

Technological Prospecion of Patents on Biodegradable Polymers for 3D Printing with Protection in Brazil

Suzi Daianne Gama Machado¹; Valdir Silva da Conceição²; Jaqueline Santos Vieira³; Cleiton Correia Viana⁴; Dayana Ferraz Silva⁵; David Vieira dos Santos⁶; Giovanna Martins Sampaio⁷; Antonio Martins de Oliveira Júnior⁸; Marcelo Santana Silva⁹; Angela Machado Rocha¹⁰

^{1,4}Master in Intellectual Property and Technology Transfer for Innovation; Federal University of Bahia

^{2, 3, 6, 7}PhD student in Intellectual Property Science; Federal University of Sergipe

⁵Bachelor in Biotechnology; Federal University of Bahia

⁸PhD in Chemical Engineering; Federal University of Sergipe

⁹PhD in Energy and Environment; Federal University of Bahia

¹⁰PhD in Energy and Environment Federal Institute of Education, Science and Technology of Bahia

*Corresponding Author: Suzi Daianne Gama Machado; Valdir Silva da Conceição

DOI: <https://doi.org/10.5281/zenodo.20823631>

Article History	Abstract
Original Research Article	<p><i>The present study aims to analyze the panorama of patents related to biodegradable polymers for filaments applied to 3D printing, focusing on the B33Y classification. The research was carried out in the Espacenet database, using the terms "Print" AND "Biodegradable", "Polymer" AND "Filament", associated with the technological domain of additive manufacturing. 23 patent families with protection were identified in Brazil between 2006 and 2026. The results show significant growth in filings from 2021 onwards, indicating a recent expansion of technological interest in sustainable materials for three-dimensional printing. There was a predominance of deposits in the United States of America (USA), Germany, France and Denmark, with companies focused on regenerative medicine, biomaterials and sustainable additive manufacturing standing out. The main IPC classifications focus on groups B33Y, A61L and A61F, related to 3D printing, biomaterials, implants and tissue engineering. The legal analysis showed a predominance of active and granted patents, indicating high strategic interest and market potential. It is concluded that 3D printing based on biodegradable polymers constitutes a strategic, interdisciplinary and expanding technological area, driven by the global demands of sustainability, personalized medicine and innovation in biomaterials.</i></p> <p>Keywords: 3D printing. Innovation. Intellectual Property. Solid waste. Sustainability.</p>
Received: 20-04-2026	
Accepted: 28-05-2026	
Published: 24-06-2026	
<p>Copyright © 2026 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.</p>	
<p>Citation: Suzi Daianne Gama Machado, Valdir Silva da Conceição, Jaqueline Santos Vieira, Cleiton Correia Viana, Dayana Ferraz Silva, David dos Santos Vieira, Giovanna Martins Sampaio, Antonio Martins de Oliveira Júnior, Marcelo Santana Silva & Angela Machado Rocha. (2026). Technological Prospecion of Patents on Biodegradable Polymers for 3D Printing with Protection in Brazil. UKR Journal of Multidisciplinary Studies (UKRJMS), 2(6), 276-290.</p>	

1 Introduction

In recent years, technology has developed rapidly and significantly, creating new needs and becoming an integral part of everyday life. An example of this is the cell phone, which has began to replace several electronic devices, such as radio, MP3 player, Discman, Walkman, GPS, calculator, television, clock, alarm clock, credit and debit cards, banking services, personal documents, landline telephone, flashlight, telephone book, camera, compass, portable video game, and voice recorder [1-6].

Today, the 3D printer has become a common piece of equipment in companies and in research and development

(R&D) laboratories, especially for the generation of prototypes. However, these prototypes are often discarded afterward, causing environmental impacts due to the use of non-degradable materials. With technological advances, this equipment has become accessible even to small laboratories [7-15].

The first concept related to the 3D printer appeared in 1974, and the first patent was granted in 1984 to inventor Charles W. Hill. The current applications of this technology are diverse, with emphasis on the healthcare field, particularly in the creation of artificial parts of the human body, as well

as the aerospace industry, for the manufacture of lightweight components. These different applications require the use of various filaments materials, which can be metallic, ceramic, polymeric, composite, or specifically designed for food use [16-27].

The fundamental parts of the 3D printer are: print bed, extruder, controller board, and filament. Polymers are the most commonly used materials in this process due to their low cost and durability. The main ones include: ABS, polycarbonate (PC), nylon, poly (ester ether ketone) (PEEK) and poly (ether imide) (ULTEM) [28-32].

Additive manufacturing, especially 3D printing, has been transforming industrial processes and demanding innovative materials that reconcile performance and sustainability. Biodegradable polymers for printing filaments represent a technological advance capable of reducing environmental impacts and opening new markets. However, the Brazilian panorama of this innovation is still little known, making it difficult to formulate incentive policies and intellectual protection strategies [33-34].

The objective of this work is to analyze the portfolio of patent families that include at least one document filed in Brazil between 2006 and 2026, related to biodegradable polymers for 3D printing filaments, identifying technological trends, main agents, as well as their temporal and spatial distribution.

2 Methodology

The research adopts a qualitative, exploratory and descriptive approach, using technological prospecting based on patent documents as an instrument for analyzing the technological evolution related to biodegradable polymers applied to 3D printing.

Data collection was carried out in the Espacenet patent database on May 6, 2026, using the terms "*Biodegradable*", "*Polymer*", "*Filament*", and "*Print*", associated with the International Patent Classification (IPC) "*B33Y*", referring to additive manufacturing and three-dimensional printing. Documents published between 2006 and 2026, with patent protection in Brazil, were considered.

After retrieving the documents, the data were organized and processed, considering variables such as main applicants, inventors, IPC classification, temporality, legal status, languages, and places of deposit. Patent titles and abstracts were also analyzed to identify technological trends, industrial applications, and innovative directions in the sector.

The treatment and analysis of the data were carried out using Excel software, with the elaboration of tables and graphs. The data were subjected to descriptive and interpretative analysis, allowing the identification of

patterns of technological development, geographic concentration of innovation, and areas of greater technological intensity. The research is based on the assumptions of technological prospecting and patent analysis as strategic tools for monitoring innovation, supporting scientific research, and understanding the dynamics of intellectual property.

In total, 23 patents were identified that met the search criteria and the temporal and geographic filters.

3 Result and Discussion

Technologies related to biodegradable polymers for 3D printing mainly focus on biomedical applications, tissue engineering, absorbable implants, pharmaceutical devices, and development of sustainable materials for additive manufacturing.

There is a strong predominance of inventions aimed at the healthcare field, especially those related to three-dimensional implants, biodegradable scaffolds, and biomaterials for tissue regeneration. A group of patents demonstrate advances in porous and bioresorbable structures produced by 3D printing, capable of promoting cell integration, vascularization, and tissue regeneration. These technologies highlight the growing convergence between additive manufacturing and regenerative medicine.

Another relevant group refers to biomaterials and bioscaffolds used in tissue engineering. Some documents present composites formed by collagen, biodegradable polymers, and biocompatible hydrogels intended for soft tissue reconstruction, orthopedic applications, and breast reconstruction. These results indicate that 3D bioprinting has been widely explored for the production of customized and biologically functional structures.

Technologies related to the formulation of new sustainable materials also stand out. There are patents aimed at developing resins derived from biobased monomers, while others describe biodegradable composites containing plasticizers and biodegradable fillers. These deposits reflect the search for environmentally sustainable alternatives to conventional polymers used in 3D printing.

In general, there is evidence that the main technological trend identified is associated with the development of biodegradable and sustainable biomaterials for 3D printing, with strong application in healthcare, regenerative medicine, tissue engineering, and personalized devices. In addition, there is a growing concern with sustainability, recyclability, and circular economy, indicating that additive manufacturing based on biodegradable polymers represents a strategic and emerging area in the global scenario of technological innovation.

