# Patenting the Glass Compositions During the Last Century

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**Abstract:** Glass is a material that is widely used in various fields of techniques and engineering (optics, electric devices, ware, medicine, etc.) due to a unique combination of properties, many of them being possible to vary in wide ranges depending on chemical composition. For this reason chemical compositions of glasses of various usage are widely patented. In the paper, the history of patenting the glass compositions since 1907 as well as present-day trends of development of new glasses are analyzed by using the database SciGlass IP containing the data about 100,000+ patents and patent applications published worldwide. Today's challenges during the development of new glass compositions and possible solutions are characterized.

**Keywords:** Glass composition, SciGlass IP, inorganic glasses, patented glasses, material, chemistry.

## INTRODUCTION

Glass is known for many thousand years as a material with unique combination of properties: hard and firm (but easy to mould), durable to wet atmosphere and most of chemicals, and transparent. Due to these properties, glass is widely used as a building and ware material and optical medium. Besides, being easy to dye, glass is widely used in applied art.

In continuation to the above, glass is a unique material with physical properties that can be gradually varied in wide ranges by changing chemical composition. Addition of different components changes physical properties in different directions. As a result, in many cases it is possible to find a composition of glass with a set of physical properties exactly satisfying prescribed requirements. However, to find such composition is generally not an easy task, especially if a number of properties to be fitted is rather big. That is why in the beginning of the last century, glass composition became a separate object of patenting.

Usually, a patent for glass composition claims a set of glass components (mostly, oxides) and specifies their concentration ranges where a satisfactory combination of properties can be achieved. Quite often it also represents some examples of particular compositions where properties are more or less close to the prescribed values. The specific composition of glass having the best combination of properties (determined by assumed application of this glass) is generally not presented in a patent; it is considered as "know-how".

A specific feature of glass as a subject of invention is a possibility to use it for multiple purposes. Thus, low-alkali and alkali-free alumino-borosilicate glasses due to unique combination of properties are widely used for production of chemical ware, medical equipment, waveguides, display substrates, sealing materials, etc.: each of these applications requires considerably different combination of properties, but all of them can, in principle, be achieved by using the glasses of rather similar compositions. Actually, many compositions of novel glasses lie within the concentration ranges claimed in very old patents which authors could not even imagine such applications of their inventions. To protect new intellectual property, the authors of new inventions specified not only the range of compositions but also the new combination of properties to be achieved.

Thus, in many cases, the same areas of compositions are frequently patented for several times. In particular, the authors of an original invention can make another application for the same compositions for which they found new and useful combination of properties. Also, the concentration limits and even the list of components can be somewhat changed when patenting the same invention in different countries.

The above-mentioned features sometimes make it difficult to separate the "patent families" for glass compositions. In principle, a patent family should combine all patent documents (patents and applications) concerning the same invention patented in various countries. For glass composition, it should consist of patents of the same authors claiming the same set of components, their concentration ranges, and achieved property values (if any) and making it possible to use a glass for a certain purpose. However, in practice, inventions of the same authors concerning glasses suggested for similar purposes are often considered as members of the same family even if they claim somewhat different compositions.

In this paper, we try to analyze the past, present and future of patenting glass compositions throughout the world by performing some statistical treatment of the patent documents and patent families. For that, we used the database SciGlass IP [1] that contains the data taken from about 100,000 patent documents claiming glass compositions published in ~70 countries during the last century. Grouping the mentioned documents to patent families was made in the same manner as in the esp@cenet database [2] supported by the European Patent Office.

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As stated in the report of WIPO [3], now more or less complete information is available for patents published before 2004. In this review, we restrict the time period to be analyzed to this year.

When analyzing the patent statistics we did not distinguish "true" patents from the author's certificates granted in the USSR and some other countries where the intellectual property including the inventions was state ownership. We consider both patents and author's certificates as documents claiming the inventions; the problems of ownership are outside of our focus.

Also, we used the global glass property information system SciGlass [4], where the data about compositions and experimentally measured properties of more than 300,000 inorganic glasses and glass-forming melts, published worldwide starting from 1880$^{th}$ to 2007. We consider that SciGlass contains a significant part (probably, the majority) of all data about chemical compositions and measured physical properties of glasses and glass-forming melts available worldwide.

## GENERAL TRENDS OF PATENTING GLASS COMPOSITIONS WITHIN THE LAST CENTURY

### Worldwide Statistics of Patents and Scientific Publications

As we know the first patents for glass compositions were granted in the beginning of the last century. In (Fig. **1**), the number of original patent documents published in different years is presented. The term "original document" means the earliest document in a patent family. In the same figure, the number of scientific publications concerning glass compositions and properties taken from SciGlass [4] is also presented.

As we can see from the figure, the number of patents correlates with the number of scientific publications. Here, we can separate three clearly different periods:

1. Slow growth (up to ~1960 for patents and ~1950 for scientific publications), with understandable decrease during the Second World War;
2. Avalanche growth (~1960-1973);
3. Variable dynamics with slow trend of growth (after 1973).

