SURFACE TREATMENT AND CHARACTERIZATION OF BIO-MATERIAL

A Project Report

Submitted by

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BONAFIDE CERTIFICATE

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Who carried out the project work under my supervision.

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AIMMS '08

National Conference on
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This is to certify that Mr./~~Ms.~~ E. PRABHU from KUMARAGURU COLLEGE OF TECHNOLOGY has presented a paper titled STUDY ON APPLICATION OF ION IMPLANTATION ON THE WEAR PROPERTY OF UHMWPE in AIMMS '08, a National Conference, conducted on 17th April 2008.

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This is to certify that Mr/Ms/Mrs E. PRABHU

has participated and presented a paper titled Study on the effect of surface treatments on wear property of ultra high molecular weight polyethylene in the 2nd National Conference on "ADVANCES IN MECHANICAL SCIENCES" during 27-28, March 2008.

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ABSTRACT

Biomaterials and biomedical devices are used throughout the human body. Since human life and well being often depends on these devices, there are stringent controls and constraints placed up on the application of devices and the materials that can be used. Polymeric materials have contributed significantly to the development and improvement of medical devices and systems. Total joint replacements has become an effective and popular surgical technique for restoring function to patients whose joint have been afflicted by major trauma or joint degenerative diseases.

UHMWPE (Ultra High Molecular Weight Polyethylene) has been used as a bearing material in total joint arthoplasty for many years. Wear of UHMWPE is one of the major problem caused which can adversely affect the performance and longevity of orthopedic implants.

In this work, samples of Ultra High Molecular Weight Polyethylene material have been treated with ion implantation technique at three energy levels using helium ions. Wear test has also been conducted and the performance of the samples at three energy levels have been analyzed. The wear test results show that there is significant improvement in the wear resistant characteristics of the material.

ஆய்வுச் சுருக்கம்

மனித உடம்பிற்குள் பயோ-மெட்ரீயல்ஸ் மற்றும் பயோ மெடிக்கல் சாதனங்கள் போன்றவை உபயோகபடுத்தப்படுகிறது. இந்த மனித வாழ்வில் மேற்கூறிய சாதனங்களை பயன்படுத்தும் போது அதன் மீது கண்டிப்பான கட்டுப்பாடுகள் மற்றும் நிபந்தங்களை விதித்து பயன்படுத்தப்படுகிறது. இன்றைய மருத்துவ துறையில். மருத்துவ சாதனங்கள் மற்றும் அமைப்புகளை உருவாக்குவதற்கும், அதன் வளர்ச்சிக்கும் பாலி - மெரிக் மிகவும் உறுதுணையாக உள்ளது.

தற்போது உள்ள மனித வாழ்வில் ட்ராவுமா (அ) மூட்டு தேய்வு போன்ற நோயால் பாதிக்கபட்டவர்களுக்கு மூட்டு அறுவை சிகிச்சை (அ) மூட்டு மாற்றம் செய்வது மிகச்சிறந்த தீர்வாய் அமைந்துள்ளது.

அல்ட்ரா ஹை மாலிக்குலார் வெயிட் பாலி எத்திலீன் என்ற மூலப்பொருள் இப்பயன்பாட்டிற்கு பல வருடங்களாக உபயோக படுத்தப்பட்டு வருகிறது. இம்மூலப்பொருட்களை பயன்படுத்தும் போது ஏற்படும் தேய்மானம் அதன் செயல்பாட்டையும், ஆயுளையும் குறைத்து விடுகிறது.

இந்த ஆய்வில் அல்ட்ரா ஹை மாலிக்குலார் வெயிட் பாலி எத்திலீன் மூலப்பொருட்கள் அயான் இம்பிளேண்டேஷன் என்ற ஆய்விற்கு உட்படுத்தப்பட்டு பின்பு தேய்மான சோதனையில் பரிசோதிக்கப்பட்டுள்ளது.

