Customized Crosslinking for Orthopedics

Opening the door for new competitive design and market opportunity
Is it possible to create a true strategic advantage in the design and development of new orthopedic implants in a highly competitive 21st century market?

Such advantages have been created in the past. The use of Ultra High Molecular Weight Polyethylene (UHMWPE) quickly found a highly strategic application in hip and knee arthroplasty beginning about 40 years ago, when joint implants and replacement strategies were largely in their infancy. Today, following generational improvements in technology, virtually all joint arthroplasty clinical solutions include some form of an UHMWPE element, whether crosslinked or not.

Is it possible to design implants that take advantage of new UHMWPE process qualities that can truly create a real competitive and profitable edge? Through advanced techniques, orthopedic professionals and engineers can design and produce a new spectrum of arthroplasty implants with strategic market-making qualities.

Through advances in electron-beam applications, innovative techniques exist to control the crosslinking depth and tensile material quality of UHMWPE to create new and highly strategic orthopedic componentry. Treated under proprietary electron-beam processes, this crosslinked UHMWPE can open new markets and add significant quantifiable value to existing orthopedic medical device designs for a whole spectrum of arthroplasty clinical settings.

In human joint loading and articulation, UHMWPE possesses several superb qualities that enable an artificial joint to closely duplicate or approximate the range of motion and load-bearing qualities inherent in natural joints. These qualities have long been exploited in orthopedic medical device design by virtually all orthopedic manufacturers.

Since the UHMWPE material is presently already in use by major manufacturers, is it possible to develop new design elements and process improvements to further reduce UHMWPE wear and improve implant survival?

With current technology and design, many orthopedic implants that use first generation UHMWPE serve well in a variety of settings. According to orthopedic implant pioneer and Biomet founder Dane Miller, PhD: “Certain designs show much longer useful product life through clinical studies.” As noted in the UHMWPE Biomaterials Handbook, other designs may serve well only for the first decade or so following surgical implantation. Following that time span, degradation of UHMWPE and other componentry, as well as possible surgical misalignments, can result in revision. Accordingly, an implant solution is often not recommended or considered for certain joint repair patients in younger demographics. As young arthroplasty patients (whether for knee, shoulder,
Developing a True Strategic Advantage

As research and operations of commercial electron-beam accelerators developed and spread in North America, Europe and Asia over the past 40 years, so did knowledge and applications for crosslinking UHMWPE. A crosslinking reaction occurs when ionizing radiation (or other radio-chemical or chemical sources) causes a cascade of reactions in molecules of compressed UHMWPE. By subsequent means of chemical (covalent) bonds, two or more polymeric chains are linked.

The process of radiation-induced crosslinking creates macroradicals and increased potential acceleration of oxidation, where tensile strength and other preferred material qualities may be reduced (see “Why UHMWPE”) while other strategic qualities are increased. Extensive and deep crosslinking can also produce physical crystalline qualities that can allow oxidation, which left uncorrected, can result in sub-performing components. However, these issues can be effectively addressed through thermal treatment (annealing) and the addition of stabilizing materials such as anti-oxidants. The dose rate available on the Iotron IMPELA© also serves to minimize oxidation and hence, unwanted effects of mechanical properties.

The superior performing quality of crosslinked UHMWPE creates higher demand for such UHMWPE componentry, as this advanced material better addresses the key strategic issues of wear and implant survival than does conventional UHMWPE. Continuing industry and academic research over the next five to ten years is expected to both confirm this and also continue producing improvements.

As research advances, so does the extended strategic use of crosslinked UHMWPE. Experience with historic and conventional UHMWPE led to a new first generation of crosslinking improvements (annealing) and then a second generation combining annealing and the introduction of antioxidants.

In the early 2000s, only two major orthopedic manufacturer integrated crosslinked UHMWPE in knee arthroplasty products. Today, virtually all major manufacturers produce implants using crosslinked UHMWPE in total knee arthroplasty (TKA) in cruciate retaining and posterior stabilized designs, reflecting the increased confidence and performance of the advanced crosslinked UHMWPE.

The knee implants in particular represent unique challenges. Conventional UHMWPE, despite an established record of high performance, over time can suffer sufficient wear and damage, thus compromising the longevity of initial knee arthroplasty. Again, the use of conventional or first generational UHMWPE can accordingly limit market breadth and optimization, particularly in young demographics where patient life expectancy can exceed expected implant survival by one to two
times. For certain demographics, the possibility and consequences of later revision should be a consideration when surveying implant options that deploy conventional UHMWPE.

**How tough is the market barrier?** Industry research shows that 15-20% of patients experience implant revision after the first decade of surgical installation.