First two of the above-mentioned periods generally correlate with the evolution of technique as a whole: in the period from 1950-1960$^{th}$, scientific and technical revolution started that greatly accelerated the appropriations for scientific investigations; as a result, the number of inventions and scientific publications also increased to a great extent, and the number of patents began to grow faster than the number of scientific publications.

After 1972, we see again a rather slow increase in the annual numbers of new inventions. At that, however, the number of scientific publications presenting new results of property measurements had no tendency to increase, and even demonstrated significant decreased since 1984.

The last result seems to be a consequence of redistribution of the investments in R&D in the glass science in favor of applied researches, many of them being performed by glass-making companies and are, therefore, classified. Thus, we can assume that the investigations of glass properties did not decrease, but the obtained results were not available worldwide.

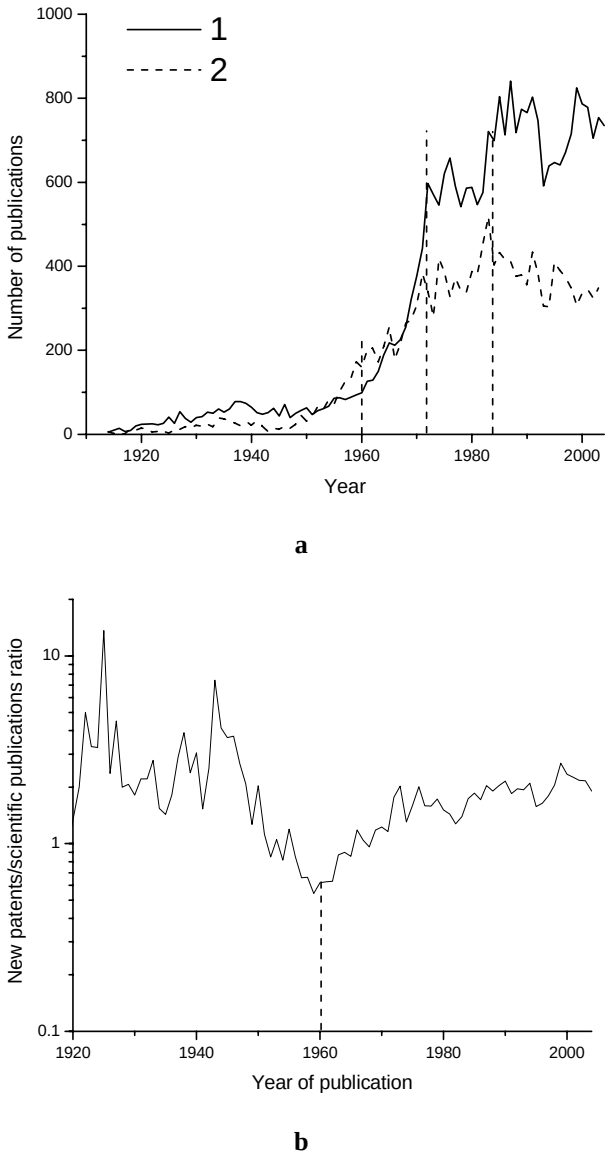



**Fig. (1).** Dynamics of publications concerning compositions and properties of inorganic glasses during the last century.
a: absolute numbers of original patents presented in [1] (1) and scientific papers presented in [4] (2); b: ratio (1):(2) in logarithmic scale.

It is worth to note that during the last time, the mentioned dynamics of applications of patents with claims on glass compositions were in a contrast with the general trend of patent applications, which number increased about twice within the decade from 1994 to 2004 [3].

### Patent Geography

In (Table **1**), some statistics about filing the patent documents (patents and applications) and disclosing the glass

**Table 1. Patent Documents Filed in Different Countries in Different Time Periods (According to [1])**

| Country | % of patent documents published in different countries | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1911-1964 | 1965-1974 | 1975-1984 | 1985-1991 | 1992-2004 | 2004 | Total |
| Japan | 0 | 14 | 29 | 33 | 29 | 24 | 25.1 |
| USA | 34 | 21 | 12 | 12 | 16 | 16 | 16.3 |
| Germany & DDR | 18 | 15 | 11 | 11 | 12 | 10 | 12.4 |
| France | 21 | 11 | 6 | 2 | 2 | 1 | 5.1 |
| USSR & Russia | 0 | 4 | 9 | 10 | 2 | 2 | 4.9 |
| United Kingdom | 18 | 10 | 6 | 2 | 1 | 1 | 4.6 |
| European Patent Office | 0 | 0 | 2 | 6 | 7 | 8 | 4.4 |
| International | 0 | 0 | 0 | 1 | 7 | 10 | 3.4 |
| China | 0 | 0 | 0 | 2 | 5 | 10 | 2.9 |
| Australia | 0 | 2 | 3 | 2 | 3 | 4 | 2.2 |
| Canada | 0 | 1 | 4 | 3 | 2 | 2 | 2.1 |
| Korea, South | 0 | 0 | 0 | 1 | 3 | 4 | 1.8 |
| Netherlands | 1 | 7 | 2 | 0 | 0 | 0 | 1.5 |
| Spain | 0 | 1 | 1 | 1 | 2 | 1 | 1.2 |
| Belgium | 1 | 5 | 2 | 0 | 0 | 0 | 1.2 |
| Others | 7 | 9 | 13 | 14 | 9 | 7 | 10.9 |

compositions taken from [1] is presented. (Fig. **2**) where we can see the annual development of the patents filed in the major countries, gives more detailed idea of the mentioned trends.