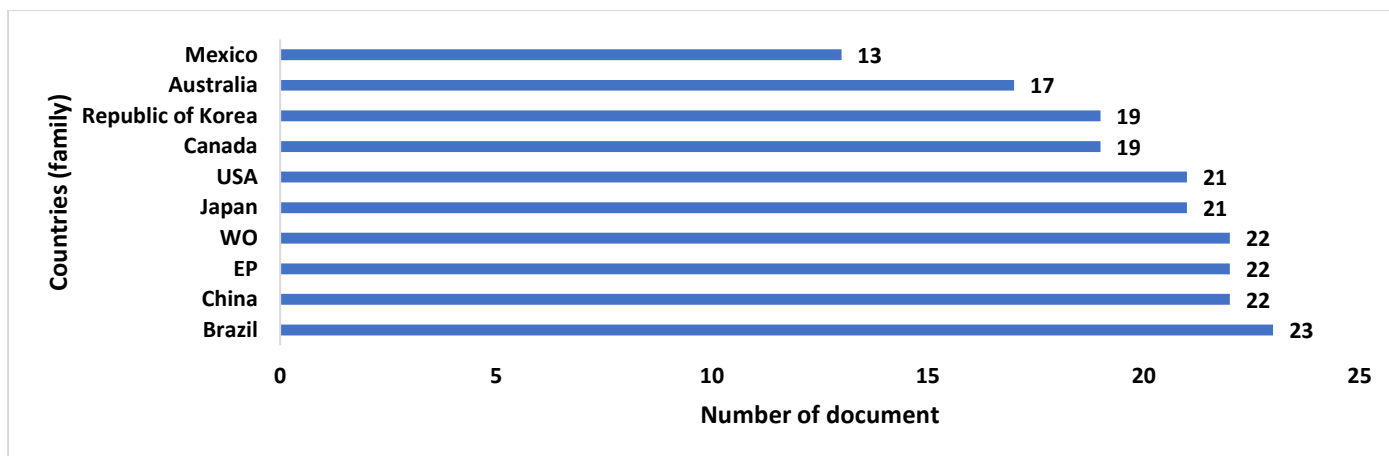
3.1 Geographical Distribution of Patent Families

A patent family corresponds to the set of applications related to the same invention filed in different countries or patent

offices. The jurisdiction of the patent families related to the

subject studied in each region or country is shown in Figure 1.

Figure 1: Jurisdictional distribution of patent families



Source: Authorship (2026).

Figure 1 shows the high level of internationalization in the protection of this technology, with filing in 32 countries or regional patent offices, which demonstrates the global interest in economies of different sizes and stages of development. These results highlight applicants' interest in protecting the technology in multiple markets, especially in regions with strong industrial and technological development.

Brazil appears with 23 documents, representing the main section of the search, since the filter applied included patent families with a presence in the country. However, this does not mean that all patents are necessarily national. This number also reflects the interest in protecting innovation in the country, considered a relevant market. The high activity in Brazil generates opportunities to establish partnerships with foreign groups focused on the development of new patents or utility models for commercial application.

About 22 patents were filed via the Patent Cooperation Treaty (PCT), which suggests the intention of the applicants to protect their innovation in the markets they consider more strategic, and not only in the local market. This practice indicates a global patenting strategy, ensuring priority and expanding competitive reach.

The filing made in the European market (22 documents) evidences the intention of patent applicants to protect their inventions in the second largest economic market, highly coveted and technologically competitive. This strategy also aims for financial gain through licensing.

China (22 documents) also presents itself as a strategic and relevant market for patent applicants.

Other prominent markets were the USA (21 documents), Japan (21), the Republic of Korea (19), and Canada (19), which reveals strong competition and possible dominance by large multinational players. This concentration can

generate negative consequences, such as technological dependence. These countries are protagonists both in technological development and in industrial production.

In Latin America, protection efforts are also observed, as in the cases of Mexico (13 documents), Chile (2), Colombia (2), Argentina (1), and Cuba (1). This strategy reinforces the relevance of the Americas market for the protection of innovation.

Intermediate participation of countries such as Spain (6 documents), Russia (4), Poland (3), and Singapore (3) is observed, while nations with a smaller number of documents such as Cuba (1), Germany (1), Greece (1), Hungary (1), New Zealand (1), and Ukraine (1), demonstrate a punctual presence in the technological scenario analyzed.

Thus, there is a great geographical diversity, with applications from European, Asian, African, and Eastern countries, which indicates the strategic interest of a broad patent. Protection in small countries signals the creation of specific market niches.

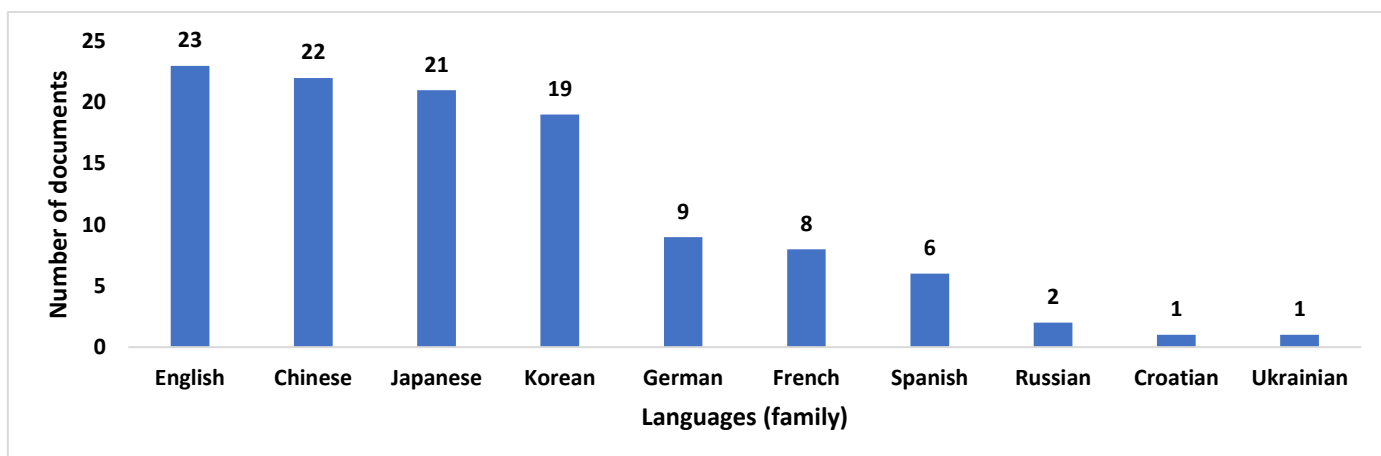
In general, the geographical distribution reveals that technologies related to biodegradable polymeric filaments for 3D printing have a global and strategic character, being the object of protection in diversified markets. In addition, the wide presence of international filings suggests growing industrial and scientific interest in sustainable solutions in additive manufacturing, in line with contemporary demands for reducing environmental impacts and developing ecologically responsible materials.

3.2 Language of the Documents

The language of the documents is a key element for the analysis of the 23 published technology patent families (not the language of the original application, but the languages available among the family members). This scenario

reveals the geographic origin, market strategy, and competitive opportunities. The distribution of languages in the document set can be seen in Figure 2.

Figure 2: Language Two Documents



Source: Authorship (2026).

Figure 2 shows that the English (23 documents) is the dominant language in publications related to the terms "Biodegradable", "Polymer", "Filament", "Print", and the B33Y classification, that is, all 23 families have at least one document published in English, mainly in international filings via PCT and EP systems, as well as English-speaking countries such as the USA (21) and Australia (17). English serves as the global language of intellectual property, science, and commercialization. Its use favors the global visibility of inventions and facilitates licensing strategies. It also reflects the global reach of inventions, especially in highly technologically competitive sectors such as additive manufacturing and sustainable materials.

The Chinese language (22 documents) appears in second place, that is, 22 of these families have a document published in Chinese (filings in China), reflecting the leadership in materials R&D and 3D printing. It also indicates significant advance in the development of these technologies. This result is consistent with the growth of Chinese innovative capacity in recent decades, driven by investments in industrial research and development and technological innovation policies.

In third place is Japanese (21 documents), in line with the country's tradition in polymers and advanced materials, industrial automation, and precision technologies, factors that contribute to the high number of publications in this language. Asian leadership, in this context, stems from the development of biopolymers and their applications in 3D printing.

A strong Asian presence is observed, China (22/23), Japan (21/23) and the Republic of Korea (19/23) are priority target markets, suggesting that inventors/applicants see these countries as important for biodegradable filament technology for 3D printing.

Europe has a moderate presence, represented by German (9 documents), French (8), and Spanish (6), typical for families that have entered the national phase, specifically via the European Patent Office. The presence of these languages is associated with the performance of European companies, universities, and research centers focused on innovation in polymeric materials and circular economy.

Eastern Europe show a low presence, with Russian presenting only two deposit families, in addition to isolated cases of Croatian (1) and Ukrainian (1), which prove to be isolated cases, perhaps national deposits of a single family.

