)functional dyes and pigments fall in a wider group of materials which can provide certain types of functionality parallel to their main operational scope. In this sense, a functional dye may for instance not only act as protective and/or decorative layer on a material (main scope), but it could act as an environment-responsive component which could in turn render a new material or device responsive and sensitive to various external stimuli (including light, pressure, heat, environment pH changes, solvent polarity etc.). In the large family of functional dyes (and pigments) fall the so-called chromic compounds/materials. These are compounds or materials which are capable of undergoing (ideally) reversible changes in a way that the user can

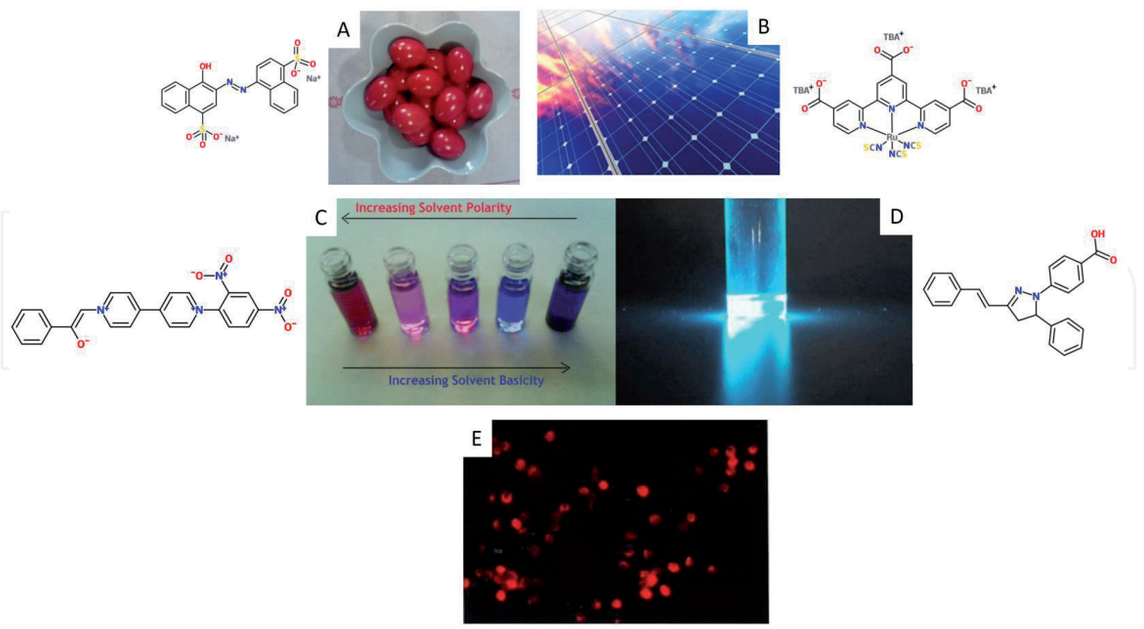

Figure 1.
Examples of dyes used in everyday life as well as in specific applications. (A) Structure of azorubine (also known as E122) a water soluble food-colorant. Photo depicts red-dyed eggs colored with azorubine. (B) Structure of "black-dye" a prominent candidate for dyes-sensitized solar cells. Photograph depicts a solar cell. (C) Structure of a viologen enolate, highly responsive in solvent polarity changes (solvatochromic dye). Photo indicates the drastic color change when moving from water (red) to solvents of lower polarity (adapted with permission by Papadakis et al. [10] (D) a pyrazoline fluorescent dye of high emission intensity. [11] (photo source: author's property). (E) Antonia Red™ Dextran: a novel polysaccharide with fluorescent labelling and its application in cell-imaging (source: TdB Labs) [12].

grasp information regarding the environment of the material/compound. [8] Novel research attempts intent to render sensing systems applicable in microenvironments e.g. living cells and they have led to a sizable family of dyes suitable for microscopy with numerous applications in biology and medicine
(see **Figure 1E**).

4. Conclusion

The variety of commercial dyes and pigments with novel properties and applications is increasing as the needs of the end-users expand. This fact is clearly reflected in the size of the corresponding market and it accounts for the extended global contemporary research endeavors towards new dyes and pigments. Based on these facts, a colorful future is envisioned.

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