As we can see from the present data, in the beginning of the last century, nearly all patents describing glass compositions were filed in Western Europe, mostly in United Kingdom, Germany, France, Finland, and Belgium - the countries having old traditions in glass making. Then, the center of patenting glass compositions moved to the United States that remained the world leader up to 1970. During all this time, the Western countries as a whole, remained unconditional leaders in patenting glass compositions.

In early 1970$^{th}$, the situation changed cardinally. Japan became the world leader whose part was sharply increased to about 30% of all patent documents filed worldwide. Besides, the USSR became one of the leading countries with the maximum part of 10-15% in 1980$^{th}$. After disintegration of the USSR, its part was mainly occupied by the USA and Western Europe.

Among other countries, only China has now remarkable fraction of the filed patents. In 2004, this fraction was about 10%, with a trend of sharp increasing.

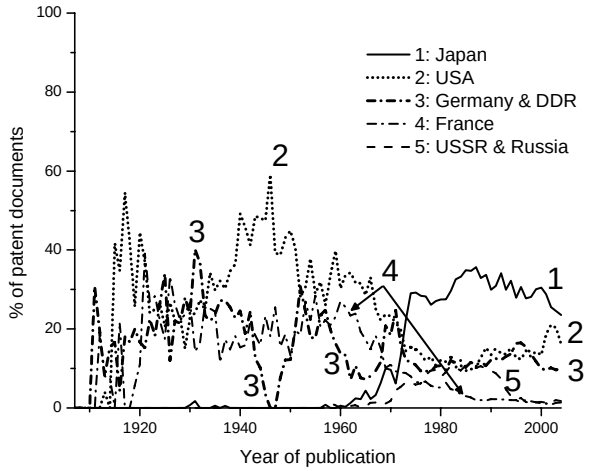
The mentioned trends mainly reflect the changing "affinity" of different markets in the world and only have indirect relation to change of the activity of different countries in patenting glass compositions. Thus, these trends are very similar to the general trends of the patent development.

To separate the contribution of different countries in inventing new glass compositions we made some statistics of the patent documents grouped by applicant country (Table **2**). It should be noted that not for all patents it is possible to exactly establish the country of applicants The documents for which the country of applicants is not clear are not included in this statistics.

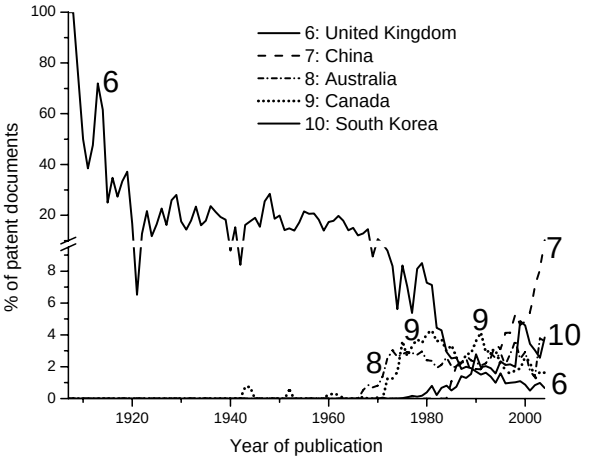
The present data give clear impression of general trend of changing the contributions of the world leaders in patenting glass compositions. First, we can see three groups of countries being world leaders in different periods of time: Western Europe up to 1970, the USSR in 1970-80, the and Asian countries (Japan, China and South Korea) since 1990; each of them applied more than a half of all patents for corresponding periods of time.

Absence of the USA in this list looks somewhat strange, especially when considering great role of the American companies (Corning group, PPG, Owens Illinois, etc.) in the development of innovative glass compositions during last century. At the same time, the contributions of the USSR in 1970-80$^{th}$ and Asian countries, especially China, within the last decade seem too large if compared to their economic level.