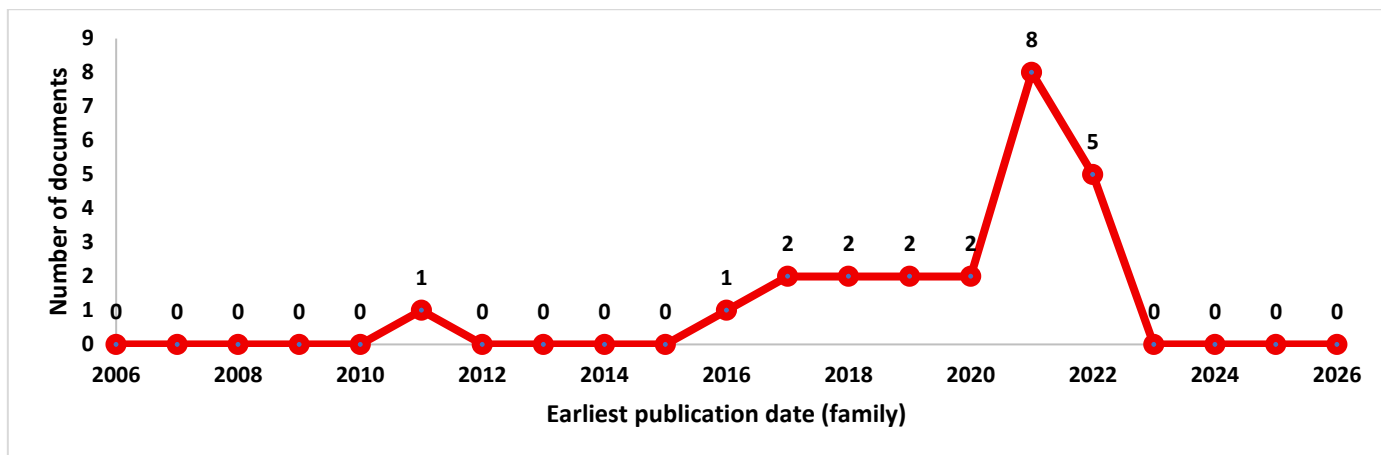
The Portuguese language does not appear in the 23 patent families, which reflects the lower internationalization of filings in the local language. Thus, most patents filed in Brazil are of foreign origin and follow the PCT standard in English. Brazil requires filing in Portuguese, but the system may be grouping it as "English" if the original document was deposited in English with a later translation.

Therefore, the linguistic distribution evidences the strong technological concentration in developed and Asian countries, especially those with robust industrial innovation ecosystems. In addition, the predominance of English reinforces its function as a universal language of

patent protection and the international dissemination of technological knowledge.

3.2 Temporal Distribution of Patents (2006-2026)

Figure 3: Temporal distribution of patents between 2006 and 2026



Source: Authorship (2026).

Figure 3 shows the temporal distribution of patent families related to biodegradable polymers for 3D printing between 2006 and 2026, considering the date of the first publication of the patent documents.

It is observed that there were no records between 2006 and 2010, indicating that, in this period, there were either no filings specifically related to the technology analyzed or that the technological field was in the initial stage of development.

The first publication took place in 2011, with only one document, representing the initial emergence of research and applications involving biodegradable polymers applied to 3D printing.

Then, between 2012 and 2015, there were no publications, suggesting a period of low technological activity or an initial stage of maturation of research related to the theme.

From 2016 onwards, there is a gradual resumption of technological interest, with slow and continuous growth until 2020, with an annual average of 1.6 patent families per year. In this interval, between one and two documents were recorded per year, evidencing the progressive consolidation of research related to sustainable additive manufacturing and biodegradable biomaterials.

Between 2021 and 2022 there is a significant acceleration, with an average of 6.5/year. The most significant growth occurs in 2021, when eight patent families were identified, representing the peak of the time series analyzed. This increase may be associated

The temporal evolution represents the life cycle of the technology. The temporal distribution can be seen in Figure 3.

with the expansion of demands for sustainable solutions, the strengthening of the circular economy, and the advancement of additive manufacturing technologies in various industrial sectors, such as biomaterials, packaging, healthcare, and product engineering.

In 2022, five documents were identified, maintaining a high level of technological activity, although lower than that observed in 2021. This result suggests continuity of research and industrial interest in the development of biodegradable polymer filaments for 3D printing.

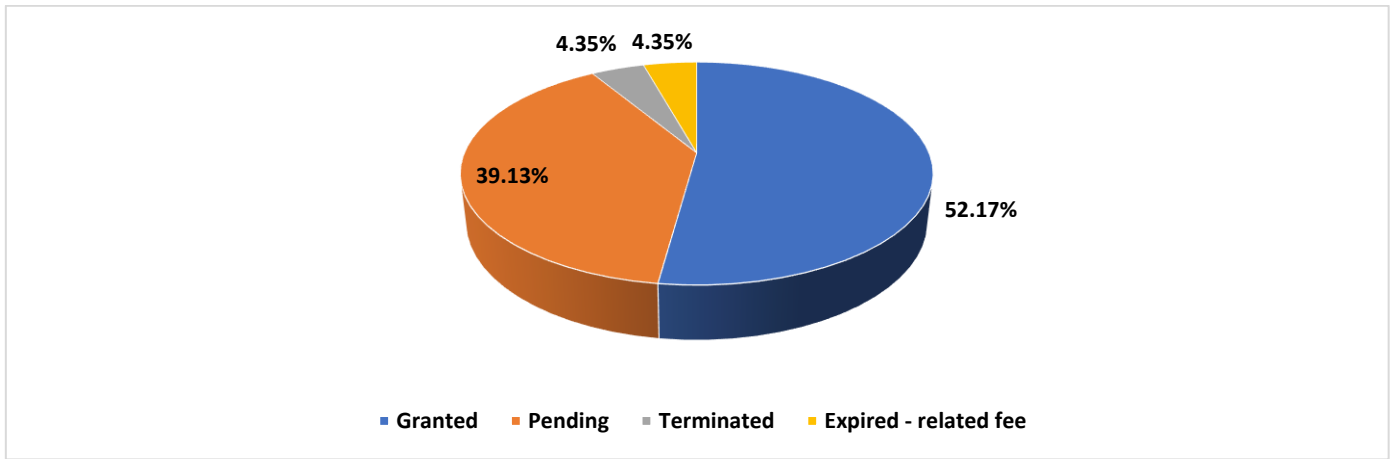
Between 2023 and 2026, there were no publications. However, this does not mean the absence of recent filings, as many patent applications remain confidential for approximately 18 months before official publication. Thus, more recent documents may not yet be available in patent databases. In addition, the result can be related to the criteria and filters used in the search strategy,

Therefore, biodegradable filament technology for 3D printing (B33Y classification) started timidly in 2011, resumed in 2016, the peak of the first publications between 2021 and 2022, indicating that patent filings in this area grew significantly in this biennium. No families with a first publication in 2023 or later appear in this specific search, which may reflect what was deposited up to the time of the consultation, or a bias of the BR filter. Post-2020 growth reflects global trends in sustainability, innovation in advanced materials, and the expansion of additive manufacturing.

3.4 Legal Situation

The legal analysis of patents related to biodegradable polymers for 3D printing demonstrates that the technological area is at an advanced stage of consolidation and still presents strong innovation dynamics, as can be seen in Figure 4.

Figure 4 – Legal status of patents



Source: Authorship (2026)

Figure 4 shows the predominance of documents granted (12 documents), accompanied by a significant number of pending applications (9 documents), indicating continuity of technological development and strategic interest in the sector.

The granted patents represent the largest portion of the sample, demonstrating that a significant part of the technologies have already gone through the technical examination process and obtained formal recognition of the requirements of novelty, inventive step and industrial application. This scenario indicates technological maturity in areas such as biodegradable biomaterials, 3D printed implants, tissue engineering, and personalized medical devices. In addition, the high number of concessions shows strong business interest in the protection of intellectual property and in the consolidation of competitive advantages in markets of high technological complexity.

Pending applications reveal that the sector remains expanding and constantly evolving technologically. The significant presence of applications still under review demonstrates continued investments in research and development (R&D), especially in emerging applications related to bioprinting, regenerative medicine, sustainable filaments, and advanced additive manufacturing. This behavior is typical of recent and

highly innovative technological areas in which the pace of scientific and industrial development is accelerated.