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LIST OF SYMBOLS, ABBREVIATION OF NOMENCLATURE

SYMBOLS	ABBREVIATION
Co	Cobalt
Cr	Chromium
Mo	Molybdenum
Ni	Nickel
Ti	Titanium
Al	Aluminum
He	Helium
UHMWPE	Ultra High Molecular Weight Polyethylene
Wt	Weight
N	Newton
Ø	Diameter
MPa	Mega Pascals
m/s	Meters per Second
mm	Millimeter
SS 316 L	Stainless Steel
C	Celcius
KV	Kilo Volt
KeV	Kilo Electron Volt
Gms	Grams

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

There are different definitions of 'Bioengineering" [Berger et al., 1996]. Here we refer 'Bioengineering' to the applications of concepts and methods of the physical sciences and mathematics in an engineering approach towards solving problems in repair and reconstructions of lost, damaged or deceased tissues. Any material that is used for this purpose can be regarded as biomaterial. According to Williams [1987], a biomaterial is a material used in implants or medical device, intended to interact with biological systems. Thus, a biomaterial must always be considered in its final fabricated and sterilized form. Examples of common medical devices are: substitute heart valves and artificial hearts, artificial hip and knee joints, dental implants, internal as well as external fracture fixators, skin repair templates as well as dialysers to support kidney functions or intraocular lenses. A material that can be used for medical application must possess a lot of specific characteristics, of which the most fundamental requirements are related with biocompatibility.

Over the last thirty years, considerable progress has been made in understanding the interactions between the materials and the tissues. It has been acknowledged that there are profound differences between non-living (avital) and living (vital) materials. Researches have coined the words 'bio-material' and 'biocompatibility' [Williams, 1998] to indicate the biological performance of materials. Thus, materials that are biocompatible can be considered as biomaterials, and the biocompatibility is a descriptive term which indicates the ability of the material to perform with an appropriate host response, in a specific application [Black and Hastings, 1998]. Researchers [Wintermantel and Mayer, 1995] extended this definition and distinguished between surface and structural compatibility of an implant. Surface compatibility means the chemical, biological and physical (including surface morphology) suitability of an implant surface to the host tissues. Structural compatibility is the optimal adaptation to the mechanical

behavior of the host tissues. Therefore, structural compatibility refers to the mechanical properties of the implant materials such as elastic modulus (or E, Young's modulus) and deformation characteristics, and optimal low transmission at the implant/tissue interface.

Optimal interaction between biomaterial and host tissue is reached when both the surface and the structural compatibilities are met. Furthermore, it should be noted that the success of the biomaterial in the body also depends on many other factors such as surgical techniques (degree of trauma imposed during implantation, sterilization methods, etc), health conditions and activities of the patient. Until recently, most medical devices are still made from single-phase homogeneous and isotropic materials such as polymers, metals and ceramics. A large number of polymers are widely used in medical applications. This is mainly because they are available in a wide variety of compositions, properties and forms (solids, fibers, fabrics, films and gels), and can be fabricated readily into complex shapes and structures. However for load bearing applications, they tend to be too exible and too weak to meet the mechanical demands of certain applications e.g. as implants in orthopedic surgery. Also they may absorb liquids and swell and leach undesirable products (e.g. monomers, fillers, platicizers, antioxidants), depending on the application and the usage. Moreover the sterilization processes may affect the polymer properties. Metals are known for high strength, ductility and resistance to wear. Most common are stainless steel, cobalt- chromium alloys as well as titanium and titanium base alloys.

Total hip and knee arthroplasties are common procedures in orthopaedic surgery and both are routine, effective and successful treatment modalities. A current estimate of the rate of total hip replacement world wide amounts approximately 1 million per year, with over 250,000 knee replacements. (Schierholz JM,) one of the most devastating complications, however, is deep periprosthetic infection. Conservative estimates of infection rates average 1 - 2% for hip implants and 2 - 4% for knee implants. In the future it is expected that incidents of the prosthetic joint infections will further increase due to (i) better detection methods for prosthetic joint infections, (ii) the growing number of implanted prostheses in an ageing population and (iii) the increasing residence time of prostheses, which are

at continuous risk for infection during their implanted lifetime. In revision surgery, the incidence of periprosthetic infection is 3.2% for hip implants and 5.6% for knee implants, and can be as high as 40% for failed hip orthoplasties with a positive intra-operative culture. Infections remain a serious problem, as it generally requires multiple operations and not in frequently amputations or mortality remain unavoidable during the treatment of these infections.