This phenomenon can be explained to a considerable extent if we keep in mind serious governmental support of inventors in the USSR and developing countries. In particular, in these countries the patents for inventions were free for the native authors and companies, and the governments




**a**




**b**

**Fig. (2).** Evolution of patent documents disclosing glass compositions filed in different countries.

even paid them for getting patents (as far as intellectual property for the inventions was the state ownership). In this situation, a considerable part of patents could be applied and issued for inventions having no practical application. If we consider only the patents filed abroad the contributions of these countries would be decreased many folds, whereas those for American companies considerably increased. In particular, if we consider the patents filed in European Patent Office during 1992-2004, only one American corporation, Corning, filed more than 10% of all of them (272 patent families from total 2674), whereas all Chinese and South Korean companies taken together filed just a few documents. Certainly, the last fact does not mean that all or majority of Chinese and Korean inventions were useless (many of them were used in the native countries of inventors), but only indicates that we should process any data concerning patent activity of the USSR and developing countries with some criticism and special care.

## Fields of Application of Patented Glasses

First patents for glass compositions did not relate to traditional application of glasses, such as building, ware or optics, but described newly discovered glasses for special applications, mostly insulators and enamels. In the future, glasses for the large-tonnage use were also patented, but these patents do not play more or less significant role, because the compositions of these glasses were kept nearly constant for many decades. Therefore, the special glasses remained the main object of patenting during the whole last century.

To get some ideas about the distribution of application areas of patented glass compositions, we used the International Patent Classification (IPC) [5]. We considered that this classification qualifies each patent not only by the essence of the invention (in our case - chemical composition of glass allowing to achieve appropriate values of specified physical properties), but also by its application. For example, a patent for a glass of optical objectives is usually assigned to the class G02B ("Optical elements, systems, or apparatus") where it is attributed to a certain group (e.g. G01B15, "Opti-cal objectives with means for varying the magnification"). Therefore, statistics for IPC classes and groups for the patents describing glass compositions can give us some ideas about the application of these patents.

The majority of the patents considering new glass compositions concerns the special glasses suggested as innovative materials to be used in rather new fields of industry, such as production of TV displays, semiconductors, data recording media, etc. Most of applications of patented glasses can be assigned to one of three large groups corresponding to three IPC classes: H01 (Basic electric elements), G02 (Optics) and C04 (Cements; concrete; artificial stone; ceramics; refractories). In Table **3**, the percentage of the original patents filed in different periods of time is presented. Fig. (**3**) presents the dynamics of its yearly change, with smoothing the curves to make general trends more visible.

If we consider this distribution in more detail, we can find top 11 groups of IPC that cover the largest number of glass compositions invented worldwide (Table **4**). Smoothed annual data for these groups are presented in Fig. (**4**).

The last figure demonstrates "wavy" changes of the interest of inventors to certain areas of application. The largest of these "waves" concerns insulators (with the peak of ~8% of all glasses patented in 1940) and light guides (with the peak of ~17% of all glasses patented in 1983).

Two features of this plot should be considered specially.

First, for each new area of application we can see some "incubation period" when the number of inventions remains rather small. Usually, this period is about 20-30 years. After that, we can see sharp growth taking 10-20 years, and then fading away during the next 10-20 years. In some cases, we reveal revival of the interest to a given application area that can even exceed the previous "wave", like semiconductor glasses in 1980s and laser glasses in 1990s.

Second, the nowadays situation is characterized by simultaneous decrease in all waves corresponding to major

**Table 2. Patent Documents Applied from Different Countries in Different Time Periods (According to [1])**

| Country | % of original patents for applicants from different countries | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1911-1964 | 1965-1974 | 1975-1984 | 1985-1991 | 1992-2004 | 2004 | Total |
| USSR & Russia | 1 | 14 | 46 | 37 | 3 | 1 | 20.5 |
| USA | 29 | 28 | 17 | 19 | 20 | 8 | 19.8 |
| Germany & DDR | 25 | 17 | 12 | 15 | 17 | 14 | 15.6 |
| Japan | 1 | 5 | 6 | 10 | 20 | 18 | 13.1 |
| China | - | - | < 0.5 | 3 | 13 | 29 | 7.2 |
| France | 8 | 8 | 4 | 4 | 6 | 6 | 5.4 |
| South Korea | - | - | < 0.5 | 2 | 5 | 8 | 3.0 |
| United Kingdom | 9 | 9 | 2 | 2 | 2 | 1 | 2.9 |
| Poland | - | 1 | 3 | 1 | 1 | < 0.5 | 1.2 |
| Netherlands | 8 | 3 | 1 | 1 | 1 | 1 | 1.1 |
| Bulgaria | - | - | 3 | 1 | < 0.5 | < 0.5 | 0.9 |
| Belgium | 3 | 3 | 1 | < 0.5 | 1 | 1 | 0.9 |
| Switzerland | 8 | 1 | 1 | < 0.5 | < 0.5 | - | 0.6 |
| Sweden | 2 | 5 | < 0.5 | < 0.5 | < 0.5 | - | 0.6 |
| Others | 8 | 8 | 3 | 5 | 9 | 11 | 7.2 |