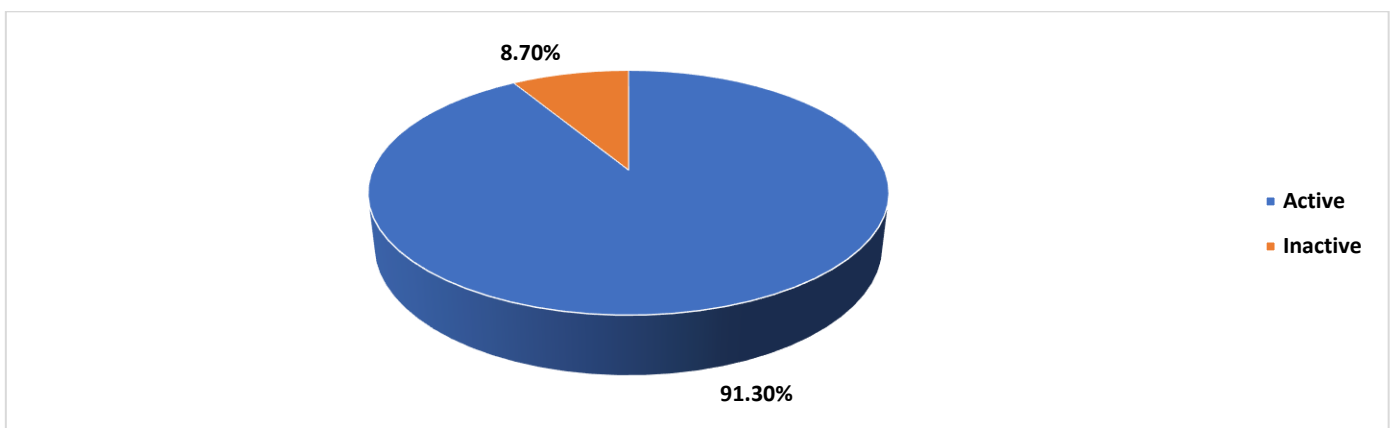
The existence of one expired patent and one expired patent due to non-payment of fees indicates a low rate of technological abandonment. This suggests that patent applicants consider these technologies to be strategically relevant and economically promising, while maintaining the necessary investments to preserve intellectual property rights. In highly competitive technological sectors, such as biomaterials and 3D printing, the maintenance of patents is usually associated with commercial potential and the expectation of economic return.

Therefore, the distribution of the legal situation shows that the field of biodegradable polymers applied to 3D printing presents high technological dynamism, strong patent protection activity, and a continuous growth trend. The results reinforce that the area is in a process of international consolidation, driven mainly by the demands for sustainability, personalized medicine, advanced biomaterials, and innovation in additive manufacturing.

3.5 Patents Validity

The analysis of the patents validity demonstrates those that remain or are not economically promising, as can be seen in Figure 5.

Figure 5 – Patents validity



Source: Authorship (2026)

The analysis of patents validity related to biodegradable polymers for 3D printing demonstrates a high level of maintenance and strategic interest in the developed technologies. Figure 5 shows a strong predominance of active patents, indicating that the sector remains technologically dynamic and economically promising.

Active patents represent 21 documents, corresponding to most of the samples analyzed. This result demonstrates that applicants continue to invest in the maintenance of intellectual property rights, which is usually associated with the high potential for industrial application, commercial value, and technological relevance of these innovations. The active permanence of patents suggests that biodegradable materials for additive manufacturing have a strong potential for use in strategic sectors, especially in biomaterials, medical devices, tissue engineering, bioprinting, and regenerative medicine.

The high number of active documents also shows that the technological field is still expanding and consolidating internationally. In emerging areas such as sustainable 3D printing and biodegradable biomaterials, patent protection is an important mechanism for competitiveness, attracting investments, and strengthening industrial and scientific partnerships.

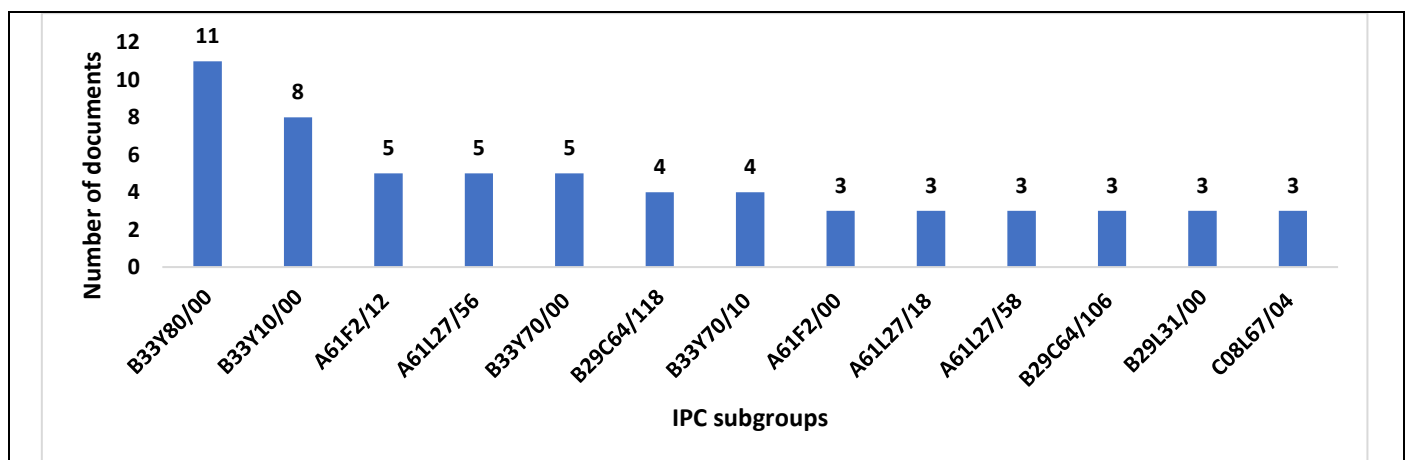
On the other hand, only two patents are in a non-active status, indicating a low rate of abandonment or technological discontinuity. This behavior may be related to strategic abandonment, lack of commercial viability, or lack of interest in maintaining fee payments. However, the small number of inactive documents reinforces that most of the technologies analyzed still have economic relevance and potential for technological exploitation.

In general, the predominance of active patents confirms that the area of biodegradable polymers applied to 3D printing has high technological and market attractiveness. The results show a sector in continuous development, supported by investments in innovation, sustainability, and advanced biomedical applications, consolidating itself as one of the main trends in contemporary additive manufacturing.

3.6 IPC Subgroup

The International Patent Classification (IPC) is a standardized and hierarchical system for classifying the technical content of patents. It is divided into sections, classes, subclasses, groups, and subgroups, with each code representing a specific technology. The analysis of the subgroups allows the identification of the dominant technological fields of patents. The most relevant in terms of the number of documents can be seen in Figure 6.

Figure 6: IPC Subgroup



Caption:

B33Y80/00: Products made by additive manufacturing;

B33Y10/00: Additive manufacturing processes;

A61F2/12: Implantable filters in blood vessels; Prostheses, i.e. artificial substitutes or replacements of body parts; Mechanisms to connect them to the body; Devices that promote clearance or prevent collapse of tubular structures in the body, e.g. stents; / Implantable prostheses inside the body; / Breast prosthesis;

A61L27/56: Materials for prostheses or for coating dentures; / Materials characterized by their function or by their physical properties; / Cellular or porous materials;

B33Y70/00: Materials specially adapted for additive manufacturing;

B29C64/118: Filament Extrusion 3D Printing

B33Y70/10: Materials for additive manufacturing – biodegradable polymers

A61F2/00: Prostheses in general

A61L27/18: Materials for prostheses or for coating prostheses; / Macromolecular materials; / obtained differently than by reactions involving only unsaturated carbon-carbon bonds

A61L27/58: Materials for prostheses or for coating prostheses; / Materials characterized by their function or by their physical properties; / Materials at least partially resorbable by the body;

B29C64/106: Extrusion 3D printing of liquid or pasty material

B29L31/00: Additive manufacturing products

C08L67/04: Compositions of polyesters

Source: Authorship (2026).

The results show a concentration of patents in the IPC subgroups related to biodegradable polymers, with a predominance of filings made by foreign companies. Technology related to the theme has a multidisciplinary character, mainly involving additive manufacturing, biomaterials, medical engineering, polymer processing, and advanced materials.

Figure 6 shows the predominance of the B33Y80/00 code (11 documents), where almost half of the patents claim specific products made by 3D printing, indicating that the applicants are concerned with protecting the final product, not just the process or material. The result demonstrates that the analyzed inventions are strongly concentrated in additive manufacturing technologies aimed at the development of new materials and processes.

Next, the subgroup B33Y10/00 (8) stands out, which concerns the methods and process of 3D printing. The high frequency of this classification confirms that the technological core of the deposits is directly related to 3D printing techniques and layer-by-layer deposition.

Code A61F2/12 (5) shows a strong focus on reconstructive applications. Code A61L27/56 (5) says porosity in scaffolds and implants. In turn, the code B33Y70/00 is aimed at specific materials for 3D printing.

The interpretation organized by categories is as follows:

Additive manufacturing (3D printing) – codes B33Y and B29C64

Most patents focus on 3D printing products and processes, with a strong presence of fused deposition modeling (FDM) and biodegradable materials and that are related to the codes B33Y80/00 (printed products – 11 patents), B33Y10/00 (printing processes – 8), B33Y70/00 (printing materials – 5), B33Y70/10 (biodegradable materials – 4), B29C64/118 (FDM filament – 4), B29C64/106 (liquid/paste extrusion - 3, plus other B29C64 (multiple processes - 1 each).