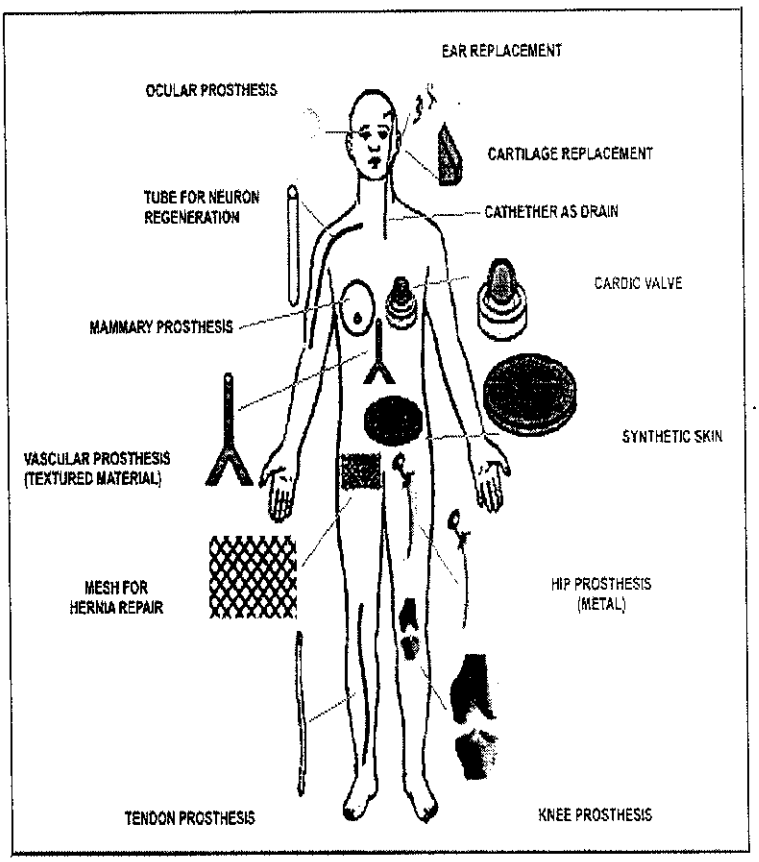


Fig 1.1 Implants in human body

BIO-PROBLEMS:

Wear of ultra high molecular weight polyethylene and resulting wear debris induced osteolysis is a major cause of failure in both hip and knee prostheses. Ultra high molecular weight polyethylene (UHMWPE) wear particles generated at the articulating interfaces, enter the periprosthetic tissues, where they are phagocytosed by macrophages which release inflammatory cytokines such as TNF alpha and lead to bone resorption. Over the last forty years, different types of UHMWPE have been used clinically. Historically UHMWPE sterilized with gamma irradiation in air was used, and this was subsequently shown to oxidize

and degrade with age resulting in accelerated wear. More recently stabilized UHMWPE and cross linked UHMWPE have been introduced. The wear, wear debris, biological activity and osteolytic potential of different types of UHMWPE have been investigated in laboratory simulations, under a range of different conditions. Laboratory studies of historical materials have been compared to clinical retrievals. The importance of investigating the nature of wear debris and its biological activity as well as the wear rate has been demonstrated. with various types of UHMWPE debris showing different levels of biological activity. Integration of results of wear simulator studies and in vitro cell structure studies has allowed the prediction of the relative osteolytic potential of different UHMWPE materials.

The various material requirements that must be met for successful total joint replacement. The ideal material or material combination should exhibit the following properties:

- A biocompatible chemical composition to avoid adverse tissue reactions.
- Excellent resistance to degradation (e.g., corrosion resistance for metals or resistance to biological degradation in polymers)
- Acceptable strength to sustain cyclic loading endured by the joint
- A low modulus to minimize bone resorption
- High wear resistance to minimize wear debris generation

Chapter 2

Problem Definition

CHAPTER 2

PROBLEM DEFINITION

As a design engineer, the professional practice of engineering is largely concerned with design is an important aspect which play a vital role. A poor design may cause heavy loss to society in usage and economical, and economically many aspects play a major role which if not considered much may lead to failure. Many parameters influence the failure such as consideration of property of the material, erection, design, manufacturability and treatments.