**Table 3. Percentage of the Original Patents Filed in Different Periods of Time (According to the Data Taken from [1])**

| Class | % of original patents for different classes | | | | | |
|---|---|---|---|---|---|---|
| | 1911-64 | 1965-74 | 1975-84 | 1985-94 | 1994-2004 | Total |
| H01 - Basic electric elements | 63 | 24 | 20 | 23 | 29 | 26 |
| G02 - Optics | 3 | 18 | 29 | 19 | 19 | 21 |
| C04 - Cements; concrete; artificial stone; ceramics; refractories | 18 | 29 | 17 | 18 | 15 | 17 |
| Others | 15 | 28 | 34 | 39 | 37 | 37 |

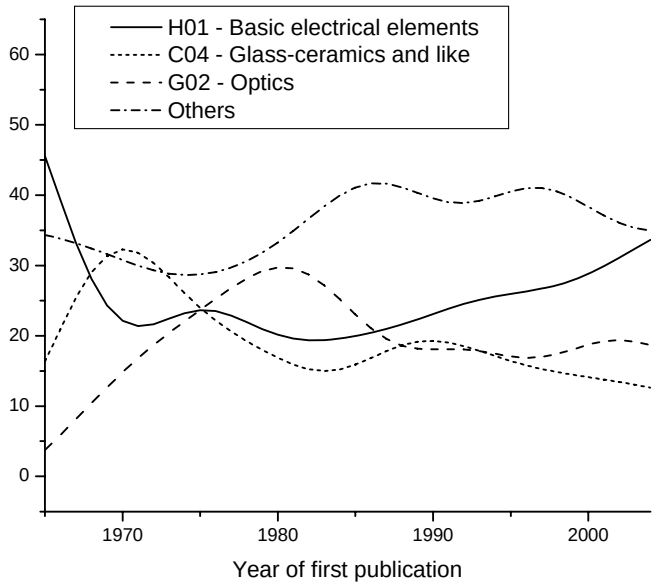



**Fig. (3).** Smoothed plot of yearly change of percentage of patents for glass compositions having different applications.

**Table 4. Percentage of Original Patents for Glass Compositions which were Qualified to Top 11 Groups of IPC**

| Group | Short description | 1911-1964 | 1965-1975 | 1975-1984 | 1985-1994 | 1995-2004 | Total |
|---|---|---|---|---|---|---|---|
| G02B6 | Light guides | 0 | 3 | 13 | 16 | 12 | 11.6 |
| H01S3 | Lasers | 0 | 2 | 0 | 6 | 7 | 3.8 |
| H01L23 | Semiconductors | 0 | 1 | 3 | 5 | 4 | 3.4 |
| G02B5 | Optics other than lens | 1 | 3 | 7 | 1 | 2 | 3.3 |
| G11B5 | Data recording | 0 | 0 | 1 | 3 | 6 | 3.1 |
| G02F1 | Optical measurements | 0 | 2 | 1 | 6 | 4 | 3.0 |
| H01B3 | Insulators | 5 | 2 | 2 | 3 | 3 | 2.6 |
| H01B1 | Electric conductors | 1 | 2 | 2 | 3 | 2 | 2.2 |
| H05K1 | Printed circuits | 0 | 0 | 1 | 4 | 2 | 2.0 |
| A61K6 | Dentistry | 0 | 1 | 1 | 3 | 2 | 2.0 |
| C23D5 | Enamels | 3 | 2 | 2 | 3 | 1 | 1.9 |