Medical implants and devices – codes A61F and A61L

Medical application are predominant, especially breast implants (5 patents), porous scaffolds (5 patents), and bioabsorbable materials (3 patents), as demonstrated by codes A61F2/12 (breast prostheses – 5 patents), A61L27/56

(porous material – 5), A61L27/18 (polymeric implant – 3), A61L27/58 (bioabsorbable/biodegradable materials – 3), A61F2/00 (general prostheses – 3), A61L27/24 (collagen – 2), A61L27/26 (polymer mixtures – 2), A61L27/44 (polymer-ceramic composites – 2), and A61L27/52 (hydrogels – 2).

Biodegradable polymers and compositions – codes C08L, C08G, and A61L27

The classified materials are PBS and other biodegradable polyesters, which have the codes C08L67/04 (biodegradable polyesters such as PLA, PHA. and PBS – 3 patents), C08L67/02 (polybutylene succinate – PBS - 2), A61L27/18 (polymeric implant - 3), A61L27/58 (bioabsorbable materials - 3), and C08G63/08 (cyclic polyesters - 1).

Ceramics and composites for 3D printing (bone/tooth) – codes C04B, A61L27/44, B28B, and B22F

In this group there is a line of patents focused on bone/dental substitutes using ceramics and composites (SEPTODONT, GRIFOLS), as shown by codes C04B28/04 (cement, such as calcium phosphate - 1 patent), C04B35/447 (ceramic, such as apatite/phosphate - 1), C04B35/632 (organic additives for ceramics - 1), A61L27/44 (polymer-ceramic composites - 2), and B22F10/10 (metal bed fusion power - 1).

Pharmaceutical and drug delivery – codes A61J, A61K, and A61P

This group is focused on pharmaceutical forms printed according to codes A61J3/02 (pill making machines – 1 patent), A61J3/06 (capsule making machines 1), A61K9/00 (medicinal preparations – 1), and A61K47/34 (drug delivery polymer – 1).

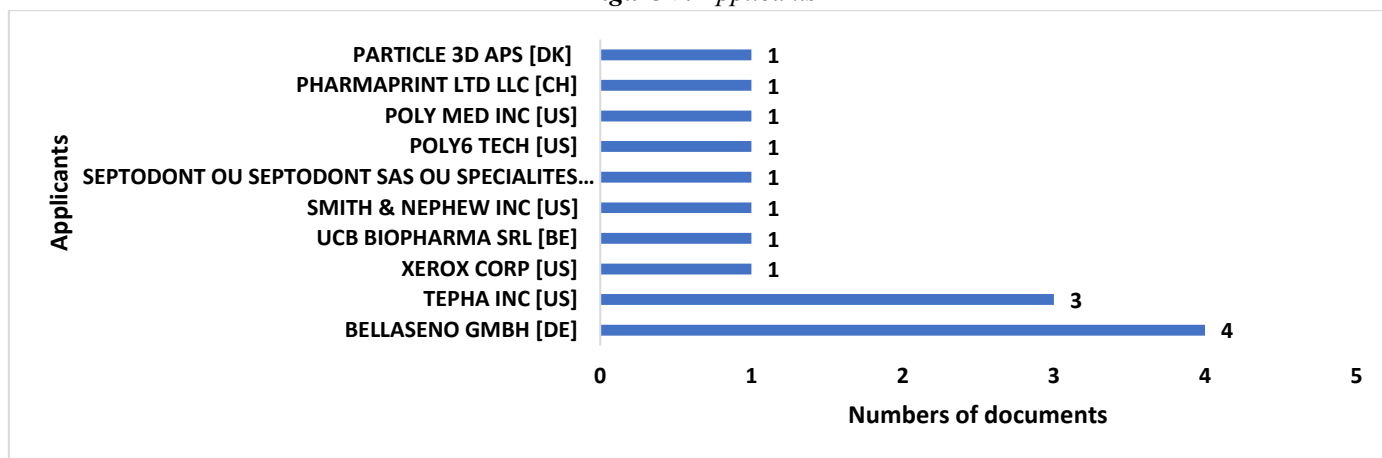
In general, the distribution of the IPC subgroups reveals a strong predominance of technologies aimed at sustainable additive and biomedical manufacturing, indicating that patent filings focus on the development of innovative biodegradable materials, advanced 3D printing processes, and personalized medical applications, reflecting contemporary trends in sustainability, regenerative medicine, and industrial innovation.

3.7 Applicants

Applicants are generally the owners of the 23 patent families who hold the rights to the patents and may be individuals and/or legal entities; in some cases, they may also coincide with the inventors. Among the legal entities, large players, universities, startups, and companies from different sectors

stand out. Individuals, on the other hand, may be independent inventors. The number indicates how many patents families each applicant has among the 23 results. The main patent applicants can be seen in Figure 7.

Figure 7: Applicants



Source: Authorship (2026).

There are 17 applicants with one rank and only two with more than one rank.

The analysis of the applicants of patent families related to biodegradable polymers for 3D printing shows strong participation of international companies specializing in biomaterials, medical devices, additive manufacturing, and advanced polymers. The results demonstrate that technological development in this area is mainly concentrated in organizations focused on the biomedical, pharmaceutical, and sustainable materials sectors.

The absolute leader in number of patents in the sample is the German company Bellaseno GMBH (4 patents), which correspond to the inventors Chhaya Mohit Prashant (4 patents), Khani Navid (4), and Sara Lucarotti (3), focused on the development of bioresorbable implants produced by 3D printing, especially for applications in breast reconstruction and tissue engineering, focused on medical applications and corresponding to 17.39% of all families. This result highlights the growing relevance of additive manufacturing applied to regenerative medicine.

Next comes the U.S company Thepa Inc (3 patents), focused on bioabsorbable polymers, known as polyhydroxyalkanoate technology (PHA). The inventor associated with the most patents is Simon F. Williams, focused on breast implants.

The other applicants with only one patent include large corporations such as Xerox (US), Evonik (DE) and Smith & Nephew (US); medical biotechnology such as Ossiform (DK) and Poly Med (US); chemicals and plastics such as Carbios (FR) and Chemson (AT); pharmaceutical

companies such as Grifols (IE) and UCB Biopharma (BE); startups/specialists such as 3D Biological Laboratory (US), Pharmaprint (CH), Poly6 Tech (US), among others.

Therefore, the market is fragmented, but with clear leaders such as Bellaseno and Tephha, which together hold 7 of the 23 patents, corresponding to 30.43% of the total, demonstrating that the field is generally composed of many small players with only one patent each.

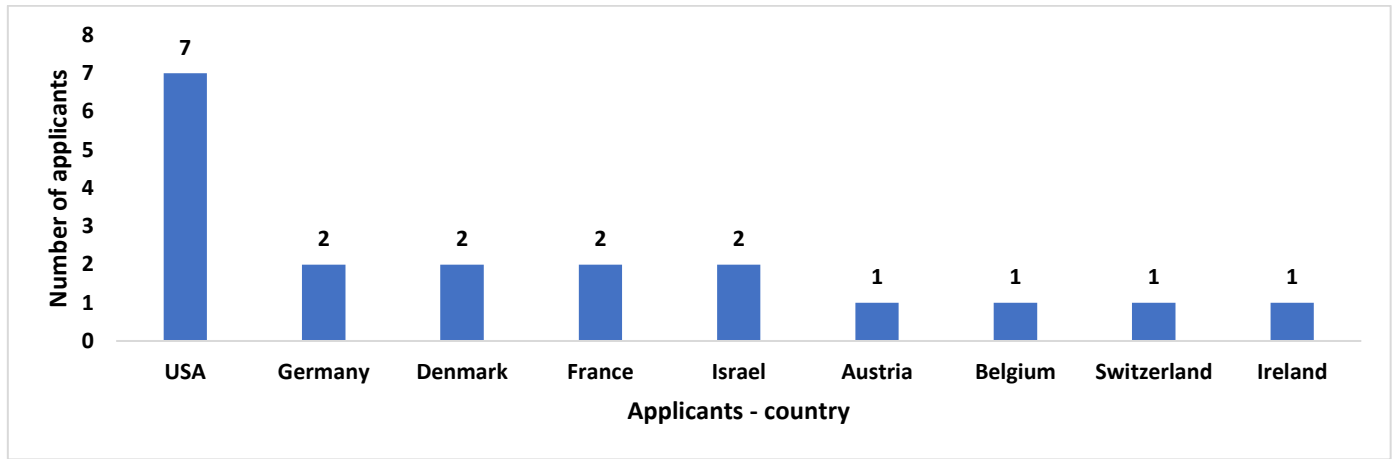
Intellectual property is dominated by German (Bellaseno) and U.S (Tephha) companies. Although China and Japan have many filings, no Chinese or Japanese companies appear in the survey, meaning that the patents protected in these countries originate from foreign companies.