A true strategic advantage then can come from highly crosslinked custom UHMWPE that possesses material qualities of long surface wear and necessary mechanical properties to mirror natural joint qualities. Iotron Industries, a leading electron-beam solutions company with decades of crosslinking experience and research, has developed a proprietary surface crosslinking techniques through its IMPELA® process that can seize this strategic advantage.

**Producing Market-making UHMWPE Components**

Advances in electron-beam crosslinking have enabled companies with high-powered electron-beam accelerators to precisely calibrate and control the crosslinking process in antioxidant-enhanced UHMWPE. Crosslinking for orthopedic products is typically achieved through radiation-induced crosslinking (as opposed to chemically induced). Electron-beam crosslinking possesses several strategic advantages over gamma-radiation induced crosslinking. Iotron’s IMPELA electron-beam process produces a positive disruptive technology that incorporates these advantages and also includes:

- Tight dose uniformity
- High dose rate for less oxidative effect.
- Electron beam polymer material modification represents a green technology.
- It uses no radioactive elements that have to be sourced and later disposed of.

These advantages, coupled with the capacity of high-powered electron-beam accelerators in the 10MeV range, produce the precision required to create a strategic advantage of crosslinked UHMWPE with multiple strategic characteristics.

“High dose-rate electron-beam cross-linking has been proven to reduce oxidation and improve wear resistance as compared with conventional UHMWPE,” says Orhun K. Muratoglu, Co-Director of the Harris Orthopedic Laboratory in Boston. “Using high-power electron-beam capacity can substantially improve overall supply chain performance. The high degree of dosage control available with electron-beam represents a natural innovation that could lead to a third generation of UHMWPE applications and the possibility of opening new markets in the orthopedic industry,” Dr. Muratoglu continued. (Dr. Muratoglu holds more than 30 published patents or pending patents in the field of UHMWPE applications and orthopedics).
How does that strategic advantage appear? UHMWPE possesses mechanical properties that help simulate original knee functions in flexibility and articulation. Because of the complexity of the knee function, historical/conventional UHMWPE may come under high stress and wear that create surface damage and degradation.

Through extensive industry research and testing, Iotron Industries deploys processes that produce crosslinked UHMWPE with both soft and hard characteristics that strategically meet a whole range of componentry requirements (third generation of development). By leveraging the advantage of a precisely calibrated electron beam, Iotron’s process can regulate the intensity and material processing of compressed UHMWPE.

This proprietary process can create a crosslinked surface that retains the long-term wear resistance of first generation UHMWPE for joint articulation, while retaining a durability in the interior that minimizes brittleness and allows longer life. Wear and surface damage in conventional UHMWPE-supported joints is recognized as a primary contributor for inflammatory bone loss and late revision of implants. With the Iotron proprietary process, such wear is significantly reduced, thus extending the longevity of the implant.

If the longevity of an implant is increased, then the possibility of effectively using crosslinked UHMWPE-enhanced implants in younger demographics also increases. Such strategic increases can provide a major competitive advantage in both opening new and younger markets, and providing added value to existing markets by reducing the probability of costly revision.

The Engineering Advantage

Since the advent of Ultra-High Molecular Weight Polyethylene (UHMWPE) as the bearing material in artificial joints for hip, knee, shoulder and other arthroplasty joint procedures nearly four decades ago, the material has continued to demonstrate lasting value. Its superb mechanical properties and low coefficient of friction while articulating between other artificial joint materials have led to widespread use. However, in its role as bearing material for the articulating surface in an artificial joint, the first generation influence UHMWPE has potential significant wear and long-term oxidation issues. From historical (non crosslinked) to new generations, strategic crosslinking addresses many of these long-term issues, particularly when the polymers undergo compression molding (from resin powder) with the inclusion of an antioxidant as a stabilizing element. Possible crystalline issues and possible fissuring are further addressed with the addition of thermal treatment (annealing).
For nearly two decades of on-site research and development, coupled with careful experiential process improvement, engineers at Iotron Industries have developed proprietary IMPELA® electron-beam techniques to extensively crosslink surface areas of UHMWPE while maintaining the superior durability and other mechanical properties in the interior of a UHMWPE joint element. This allows the engineering virtues of crosslinking and conventional UHMWPE to be used in tandem in any given arthroplasty-designated joint material. The only requirement for optimization is that the medical device needs to be designed and engineered to take full advantage of this tandem opportunity.

Opening New Markets – Crosslinking and CEOs

The global orthopedic industry represents one of the most competitive marketplaces in human history. The development of intellectual capital and the protection of human capital for implant and medical device innovation can only be described as fierce, perhaps even vicious as companies seek to defend market share.

Applying technologies and proven processes from other industries and sectors can lead to major market-making advances. The process of crosslinking Ultra-High Molecular Weight Polyethylene (UHMWPE), coupled with the introduction of an anti-oxidant as a stabilizer and thermal treatment (annealing) to address possible delamination and free radical issues, has and continues to lead to several new profitable ventures in the medical device industry.

