# Part I

*High Performance Pigments*. Edited by Edwin B. Faulkner and Russell J. Schwartz

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# 1
# Introduction to Inorganic High Performance Pigments

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## 1.1
## Introduction

In 2005 the world production of inorganic pigments was approximately 6 million tonnes, representing a value of about $14 billions. For high performance pigment applications the market in paints and coatings is of special interest and was estimated at 2.4 million tonnes representing a value of about $5.6 billions. Some years ago the British Color Makers Association estimated the economic value of downstreamed colored industrial products using inorganic pigments at about the 80-fold of the pigment value.

In writing an introductory chapter to colored Inorganic High Performance Pigments, one is faced with a definitional dilemma, as the term "high performance pigment" is more usually met with in organic rather than inorganic literature. Cost alone is not the determining factor, otherwise the natural semiprecious stone lapis lazuli would have to be included, with its deep blue characteristics. One of the problems with high performance inorganic pigments is the limitation in available chemistry, so that very few really new compounds have been developed in recent decades.

Most inorganic pigment applications have thus been achieved by the well-known "workhorses" of conventional pigments, but the economic pressures of the last decade have dictated two main directions for product development: on the one hand an economization of existing pigment manufacture, in line with world price competition, and on the other hand, discovery and development of "new" and "improved" inorganic pigments with higher performing characteristics. Even in the more "commodity" or conventional inorganics such as chrome yellow, titanium dioxide, iron oxide, and carbon black, incrementally improved performance is required, e.g., in dust free preparations for the construction industry.

A third development started earlier. Driven by national laws and regulations in the ecological and toxicological area, "sustainable development" and substitution pressures have resulted in the replacement of formerly well known, and highly recommended inorganic pigments, such as red lead, lead molybdate, and chrome orange, by more "environmentally friendly" or less toxic substances, which can surely be considered as "high performance" pigments.

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Finally, in the field of “functional pigments” such as corrosion inhibiting or optically variable types, the development of “high performance” types has been necessary.

## 1.2
## Survey of Inorganic Pigments

When we consider a short survey of today’s major inorganic pigments, we are faced with the realization that the three major pigment families: titanium dioxide, carbon black, and iron oxides, accounting for more than 90% of the worldwide tonnage, as shown in Table 1.1, are all outside of our subject matter. They are well known to everyone, and have already been discussed in depth in recent handbooks [1, 2].

Further inspection of Table 1.1, however, reveals a selection of “high performance” pigments classified according to their chemical composition. In particular, the families of complex (or mixed) metal oxides, and functional pigments show a wide variety in their chemical composition.

**Table 1.1** Inorganic pigments, classified by composition.

| Class | Pigment | High performance |
|---|---|---|
| Elements | | |
| | Carbon black | + |
| | Al-flakes | + |
| | Oxide coated Al, Zn/Cu flakes | + |
| | Zn-dust | |
| | Nanoscale silicon | # |
| Oxides/hydroxides | | |
| | Metal-oxide flakes | + |
| | $TiO_2$ | |
| | $Fe_2O_3$ | |
| | FeOOH | |
| | $Fe_3O_4$ | |
| | $Cr_3O_3$ | |
| | $Pb_3O_4$ | |
| Mixed metal oxides | | + |
| | $ZnFe_2O_4$ | + |
| | $CoAl_2O_4$ | |
| | $(Co,Ni,Zn)_2TiO_4$ | + |
| | $Ti(Ni,Nb)O_2$ | + |
| | $Ti(Cr,Nb)O_2$ | + |

**Table 1.1** Continued

| Class | Pigment | High performance |
|---|---|---|
| Sulfides | | |
| | ZnS | |
| | $ZnS/BaSO_4$ (lithopone) | |
| | CdS | + |
| | $Ce_2S_3$ | + |
| Oxide/nitride | | |
| | $(Ca,La)Ta(O,N)_3$ | # |
| Chromates | | |
| | $Pb(Cr,S)O_4$ | |
| | $Pb(Cr,Mo,S)O_4$ | |
| Vanadates | | |
| | $BiVO_3$ | + |
| Silicates | | |
| | $Na_3Al_6Si_6O_{24}S_3$ (ultramarine) | |
| | Mica, $SiO_2$ and glass-based effect pigments | + |
| Cyanides | | |
| | $KFe[Fe(CN)_6]$ | |

**Note:** # not yet in industrial scale

In every pigment class illustrated, one will find at least one grade with a high performance characteristic, which may be the determining factor, or driver, for the end user to purchase this pigment in their application. It is self-evident, therefore, that degree of performance for a pigment depends on the demands imposed upon it for its intended application.

## 1.3
## New Candidates on the Catwalk of Color

Bearing in mind the limitation in the color of inorganic pigments, one has to be surprised at the numbers of new compounds introduced with good pigment performance. More and more, specialized physical effects appear to dominate over variation in chemical composition. In Table 1.1, for example, we must point out that mica-based effect pigments, being still a "young" pigment class, have already become well established since their "breakthrough" introduction. Again, while bismuth vanadate yellow is in the early stages of its growth potential, cerium sulfides are in their industrial infancy, and are attempting to carve out a niche for themselves in applications where the well-established cadmium sulfide family is no longer the pigment of choice. On the more experimental side, "nanoscale silicon," with particle size below 5 nm, is now available as a laboratory curiosity in microgram quantities as the first in the series of "quantum effect pigments" predicted by theoretical physicists [3]. Nearer to introduction is another new family, the calcium, lanthanum, tantalum oxide-nitrides [4]. Reproducibility, however, must be proven first. Their published properties, viz., brilliance of color coupled with non-toxicity, appear ideal for inclusion in the high-performance category.

A study of the "old fashioned" and almost forgotten workhorse pigment ultramarine blue could also be significant in the light of its revival through recently introduced new manufacturing technology. And so it is possible that, in the future, development of new manufacturing processes for "old" pigments and enhancement of their properties might well revitalize these products to the point where they could also join the ranks of truly high performance pigments.

## 1.4 Challenges for the Future

This leads us to consider challenges for new high performance pigments, which can be designated as *Three Essential Es*:

| | | |
|---|---|---|
| *Effectiveness* | = | Technical performance |
| *Economy* | = | Benefits for the customer |
| *Ecology* | = | Environmental and toxicological safety |

Better effectiveness could include higher tinting strength, greater ease of dispersion, better fineness of grind, higher saturation, and so on.

Better economy could include widening the fields of application for known high performance pigments by giving the customer enhanced value-in-use. And better ecology is today's task for industry as a whole, and is self-evident.

All three "E" will be optimized further on. New inventions will be made, hand-in-hand with steady process and product development. And as we can learn from a study of today's lowercost pigments, such as lead chromate, where the encapsulated specialties of yesteryear are now the norm for coatings application, the high performance pigments of today will become the conventional standards of tomorrow, with those of tomorrow having to be invented now. And so the development of high performance inorganic pigments is, in reality, a never-ending story.

## References

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