Therefore, the distribution of applicants reveals a predominance of companies focused on the biomedical, pharmaceutical, and advanced materials sectors, indicating that the main technological direction of the analyzed patents is related to regenerative medicine, biodegradable implants, bioprinting, and sustainability in additive manufacturing. In addition, the diversity of countries and organizations highlights the global and strategic character of this emerging technological segment.

3.8 Geographical Distribution of Patent Applicants

The geographical distribution of applicants – individuals or legal entities that hold intellectual property rights – grouped by host country. The number represents how many different applicants are based in each country as can be seen in Figure 8.

Figure 8: Geographical distribution of patent applicants



Source: Authorship (2026).

The analysis of the distribution of applicants by country shows a strong concentration of innovative activities related to biodegradable polymers for 3D printing in technologically advanced economies, especially in the USA and European countries. The results demonstrate that the development of these technologies is strongly associated with consolidated ecosystems of research, biomedical industry, advanced manufacturing, and innovation in sustainable materials.

Figure 8 shows the hegemony of the USA, with seven applicants, confirming that the country is a global center of technological innovation in this area. This result reflects the high investment in R&D, the robustness of the country's ecosystem, and the strong presence of leading companies in polymers, biomaterials, medical devices, additive manufacturing, and 3D printing. Companies such as Thepa Inc., Smith & Nephew Inc., and Poly-Med Inc. demonstrate the country's leading role in the development of biodegradable implants, residual engineering, and personalized medical applications.

It is followed by Germany, Denmark, France, and Israel, with two applicants each, indicating relevant participation in specific technological niches.

In Germany, Bellaseno GMBH (4 patents) and Evonik Industries (2) stand out. German performance reflects the country's strong tradition in materials engineering, biotechnology, and advanced industrial manufacturing, especially in biomedical applications and functional polymers. The concentration of patents in Germany is greater than the number of applicants.

The other countries – Austria, Belgium, Switzerland, and Ireland – appear with one applicant each, demonstrating

more punctual but strategic participation in the development of technologies associated with sustainable additive and biomedical manufacturing. These holdings reflect the technological expertise of certain companies and innovation centers in specific applications, such as functional polymers, pharmaceutical formulations, and advanced biomaterials.

Europe has seven other applicants, excluding Germany. The countries are Denmark (2 depositors – Ossiform APS and Particle 3D APS), France (2 – Carbios and Septodont), Austria (Cheson), Belgium (UCB Biopharma), Switzerland (Pharmaprint), and Ireland (Grifols).

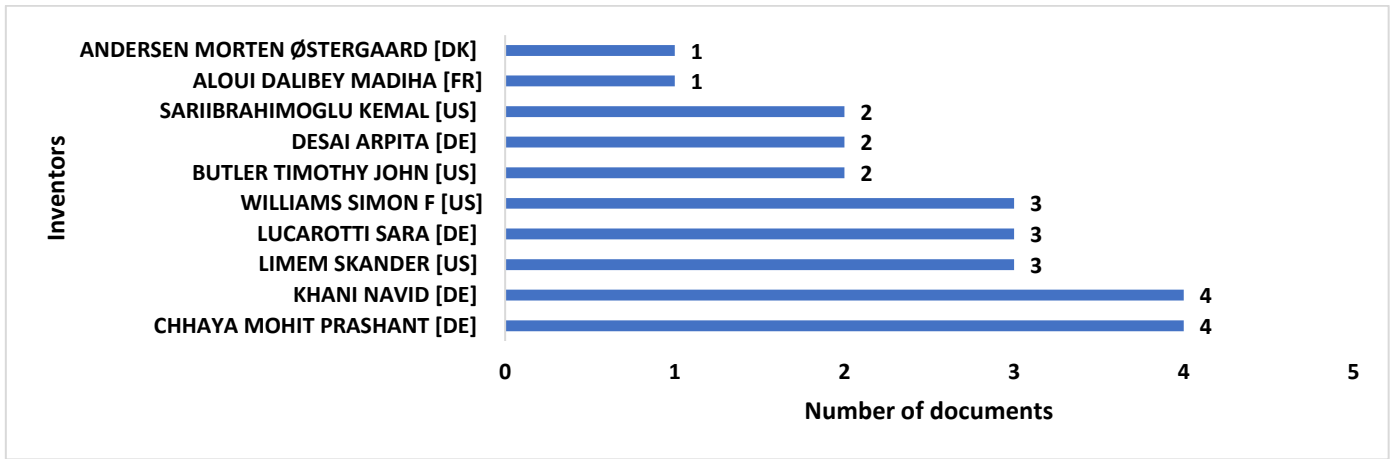
The U.S. dominates intellectual property related to biodegradable filament technology for 3D printing (B33Y), accounting for about 30.43% of what is being developed and patented by the country's companies.

Therefore, intellectual property in biodegradable filaments for 3D printing, with protection in Brazil, is concentrated in the USA, with secondary contributions from Germany, Denmark, and France. Brazilian and Asian companies are absent as applicants and appear only as target markets.

3.9 Inventors

The frequency with which each inventor appears in the 23 patent families related to biodegradable polymers for 3D printing shows a strong concentration of researchers linked to the areas of biomaterials, tissue engineering, additive manufacturing, and advanced medical devices. The results can be seen in Figure 9.

Figure 9: More productive inventors



Source: Authorship (2026).

Figure 9 shows that the variation among inventors indicates the existence of collaborative work in the development of technology, in addition to demonstrating that technological production in this domain is highly interdisciplinary and internationalized.

Only eight inventors appear with more than one patent, ranging from two to four occurrences. The other 63 inventors appear only once each, indicating that most teams are distinct from one another, with low repetition. There are few research groups with multiple patents in the area. The field is still fragmented, with many different actors.

German inventors Chhaya Mohit Prashant (4 patents), Khani Navid (4), Lucarotti Sara (3), and Desai Arpita (2), who work together at Bellaseno GMBH - a startup focused on tissue engineering - reinforce the country's position as an important hub for innovation in biomaterials.

Inventors Limem Skander (3 patents), Williams Simon F (3), Timothy John Butler (2), and Kemal Sariibracioglu (2) work together at Tepha Inc. in the development of biomaterials for medical applications. The company makes

major investments in R&D to remain at the forefront of its segment.

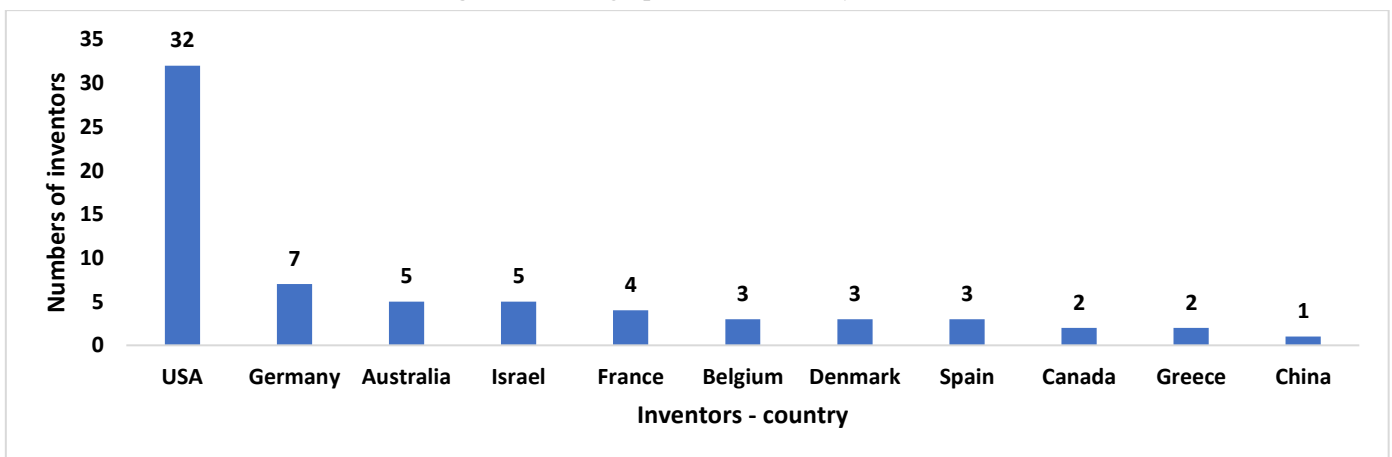
In total, there are 30 inventors residing in the USA, indicating the greatest diversity of American teams in the development of 3D printing technologies, in addition to revealing high inventive activity in this technology.