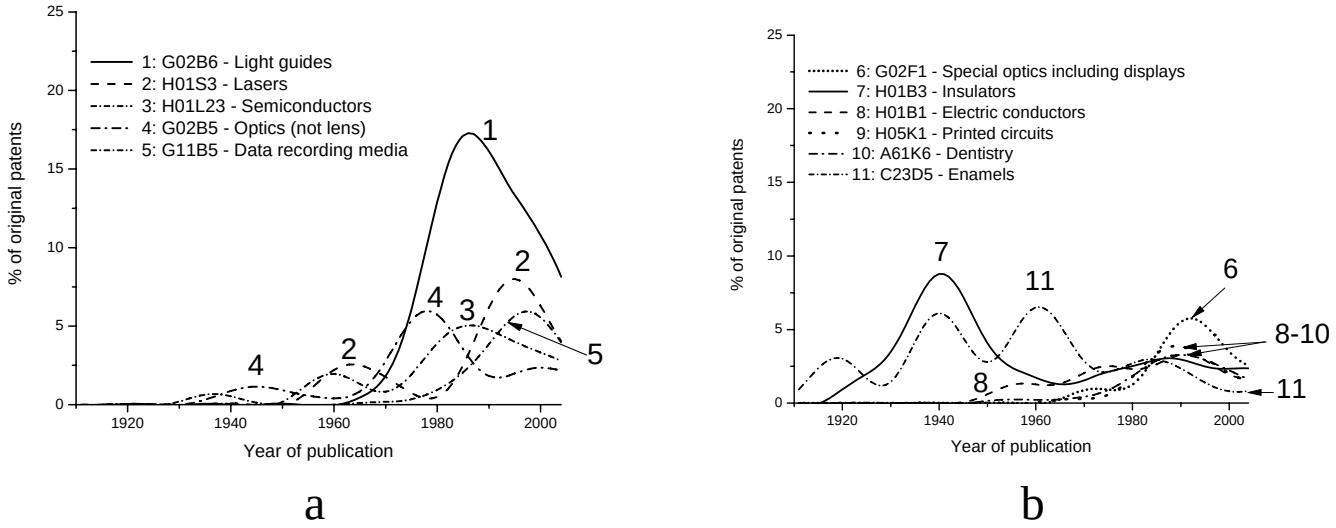



**Fig. (4).** Smoothed annual percentage of patents for glass compositions qualified to top 11 groups of IPC [5] (according to the data taken from [1]).

areas of application: light guides, lasers, special optics (including displays), data recording media, and semiconductors. Only once we could reveal somewhat similar in the past, in 1960s when the interest to all major applications of that time was decreased (see Fig. **4**). This period preceded several "waves" developing simultaneously during the following two decades.

We have some reasons to assume that now we are witnesses of similar situation. Indeed, decreasing the percentage of patents related to the most important (for nowadays) application areas means that the attention of most of the researchers has been switched to search for new applications. Thus, we can expect rapid development of principally new applications of glasses in the next 20 years.

## Chemistry of Patented Glasses

What would be the chemical compositions of glasses which are to be invented in the next few decades? In order to make a prognosis, we analyzed here the develop-ment of patented glass compositions in the past.

From ancient time to the middle of the last century, silicate glasses were almost the only inorganic glasses having practical application. Then the inorganic glasses of other chemical nature were intensively investigated. Some of these glasses had unusual combinations of physical properties making it in principal possible to use them for various purposes.

Most of the known inorganic glasses can be assigned to one of three major groups considering their chemical nature:

- Silicate glasses: glasses containing considerable amount of silica (mostly, not less than 40 mol.%) and rest of various oxides;
- Non-silicate oxide glasses: glasses containing considerable amount of glass-forming oxides other than silica

(mostly, oxides of boron, phosphorus and germanium) and rest of the other oxides;

- Non-oxide glasses: glasses which compositions do not contain oxides; the most important of non-oxide glasses are based on glass-forming halides and chalco-genides.

In Fig. **5**, dynamics of patenting the glasses of these three types of glasses is presented.

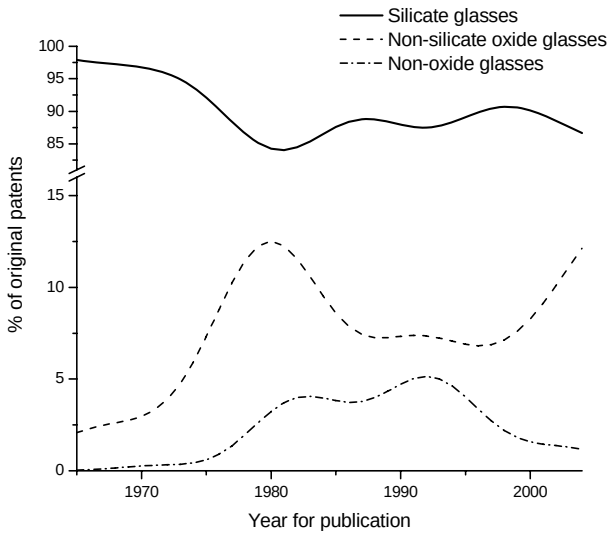



**Fig. (5).** Smoothed dynamics of percentage of original patents disclosing compositions of inorganic glasses of three major types of chemical nature.

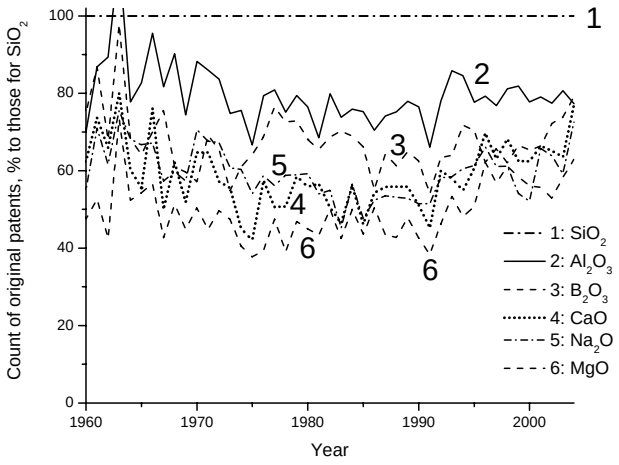
As we can see from the plot, now as well as several thousand years ago, the silicate glasses remain the most important type of inorganic glasses having practical application. After 1975, their fraction varies with time within rather small range about ~85-90% of the total number of patented glasses.

