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2026 Volume 11, Issue 3
Advances in Precision Medicine
ISSN: 2424-9106 (Online)
ISSN: 2424-8592 (Print)

Research on the Application of PTFE Material in Medical Devices

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Abstract: This paper systematically studies the application value of tetrafluoroethylene (PTFE) in medical devices based on its special chemical structure and physical properties, with a focus on its advantages such as good biocompatibility, low friction, and stable chemical inertness. In the context of clinical scenarios, the article elaborates on the practical application of PTFE coating technology and porous structure design in the production of medical devices. The study structure shows that proper modification and processing of PTFE can significantly reduce friction between medical devices and human tissues, while enhancing the bonding effect of implants to bones. This paper also analyzes the application techniques of PTFE in medical sealing and reconstructive surgery, providing a corresponding technical basis for understanding the important role of this material in high-end medical equipment.

Keywords: Polytetrafluoroethylene; Expanded polytetrafluoroethylene; Medical devices; Biocompatibility; Surface modification; Interventional devices

Online publication: March 26, 2026

1. Introduction

PTFE (Polytetrafluoroethylene), with excellent comprehensive performance, has become indispensable in modern medical equipment manufacturing macromolecule material. As a perfluorinated polymer, it has a very low coefficient of friction and good biological inertness, and can remain stable for a long time in the complex physiological environment of the human body. The following is a systematic introduction to the material properties of PTFE, as well as its specific application forms and technical points in multiple medical specialties.

2. Introduction to PTFE materials

PTFE is a high-molecular-weight compound formed by the polymerization of tetrafluoroethylene monomers. In its molecular structure, fluorine atoms tightly wrap around carbon chains to form a stable spatial barrier, giving the material excellent chemical stability, high and low temperature resistance from -200°C to 260°C, and extremely low surface energy. In terms of technical parameters, the application of PTFE in the field of medical devices mainly relies on three properties. First, the coefficient of friction is approximately 0.05-0.1, which is at a relatively low level among solid materials and is suitable for use as a lubricating

coating. Second, it is biocompatible and does not cause rejection or sensitization when implanted in the human body. Third, it has outstanding hydrophobicity and is less likely to adhere to blood or tissue fluid [1].

3. Specific applications of PTFE in medical devices

3.1. Cardiovascular interventional devices

In the field of cardiovascular interventional devices, PTFE is often used as a coating for guidewires, catheters, and covered stents, or as a base material. Metal guide wires coated with PTFE can significantly reduce friction when passing through the location of vascular lesions.

After percutaneous coronary intervention, PTFE-coated guidewires can reduce propulsion resistance by 30% to 40%, helping to lower the risk of vasospasm. Expanded polytetrafluoroethylene (ePTFE), which has a uniform microporous structure with diameters generally controlled at 20–30 μm, can both promote endothelial cell adhesion growth and prevent hyperplastic tissue from passing through the stent. Therefore, it is often used as the membrane material for covered stents to treat aneurysms or prevent vascular restenosis. The lubrication effect of the PTFE coating can be quantitatively characterized by the coefficient of friction μ: after coating, the value can be reduced from 0.2-0.3 of the metal to 0.05-0.1, and the frictional resistance is reduced by approximately 60%–75%.

$$\mu = \frac{F}{N}\ \mu \quad [2]$$

3.2. Orthopedic implants

In orthopedic applications, PTFE generally does not play a major load-bearing role and is often used as a friction fit component for joint prostheses or as an auxiliary material for ligament reconstruction. Ultra-high molecular weight polyethylene is mainly used in artificial joint replacement surgeries, while modified PTFE composites, with their self-lubricating properties, can be used as meniscus replacement materials or glenoid backing materials. In spinal surgery, ePTFE materials can be made into artificial ligaments or patches for the repair of damaged tendons and ligaments. **Table 1** shows a comparison of typical applications of PTFE in orthopedic implants.

Table 1. Typical applications of PTFE in orthopedic implant species

Application areas	Product form	Main technical advantages
Joint materials	Glenoid backing, meniscus replacement	Very low wear rate, good stress buffering
Spinal surgery	Artificial dural patch	Anti-adhesion, good flexibility, fits the cerebrospinal fluid circulation
Trauma/Sports medicine	Artificial ligament/suture coating	Reduce soft tissue cutting and promote tissue sliding

3.3. Neurosurgical instruments

Neurosurgery places extremely high demands on the precision of instruments and tissue protection, and the low-friction properties of PTFE play a crucial role in this field. During the manufacturing process of the ventriculoperitoneal emptying tube, a PTFE coating is applied to the inner wall, which prevents protein components in cerebrospinal fluid from adhering, thereby reducing the incidence of tube blockage. In intracranial aneurysm clipping surgery, the surface of the titanium alloy aneurysm clip that is permanently implanted in the human body is usually covered with a very thin PTFE insulating layer. The technical difficulty of this insulating layer is to control the thickness within 10 μm and ensure uniformity without pinholes to prevent excessive artifacts or heat generation during MRI examination after surgery [3].