In general, the distribution of inventors shows a strong predominance of specialists linked to the biomedical and materials engineering areas, reinforcing that the main applications of the technologies analyzed are concentrated in bioresorbable implants, regenerative medicine, bioprinting, and customized devices produced by additive manufacturing. In addition, the results reveal a high degree of internationalization and scientific cooperation, typical characteristics of emerging and highly knowledge-intensive technological sectors.

3.10 Geographical Distribution of Inventors

The geographical distribution of inventors (researchers) responsible for the development of these technologies. The number represents the number of inventors residing in each country, as can be seen in Figure 10.

Figure 10: Geographic distribution of inventors



Source: Authorship (2026).

The U.S. has the highest number of incumbents and inventors of any country, consolidating itself as the dominant center of innovation. There is also a large concentration in European countries.

Figure 10 shows the dominance of the USA with 32 inventors responsible for nine documents, confirming its leadership in this technological field. This high number reflects the strong performance of U.S. companies specializing in biomaterials, medical devices, tissue engineering, and 3D printing, such as Tepha Inc., Smith & Nephel Inc., and Poly-Med Inc. The country's predominance also highlights high investment in applied research, industrial development, and biomedical innovation.

Next comes Germany with seven inventors responsible for four patents, standing out mainly for the work of Bellaseno GMBH and Evonik Industries. The country has a strong tradition in materials engineering, industrial chemistry, and medical technologies, factors that favor the development of biodegradable implants and 3D-printed structures for regenerative applications.

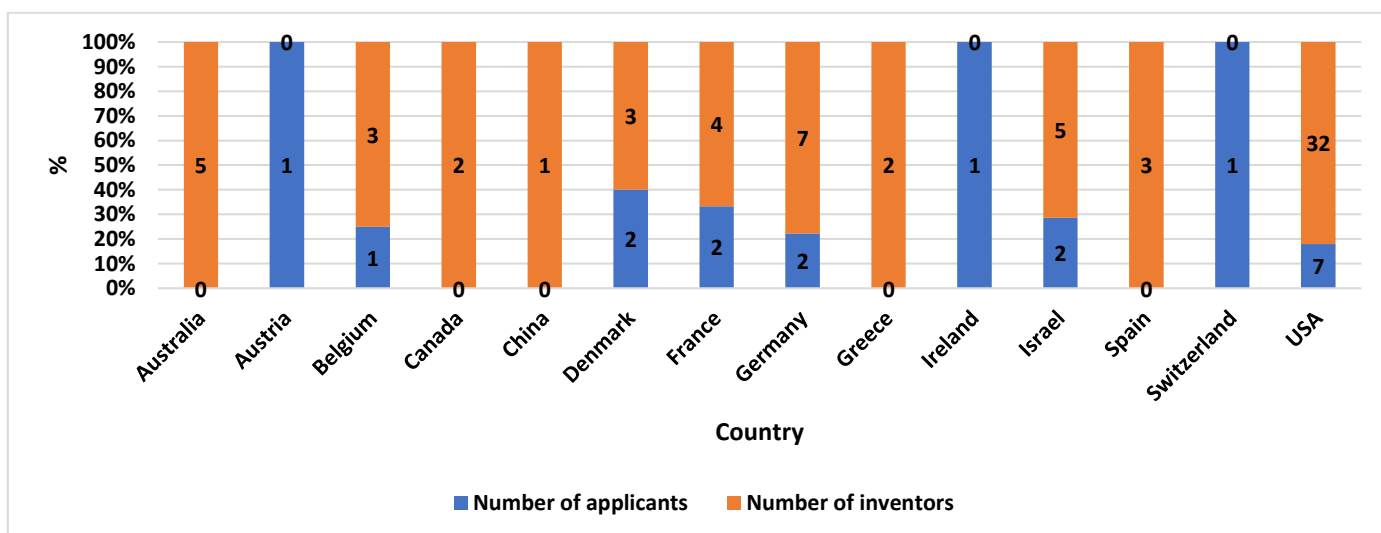
Australia features five inventors, demonstrating significant participation in specific technological niches. These inventors are associated with the Austrian company Chemson Polymer Additive AG, mainly in the development of polymers for additive manufacturing and advanced thermoplastic materials.

Therefore, the geographical distribution of inventors reveals a predominance of countries with high scientific capacity and consolidated technological infrastructure, especially in the biomedical and materials engineering areas. The results reinforce that technologies related to 3D printing with biodegradable polymers constitute a highly interdisciplinary and knowledge-intensive field, concentrated mainly in leading nations in innovation and applied research.

3.11 Comparison Between Inventors and Patent Applicants

The comparison between two types of actors in the patent system by country is shown in Figure 11.

Figure 11 – Comparison between inventors vs. patent applicants



Source: Authorship (2026)

The comparative analysis between the number of applicants and inventors per country shows important differences in the dynamics of technological development and in the organization of innovation ecosystems related to biodegradable polymers for 3D printing. The results reveal both countries with strong entrepreneurial capacity and patent protection, and nations that participate mainly through international scientific and inventive collaboration.

The U.S. leads by a wide margin, with seven applicants and 32 inventors. The country not only produces innovation (a high number of inventors) but also holds the rights (the largest number of applicants). This condition demonstrates that its ecosystem is comprehensive, encompassing both

creation and commercial protection, which demonstrates the ability to transform scientific knowledge into intellectual property assets and commercial applications.

Germany occupies a prominent position, with two applicants and seven inventors, indicating high technological density. Despite the small number of companies, there is a strong concentration of expertise in biodegradable biomaterials and 3D printed implants, especially associated with Bellaseno GMBH and Evonik Industries. This demonstrates a model based on high technological specialization and high value-added innovation.

On the other hand, countries such as Australia, Canada, Greece, Spain, and China have inventors but do not have their own applicants in the analyzed sample. This behavior suggests predominantly collaborative participation in international projects, in which researchers from these countries work linked to foreign companies or global innovation networks.

In contrast, Austria, Ireland, and Switzerland have applicants but do not have identified domestic inventors. This may indicate business models based on international cooperation, hiring foreign researchers, or multinational corporate structures that concentrate patent ownership in these countries.

In general, the analysis reveals that the technological development associated with biodegradable polymers for additive manufacturing has a strong international and collaborative character. There is a predominance of developed countries, especially those with consolidated infrastructure in biotechnology, biomedical engineering, and advanced materials. In addition, the results show that technological leadership is concentrated in nations capable of integrating scientific research, industrial development, and intellectual property protection strategies.

4 Conclusion

The results of the technological prospecting demonstrate that biodegradable polymers applied to 3D printing constitute an emerging and highly strategic field in the context of sustainable additive manufacturing. The temporal evolution of patent filings showed significant growth from 2021 onwards, especially in biomedical and regenerative applications, indicating recent technological consolidation and high potential for industrial expansion.

The geographic analysis revealed a strong concentration of inventive and entrepreneurial activities in developed countries, especially the USA, Germany, Denmark, and France, which have robust innovation ecosystems in biomaterials, tissue engineering, and 3D printing. The USA stands out for its quantitative leadership in both inventors and applicants, while Germany has demonstrated high technological expertise in bioresorbable implants and advanced biomaterials.

The results also show a high level of technological protection, with a predominance of active and granted patents, demonstrating strong strategic interest and potential for industrial exploitation. In addition, there has been a growing integration between sustainability, circular economy, and technological innovation, especially in the development of biodegradable and recyclable materials for 3D printing.

The identified IPC classifications showed a predominance of areas related to additive manufacturing, biomaterials, medical devices, and regenerative engineering, especially in groups B33Y, A61L, and A61F. The patent titles and abstracts confirmed that the main applications focus on biodegradable implants, regenerative scaffolds, bioprinting, personalized pharmaceutical devices, and sustainable materials for three-dimensional printing.

In addition to the biomedical sector, there was a growing concern with sustainability, circular economy, and polymer recycling, demonstrating that the integration between technological innovation and environmental responsibility is one of the main trends in the sector.

The results also show a concentration of innovations in biomedical, medical-hospital, applied biotechnology, and additive manufacturing applications, highlighting the strategic role of biodegradable polymers in 3D bioprinting.

The growing use of biodegradable polymers associated with additive manufacturing represents a strategic opportunity for Brazil, especially in a context of transition to a sustainable economy. Strengthening the interaction between universities, companies, and the government, combined with targeted investments, can increase national competitiveness and position the country as a protagonist in sustainable innovation.

However, the study has some limitations. The search was carried out exclusively in the Espacenet database, which may restrict the scope of certain patent documents that are not indexed or have recent updates in other international databases. In addition, the use of specific search terms and the B33Y domain may have limited the retrieval of related documents classified under other IPC codes or written with different terminologies. Another limitation refers to the fact that patent data represent technological intentions and intellectual protection strategies, and do not necessarily reflect products already commercialized or technologies effectively implemented in the market.