Interest to non-silicate oxide glasses had a "splash" near 1980, where they were suggested in ~12% of all patents for glass compositions. After some decrease in 1980-90, now the interest to this type of glasses has increased again, and in the near future we can expect further growth of their application. It seems quite possible that they would exceed 15-20% of all patented glass compositions.

Non-oxide glasses, the most specific group of inorganic glasses, were rather actively patented in 1980$^{th}$, and early 1990$^{th}$, but now their fraction in patented compositions is less than 2% and reduces with time. Prospects of their application in the future are not clear, but within the next 10-20 years we unlikely could expect very large interest to this type of glasses that would be more or less comparable with the interest to oxide glasses.

As a whole, we can expect that in future the silicate glasses will remain the most important type of inorganic glasses having practical application.

In Fig. (**6**), the relative frequencies of use of most important components of patented glasses is presented. Considering the above-mentioned statistics, the percentage depicted in the figure mostly relates to silicate glasses.

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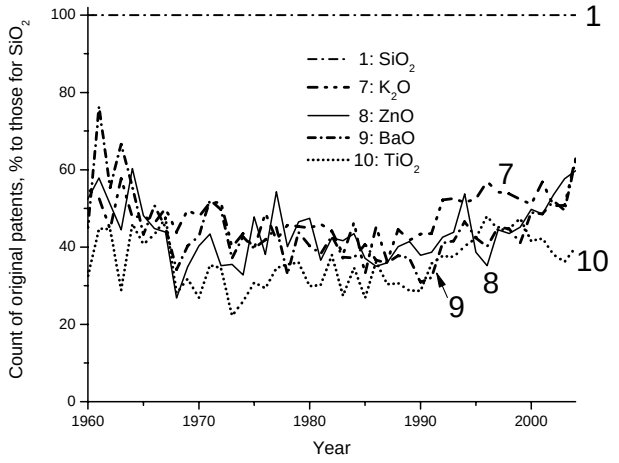


**b**

**Fig. (6).** Count of original patents claiming different components, in % to those for $SiO_2$ (considered as 100%).

As we can see, the frequency of use of the most important oxides very slowly changes with time. This means that the majority of new patents claim the same or almost the same set of components that was widely used many decades ago. In other words, new combinations of glass properties satisfying new requirements are usually found within a very limited circle of basic composition areas.

Analysis of the data related to non-silicate oxide glasses (Table **5**) leads to a similar conclusion: relative frequencies of using particular components remained about the same within several decades when these glasses were patented, and we could hardly expect somewhat fundamentally different frequencies within few next decades.

**Table 5. Frequency of Claiming Major Oxides in Non-Silicate Oxide Glasses, in % to Total Number of Original Patents Published in Different Periods of Time**

| Oxide | 1975-84 | 1985-91 | 1992-2004 |
|---|---|---|---|
| $P_2O_5$ | 12.8 | 13.3 | 9.3 |
| ZnO | 9.4 | 5.6 | 8.9 |
| CaO | 6.5 | 8.5 | 8.0 |
| $Al_2O_3$ | 10.5 | 10.0 | 7.8 |
| $B_2O_3$ | 11.5 | 7.6 | 7.7 |
| $Na_2O$ | 6.7 | 6.8 | 7.6 |
| BaO | 8.1 | 5.8 | 6.2 |
| MgO | 5.4 | 4.8 | 5.3 |
| $K_2O$ | 6.4 | 3.9 | 5.0 |
| $Li_2O$ | 3.2 | 3.8 | 4.6 |
| PbO | 6.8 | 6.6 | 4.5 |
| $TiO_2$ | 2.5 | 2.8 | 4.3 |

## CONTEMPORARY PROGRESS IN PATENTING GLASS COMPOSITIONS

Among the latest trends of patenting glass compositions, several main directions can be found:

- Glasses for various electrical and magnetic devices (substrate glasses [7], magnetic heads [8], electronic tubes [9] and others);
- Laser and other optical devices [10, 11];
- Fuel cells [12],
- Batteries and other energy-saving devices [13].

Besides the above-mentioned directions, other inventions can be found among the latest patents. Thus, Aitkin [14, 15] and Lewis [16] have recently patented compositions of fire-existing glass. Marquies has patented crystallization-resistant glass [17]. Smith has patented colored glass [18].

All these applications relate to "high technologies", and most of them solve the specific problems of XXI century, such as energy saving and ecology. We consider that in the near future this trend will be continued.

## NOWADAYS CHALLENGES AND PROBABLE SOLUTIONS

Let us summarize the above-mentioned statistics and try to make some prognosis for the near future of patenting the compositions of inorganic glasses.

It seems that now we are near to a very important cross-road that might determine the main streams of application of new glasses for several next decades. We do not know what would be these applications, but most probably they would not be connected with the main application fields for which most of currently invented glasses are suggested (light guides, lasers, display substrates, data recording media, etc.) Most probably, it would be something else, with considerably new requirements to glass properties comparing with nowadays needs.

We can now predict with very large probability that most of new property requirements could be satisfied by using the oxide glasses of well-known types, silicate glasses are among the first of them.