3.4. Medical seals and auxiliary devices

PTFE is widely used in the production of sealing components in operating rooms and various assistive devices due to its excellent chemical inertness. In puncture devices used in minimally invasive surgeries such as laparoscopy, the sealing rings are usually made of PTFE material, which can maintain stable airtightness when the instrument is repeatedly entered and exited, avoiding fluctuations in pneumoperitoneum pressure due to gas leakage. In the production process of the injection needle, the PTFE modification of the needle tip results in less cutting resistance when puncturing a rubber stopper or human skin, and significantly reduces the probability of shedding [4].

3.5. Reconstruction of surgical instruments

In plastic and reconstructive surgery, ePTFE (such as GoreTex®) is widely used. Its micro-porous structure of 10–30 μm enables human tissues to grow in, achieving a stable combination of the prosthesis and the patient's tissue. The material is often used in surgeries such as facial fillings, rhinoplasty and laryngoplasty, and needs to be processed to different hardness levels to meet the mechanical requirements of each part. The ePTFE patch used for laryngeal reconstruction also needs to have sufficient tensile strength to withstand the impact of the airflow during vocalization.

4. Thoughts on the application of PTFE in medical devices

4.1. Surface modification and hydrophilic treatment challenges

PTFE has a very low surface energy of about 18.5 mN/m and excellent non-adhesive properties, but it is difficult to be wetted by adhesives, affecting the bonding strength of products such as catheters and implants. Sodium naphthalene etching and low-temperature plasma are commonly used for surface modification in the industry: the former is uniform but causes discoloration of the material and poses a risk of residual sodium ions, which requires strict GMP control. The latter process is environmentally friendly and does not damage the substrate, but hydrophobic recovery occurs and immediate coating and encapsulation are required after treatment. The relationship between surface γ and contact Angle θ conforms to the Young equation, which is expressed as: $\tilde{a}_{sv} = \tilde{a}_{s} + \tilde{a}_{v} \cos\theta$ PTFE material has a higher water contact Angle, ranging from 108° to 112°, corresponding to a surface energy of approximately 18.5 mN/m; After plasma treatment, the water contact Angle of PTFE is significantly reduced to between 50° and 70°, while the surface energy is increased to 30 to 40 mN/m [5].

Table 2. Comparison of major surface modification techniques for PTFE

Technology types	Working mechanism	Advantages	Limitations
Sodium naphthalene chemical etching	Chemical corrosion defluorination, introducing polar groups	High treatment strength and reliable adhesion	The wet process has a high risk of contamination and changes in appearance
Low-temperature plasma	High-energy particle bombardment, surface grafting	Environmentally friendly, the modified layer is extremely thin and does not affect the body	The equipment cost is high and the treatment effect has a time limit
The surface is coated with a hydrophilic layer	Physical coating of polymers such as polyvinyl alcohol	The process is simple and the lubrication effect is immediate	The coating is prone to peeling off and has poor durability

4.2. Mechanical properties and long-term implant fit

Mechanical durability of PTFE as a permanent implant is crucial in the orthopedic and cardiovascular fields. It is chemically stable and does not degrade, but its low modulus and high creep limit load-bearing applications. Pure PTFE is prone to deformation and loosening of joints when subjected to long-term stress. The creep resistance and wear resistance can be significantly improved by adding glass fiber, carbon fiber, or PEEK microparticles for modification. ePTFE, on the other hand, optimizes the microstructure through stretching and sintering, and the artificial blood vessel uses a multi-

layer composite structure to ensure sufficient strength at a porosity of 50% to 70%. The creep behavior of PTFE can be described using the Findley power-law model, which is expressed as: $\varepsilon(t) = \varepsilon_0 + \mathrm{m}.t^n$ In the formula, is the strain over time, is the initial strain, and m and n are material constants. ε（t) ε_0 After filling and modifying PTFE, the creep rate of the material can be reduced by 40% to 60% [6].

4.3. Biosafety and host response considerations

Although PTFE is considered a bioinert material, the biological reactions brought about by its physical form after long-term implantation have gradually gained attention. During joint friction and surgical implantation, PTFE may produce abrasive or exfoliated particles. These particles, when phagocytosed by macrophages, continuously release inflammatory factors that cause peri-implant osteolysis or granuloma. Therefore, the surface roughness Ra value of implant-grade PTFE components should be controlled below 0.4μm to reduce particle production. The particle size distribution of PTFE debris conforms to the lognormal distribution function, and its standard expression is: where is particle size, is logarithmic mean, and is logarithmic standard deviation. $f(d) = \frac{1}{\mathrm{d}\sigma\sqrt{2\pi}}\exp(-\frac{\mathrm{h}\ d-\mu)^2}{2\sigma^2})$ $d\ \mu\ \sigma$ When the particle size is less than 10μm, the risk of macrophage activation increases significantly.