As future perspectives, it is recommended to expand the analyses to other international patent databases, such as WIPO Patentscope and Google Patents, as well as to integrate bibliometric and scientific studies to correlate academic production and technological development. It is also suggested to deepen investigations on mechanical performance, biodegradation, biocompatibility and clinical applications of polymers used in 3D printing. Another relevant perspective consists of the analysis of trends associated with bioprinting, personalized medicine, circular economy and the use of residual biomass in the production of sustainable filaments. Additionally, future studies can explore international collaboration networks, technology transfer, and market potential of these innovations,

contributing to the strengthening of research, development, and sustainable innovation strategies.

Acknowledgment

To the research project "Evaluation of post-seal sustainability indicators of Geographical Indications in the State of Bahia under the aegis of the Sustainable Development Goals (SDGs)", approved by Call No. 40/2022 – Pro Humanidades 2022 – Line 4B – Network Projects – Public policies for innovation of the National Council for Scientific and Technological Development (CNPq).

References

1. Hoffman, D. L., Novak, T. P., & Venkatesh, A. (2004). Has the Internet become indispensable? *Communications of the ACM*, 47(7), 37-42.
2. Baker, W. M., Lusk, E. J., & Neuhauser, K. L. (2012). On the use of cell phones and other electronic devices in the classroom: Evidence from a survey of faculty and students. *Journal of Education for Business*, 87(5), 275-289.
3. Misra, G., Kumar, V., Agarwal, A., & Agarwal, K. (2016). Internet of things (iot)—a technological analysis and survey on vision, concepts, challenges, innovation directions, technologies, and applications (an upcoming or future generation computer communication system technology). *American Journal of Electrical and Electronic Engineering*, 4(1), 23-32.
4. Kumar, S., Tiwari, P., & Zymbler, M. (2019). Internet of Things is a revolutionary approach for future technology enhancement: a review. *Journal of Big data*, 6(1), 1-21.
5. Da Conceição, V. S., Rocha, A. M., Silva, M. S., & Conceição, M. D. (2020). The impact of technology in the world of work. *International Journal of Advanced Engineering Research and Science*, 7(6), 337-344. DOI: 10.22161/ijaers.76.42.
6. Oliveira, F. A. F. D., & Barroco, S. M. S. (2023). Technological revolution and smartphone: considerations on the constitution of the contemporary subject. *Psychology under study*, 28, e51648.
7. Matias, E., & Rao, B. (2015, August). 3D printing: On its historical evolution and the implications for business. In *2015 Portland International Conference on Management of Engineering and Technology (PICMET)* (pp. 551-558). IEEE.
8. Ballardini, R. M., Norrgård, M., & Partanen, J. (Eds.). (2016). *3D Printing, Intellectual Property and Innovation*. Kluwer Law International BV.
9. Coakley, M., & Hurt, D. E. (2016). 3D printing in the laboratory: maximize time and funds with customized and open-source labware. *Journal of laboratory automation*, 21(4), 489-495.
10. Florêncio, E. Q., Marques, L. M. E. de B., Corso, N. T. P., Lima, T. A. A., & Uchôa, S. B. B. (2017). Concrete for use in 3D printing and its use in the construction of buildings: a prospective study. *Cadernos de Prospecção*, 10(3), 578. <https://doi.org/10.9771/cp.v10i3.23203>
11. Dos Santos, V. P. (2018). Study and development of an FDM 3D printer. 59 f. Final Paper (Bachelor's Degree in Electrical Engineering) – Federal University of Maranhão, São Luís, 2018.
12. De Oliveira, B. M. (2021) Construction of a 3D printer with low-cost materials for use in the elaboration of didactic models for the teaching of Science. 42 f. Final Paper (Graduation in Physics) – Federal University of Espírito Santo, Alegre, 2021.
13. Panda, S. K., Rath, K. C., Mishra, S., & Khang, A. (2023). Revolutionizing product development: The growing importance of 3D printing technology. *Materials Today: Proceedings*.
14. De Abreu, R. (2025). 3D printing in the production of materials for the Physics laboratory: a possibility. 127 f. Dissertation (Master's Degree in Physics Teaching) – Federal University of São Carlos, Sorocaba, 2025.
15. Doloi, S., Das, M., Li, Y., Cho, Z. H., Xiao, X., Hanna, J. V., ... & Tat, L. N. W. (2025). Democratizing self-driving labs: advances in low-cost 3D printing for laboratory automation. *Digital Discovery*, 4(7), 1685-1721.
16. Wohlers, T., Gornet, T., Mostow, N., Campbell, I., Diegel, O., Kowen, J., ... & Peels, J. (2016). History of additive manufacturing. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4474824. Accessed on: 10 May. 2026.
17. Mendis, D., Lemley, M., & Rimmer, M. (Eds.). (2019). *3D printing and beyond: intellectual property and regulation*. Edward Elgar Publishing.
18. Parupelli, S. K. (2019). A comprehensive review of additive manufacturing (3D printing):

Processes, applications and future potential. *American journal of applied sciences*.

19. Morandini, M. M., & Del Vechio, G. H. (2020). 3D printing, types and possibilities: a review of its characteristics, processes, uses and trends. *Interface Tecnológica Magazine*, 17(2), 67-77.
20. Dey, A., Roan Eagle, I. N., & Yodo, N. (2021). A review on filament materials for fused filament fabrication. *Journal of manufacturing and materials processing*, 5(3), 69.
21. Dariva, M. T. (2022). Composites of polymeric materials with ceramics for 3D printing. 48 f. Final Paper (Graduation in Chemical Engineering) – University of Caxias do Sul, Caxias do Sul, 2022.
22. Nainwal, N., Bahuguna, R., Banerjee, S., & Saharan, V. A. (2022). Historical developments on computer applications in pharmaceuticals. In *Computer Aided Pharmaceutics and Drug Delivery: An Application Guide for Students and Researchers of Pharmaceutical Sciences* (pp. 39-72). Singapore: Springer Nature Singapore.
23. Fidan, I., Huseynov, O., Ali, M. A., Alkunte, S., Rajeshirke, M., Gupta, A., ... & Sharma, A. (2023). Recent inventions in additive manufacturing: Holistic review. *Inventions*, 8(4), 103.
24. Jayakrishna, M., Vijay, M., & Khan, B. (2023). An overview of extensive analysis of 3D printing applications in the manufacturing sector. *Journal of Engineering*, 2023(1), 7465737.
25. Leontiou, A., Georgopoulos, S., Karabagias, V. K., Kehayias, G., Karakassides, A., Salmas, C. E., & Giannakas, A. E. (2023). Three-dimensional printing applications in food industry. *Nanomanufacturing*, 3(1), 91-112.
26. Islam, A., Alok, A., Borra, V., & Cortes, P. (2024). A High-Temperature Thermocouple Development by Additive Manufacturing: Tungsten-Nickel (W-Ni) and Molybdenum (Mo) Integration with Ceramic Structures. *arXiv preprint arXiv:2408.04800*.
27. Shaikh, S. (2024). 3D Printing in Prosthetics and Orthotics. *Biomedical Materials for Multi-functional Applications*. Singapore: Springer Nature Singapore.
28. De Almeida, J. G. (2021) Construction of a low-cost 3D printer. 63 f. Monograph. (Graduation in Industrial Mechatronics) - Federal Institute of Education, Science and Technology of Amazonas, Manaus, 2021.
29. Krishnanand, S. S., & Taufik, M. (2021). Design and assembly of fused filament fabrication (FFF) 3D printers. *Materials Today: Proceedings*, 46(11)..
30. Soni, S., & Taufik, M. (2021). Design and assembly of fused filament fabrication (FFF) 3D printers. *Materials Today: Proceedings*, 46, 5233-5241.
31. Mantovani, J. (2023). Use of polymeric residues of acrylonitrile butadiene styrene (ABS) from electrical and electronic equipment (WEEE) to obtain filaments for 3D printing. 85 f. Dissertation (Master's Degree in Materials Technology and Engineering) – Federal Institute of Education, Science and Technology of Rio Grande do Sul, Farroupilha, 2023.
32. Schuh, J. F. (2024). Construction of a low-cost 3D printer. 117 f. Final Paper (Bachelor in Information Systems) – Regional University of Blumenau, Blumenau, 2024.
33. EMBRAPII. (2023). 3D printing: how additive manufacturing can transform the industry. Available at: https://embrapii.org.br/impressao-3d-como-a-manufatura-aditiva-pode-transformar-a-industria/?utm_source=chatgpt.com. Accessed on: 11 May. 2026.
34. Thyssenkrupp. (2023). Additive manufacturing: key technology of Industry 4.0. Available at: https://www.thyssenkrupp-brazil.com/br/blog/manufatura-aditiva?utm_source=chatgpt.com. Accessed on: 12 May. 2026.