Crosslinked UHMWPE, particularly when paired with stabilizing and anti-delamination strategies, creates a whole new spectrum of profitable implant and medical device design. The new crosslinked material possesses numerous advantages over conventional UHMWPE.

This advantage is further increased when electron-beam technologies are utilized over gamma radiation, as the application electron-beam can be strategically calibrated to produce specially crosslinked UHMWPE that possesses positive mechanical attributes of both modified and conventional UHMWPE.

Further, use of the Iotron IMPELA® electron-beam process further lowers oxidizing effects and its high dose rate may eliminate whole processes requiring inert packaging environments such as are required in the usage of gamma radiation for crosslinking to minimize shelf life aging (oxidation).

Such specialized UHMWPE hold much promise for the new design of orthopedic implants and new medical devices, which in turn can open new markets. Specialized UHMWPE with the attributes of conventional and crosslinked properties can be incorporated in new designs that have the potential for much longer survival rates, minimizing wear and oxidation issues for decades.

With these longer survival rates and the proprietary surface crosslinking available through IMPELA®, orthopedic manufacturers have the capacity to design and build new arthroplasty implants that can last 30% longer and open new markets.
Why UHMWPE?

As implant technology advanced in the 1970s and 1980s, the wear, durability and other mechanical properties of UHMWPE were found to lend themselves well to inclusion of joint replacement, repair and arthroplasty procedures. For a time, conventional UHMWPE was thought to be a universal replacement for certain types of metal or ceramic componentry.

However, challenges arose. Among other issues, gamma sterilization in air of UHMWPE components was found to accelerate unwelcome oxidation levels. Subsequent wear and abrasions of UHMWPE implant parts (whether from material degradation or from misaligned insertion by orthopedic surgeons) also contributed to higher levels of revision and the need for implant repair.

Radiation-induced crosslinking (first generation) was introduced to combat these issues in the 1990s, producing what is now termed the first generation of highly crosslinked implants. While improving wear and abrasion degradation and improving device longevity, the crosslinking processes themselves created a set of new challenges for engineers and medical device designers. The creation of free radicals and new crystalline structure issues could result in fissuring and other undesirable mechanical attributes.

These issues were largely resolved with the introduction of antioxidant dispersion as a stabilizing agent during the compaction process (conventional UHMWPE first begins as a compacted resin powder). The effect of present radicals is now effectively addressed through thermal treatment (annealing).

Today experts agree that highly crosslinked UHMWPE, coupled with antioxidant stabilization and thermal treatment/annealing, offers a broad spectrum of implant and medical device strategic options that are still to be fully explored.
Capture the Iotron Advantage

**Iotron: the industry leader in development and applications of electron-beam**, particularly in the crosslinking segment. Iotron engineers can partner directly with your company's engineers, supply chain executives and process improvement experts to create a unique competitive advantage, increase productivity and profitability and open new markets.

A profound key to success in orthopedic implant and medical device manufacturing is simple: *go where others aren’t in the marketplace and achieve category dominance.*

**In a highly cluttered and intensely competitive market**, orthopedic and medical device companies must fiercely protect their intellectual property (IP) and proprietary processes to preserve profitable operations. The introduction of UHMWPE in the late 20th century represented a serious game changer for the industry.

Today, as experts agree, second generation highly crosslinked UHMWPE stabilized by antioxidants (to reduce oxidation and degradation) and cured through thermal processing/annealing (to reduce free radicals and fissuring properties) represent key development potentials that have not yet been fully explored.

Recent advances in crosslinking through electron-beam processing (as opposed to gamma radiation, which has its own set of challenges) more than suggest that all-new profitable markets can be tapped. Deploying electron-beam crosslinking, coupled with antioxidant stabilization and thermal treatment/annealing, as a true disruptive technology possesses the potential to design and manufacture orthopedic and medical device products that can create and dominate new critical markets, particularly in the younger demographics.

Many companies who offer electron-beam treatments fall into one of three categories:

1) they recently added electron-beam services to their portfolio and are new to the industry;
2) their electron-beam accelerator is relatively low-powered and limited in production capacity;
3) they offer a limited array of service options and industry experience.

**Iotron leads in all three categories:** Iotron is a demonstrated and recognized innovator and leader in the electron-beam industry; its high-power IMPELA electron-beam accelerator is capable of a full-range of required on-demand capacity; and Iotron offers a broad array of service solutions, many of which include recommendations and consulting for supply chain management and human capital deployment. Iotron engineers possess deep experience and are fully capable to providing expert consulting and advice to product designers and engineers on how to best integrate electron-beam services to produce superior quality and superior design for a heretofore unknown and unexplored third generation of UHMWPE-based implants and medical devices.