At the same time, the anti-adhesion properties of PTFE slow down the rate of human cell attachment, and ePTFE patch implantation is prone to bacterial colonization, causing delayed infection in the early stage. It can be improved by silver ion or antibiotic coating, but there is still a problem of insufficient adhesion of the coating [7].

4.4. Adaptation selection of sterilization methods

PTFE has good physicochemical stability but is sensitive to high-energy irradiation. Gamma ray or electron beam sterilization can cause molecular chain breakage and reduced mechanical properties, and is not recommended for long-term implant devices. Ethylene oxide sterilization is the mainstream method, which is highly penetrating but requires strict control of residue to avoid tissue irritation. PTFE can withstand temperatures up to 260°C and theoretically can be sterilized with steam, but repeated treatment can cause the pore structure of ePTFE to collapse and reduce its flexibility, affecting tissue growth. The relationship between radiation dose and molecular weight can be described by the Charlesby-Pinner equation: where is the soluble part, is the radiation dose, and is the material-dependent constant. $s+\sqrt{s} = \frac{p_0}{q_0} + \frac{1}{q_0 u_1 D}\ s$ $D\ p_0\ q_0\ u_1$ When the irradiation dose exceeds 25 kGy, the molecular weight of PTFE decreases by 30% to 50%.

4.5. Future directions of technological evolution

The future application of PTFE in medical devices will shift from traditional physical barriers and lubrication layers to functionalization and intelligence. Researchers have loaded antiproliferative drugs such as paclitaxel and rapamycin into ePTFE micropores through solvent impregnation or electrospinning techniques to create drug-loaded materials, achieving the integration of inhibiting intimal hyperplasia and tissue repair. Meanwhile, research on biodegradable PTFE composites is advancing by blending PTFE micropowder with polylactic acid and polycaprolactone to provide support and lubrication in the early stages of implantation, which is absorbed by the biodegradable components and replaced by new tissue, achieving a dynamic balance between temporary support and tissue regeneration. In addition, selective laser sintering technology enables 3D printing of PTFE powder to rapidly produce complex structures such as personalized skull patches and airway stents, providing a new path for precision medicine and customized implants. Fitting with the drug release kinetics **RitgerPeppas** model $\frac{M_t}{M_\infty} = k.t^n$, where is the cumulative drug release rate, is the release rate constant, is time, and is the release index, values can be optimized by regulating the aperture of ePTFE to achieve zero-order or first-order drug release. $\frac{M_t}{M_\infty}\ k\ t\ n\ n$ [8]

5. Closing remarks

To sum up, PTFE has become a core material for the manufacture of cardiovascular, orthopedic and neurosurgical

medical devices due to its extremely low coefficient of friction, stable chemical inertness, and good biocompatibility. By precisely regulating the microporous structure of ePTFE and optimizing surface modification techniques, researchers have advanced its application from traditional physical coatings to functionalized composite implants. With the maturation of new processes such as drug delivery technology, degradable composite systems and 3D printing, PTFE will show broader application prospects in the future development of precision medicine and high-performance implantable devices.

Disclosure statement

The author declares no conflict of interest.

References

[1] Wu H, Zhang B, 2020, Applications of Hydrogel Materials in Medical Devices. Yunnan Chemical Industry, 52(8): 34–37.

[2] Hu C, 2025, Research on the Application of New Nanomaterials in Surface Modification of Medical Devices. Zhangjiang Science and Technology Review, (4): 11–13.

[3] Yu K, Liang J, Ai C, et al., 2023, Development and Application of Fiber Materials in Medical Devices. Plastic Additives, (2): 77–79.

[4] Yu X, Xing Y, 2021, Research on the Application of Molecular Materials in Medical Device Manufacturing. Chemical Fiber and Textile Technology, 50(7): 93–94.

[5] Wang P, Zhang L, 2020, Research on the Application of Polymer Materials in Medical Devices. Contemporary Chemical Engineering Research, (18): 102–103.

[6] Huang S, Yu X, Zheng Z, et al., 2019, The Application Status of Polymer Materials in Medical Devices. Medical Equipment, 32(3): 196–199.

[7] Huang H, 2017, Application of Molecular Materials in Medical Device Manufacturing. Technology and Market, 24(11): 173.

[8] Zhang Q, Yan Y, 2012, Applications of Composites in Medical Devices. China Medical Device Information, 18(2): 13–17.