In this connection, we would like to stress again that many of latest patents actually claim the glass compositions that were already invented sometimes ago, with the only novelty considering the new combinations of properties found for already known areas of chemical compositions.

This conclusion seems to be very important. Actually, it means that inventing new glass compositions can be facilitated greatly if one could predict corresponding properties of glasses which compositions are well-known but their properties have not been measured yet.

In this connection, however, we should note that now dozens of models predicting the physical properties of glasses and glass-forming melts from their chemical compositions and temperature are available from the literature. However, the predictions made by using these models can sometimes considerably differ from each other, and it is not a simple task to select a model that could give satisfactory prediction of a given property for a given composition. Such conclusion can be made only after comparison of model predictions with reliable experimental data that a glass researcher not always has.

Further, to avoid the conflicts with the existing patents, a researcher should be able to analyze the available patent documents claiming compositions of glasses. Now their total number can be estimated as ~100,000, and it continues to increase.

It should also be underlined that in many contemporary patents, to avoid conflicts with older patents, glass compositions are often presented in non-traditional ways: in atomic, cation or anion percent, in terms of complex silicates and other minerals, etc. Also, the requirements to glass compositions are often specified in multiple claims having rather complex relationships to each other. To compare the concentration ranges expressed in different units is generally not a simple task but requiring not only considerable efforts but also special knowledge in chemistry.

One should also consider a possibility to contest a patent by referring to non-patent scientific publications where the compositions and properties of similar glasses were described. Considering the fact that the major composition area of patented glasses was not greatly changed during the last century, the number of publications to be kept to attention is tremendous. It should be noted that in the scientific publications, the composition and property data are also expressed in different units and, that is even more important, often presented in graphical form, so that it is not easy to compare them with each other.

In this situation, even a highly-qualified patent lawyer can sometimes be unable to make a correct judgment about patent novelty and non-infringement of a newly developed glass composition, which can result in contesting the already

obtained patents and other actions of law against a company that would produce this glass.

Thus, now the process of development of new glass compositions to be patented requires not only serious experimental work of glass researcher and qualified expertise of a patent lawyer, but also the abilities to search for available data from numerous sources, and select proper models permitting satisfactory predictions of glass properties from chemical compositions.

We consider that the only available way of solving this problem is a wide use of global databases presenting the data about glass compositions and properties.

Historically, the first such databases was Interglad (International Glass Database) [6] developed in the later 1980$^{th}$ by the Japanese company "New Glass Forum". Few years later, in 1996, the second database of this kind appeared - it was the SciGlass Information System that was initially developed by the American company SciVision and now is supported by the Institute of Theoretical Chemistry (ITC) [4].

Now the Interglad database [6] contains property data for about ~260,000 substances including not only glasses but also some materials containing both glassy and crystalline phases, as well as commercial glasses for which only their trademarks and properties are known.

SciGlass database [4] currently contains the published data for more than 300,000 glasses and glass-forming melts; for each of them the chemical compositions, measured physical properties, and some additional information about synthesis and property measurements specified in the original papers (if any) is presented. Besides, the SciGlass database contains more than 100 built-in property prediction models and some tools allowing to determine which of them are the most reliable within a concentration range under the interest.

Each of these databases contains a rather sophisticated search interface allowing to find experimental data about glass compositions and properties satisfying user requirements.

The database SciGlass IP [1] allows search for the components and properties specified in the patent claims that they can help to get the information which is not presented in the above-mentioned databases.

We suppose that in the near future, the mentioned databases and their future analogs (if they appear) will become a necessary tool for any inventors of new glass compositions.

## CURRENT AND FUTURE DEVELOPMENTS

Using the patent database of glass compositions SciGlass IP, we analyzed the history of patenting new chemical compositions of inorganic glasses for the last century. The trends of patent development considered from different viewpoints (historical, geographical, chemical, etc.) were presented. We reviewed the general dynamics of this kind of patents, traced the changes of global leaders in patenting glass compositions, mainstreams of applications of these glasses, and presented other information concerning this kind of patents.

On the basis of this analysis, some prognoses for the near future of patenting glass compositions were made.

Thus, we came to an assumption that within next few decades we can expect invention of new areas of application of inorganic glasses. We have no idea about these new areas, but only assume that they would considerably differ from the main focuses of current applications of glass.

Probably, glasses to be used for these purposes should have new combinations of physical properties. However, we do not expect drastic changes in the areas of compositions. We assume that at least during next few decades, silicate glasses will remain the main focus of development of new glass compositions. As a secondary area of interest, we could consider non-silicate oxide glasses (mainly, borate and phosphate ones). All these kinds of glasses are well known. Wide use of other types of inorganic glasses could probably be possible only after considerable time and rerearch.

In this situation, search for relevant information contained in both patent and non-patent sources becomes one of the most important problems in the development of new glass compositions. We expect that the use of global glass property databases can considerably help in solving this problem.

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