But, in the field of biomechanical the situation turns crucial once the component fails. Though they are capable to satisfy the bio-functionality, interfacing surface in relative motion causes friction, wear causes damage to the one or both surface generally involving progressive loss of material. Worn surface will produce wear debris which influences the host failing in its biofunctionality. As said above the design engineer can't eliminate the wear and mechanical properties completely so as we can study the material characteristics by which manufactures will be benefited.

Various combinations of material are used for the TKR, such as UHMWPE with other steels. More than several decades these polymers has been widely in use causing so many problem after certain period. Though they are functionally capable to satisfy the bio-compatibility the wear debris formed due to worn surface may cause problem in host body having more influences towards the failure of the bio-functionality.

Aseptic loosening of prosthetic components may eventually lead to pain, instability and loss of function, and thus constitute a failure. In aseptic loosening, the interface between implant/cement and bone is overloaded, compressed, resorbed or remodeled so that the implant subsides, tilts and/or rotates. The position of the implant eventually becomes overtly changed, which can be seen on

regular radiographs when it shows more than 2-3 mm. flat interfaces. when imaged parallel to the surface, may show a radiolucent zone as a sign of soft tissue interposition at the interface.

Several theories have been proposed to explain the reason for and mechanism behind loosening. These include toxic effects on the bone bed, thermal damage during bone cutting, overload due to malalignment or tense soft tissues, failure of initial fixation with micromotion, pressure waves in the fluid of the interface and osteolysis triggered by wear particles from the implant.

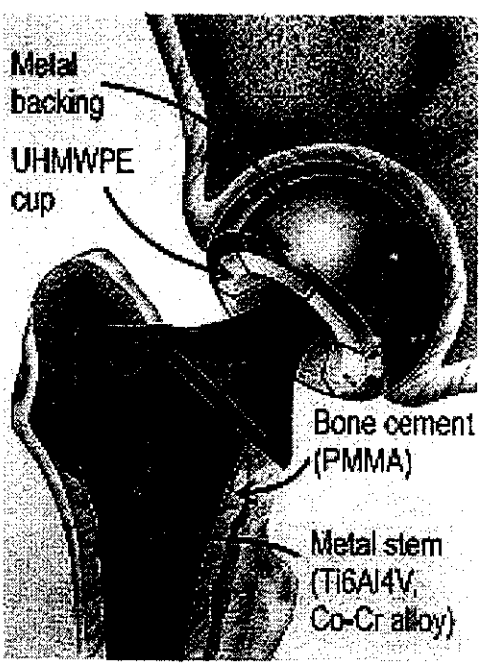


Fig 2.1 Implantation set up for knee joint

The end-stage of aseptic loosening usually implies loss of condylar bone, metaphyseal osteolysis, fracture of the overloaded side, malalignment and secondary changes in the supporting soft tissues with either contracture or insufficiency. The implant may be damaged with fatigue fractures. Polyethylene parts may be worn down with huge amount of plastic debris and metal may be articulating against metal, causing metallosis. The cement mantle may also be separated and fractured. The loss of function may also cause adhesion in the gliding mechanism of the muscles with limitations in range of motion.

As shown in figure 2.1 UHMWPE material has the metal backing with it, hence during movement friction happens and due to the friction wear happens. The wear debris formed will lead to the loss in bio functionality and hence leads to the failure of the material.

Thus as a conclusion to the problem definition, it can be said that the wear which is caused due to friction is the major cause for the failure of bio-materials.

Chapter 3

Biomaterials

CHAPTER 3

BIOMATERIALS

Biomaterials and biomedical devices are sometimes used throughout a human body. When a prosthetic device is placed into a body two aspects must be taken into account.

3.1 BIO FUNCTIONALITY:

This concerns the effect of the physiological environment on the material device. The materials must satisfy its design requirements in service. The varied functions of biomaterials include:

Load transmission and stress distribution – e.g. bone replacement
Articulation to allow movement – e.g. artificial knee joint
Control of blood and fluid flow – e.g. artificial heart
Space filling – e.g. cosmetic surgery
Electrical stimuli – e.g. pace maker
Light transmission – e.g. implanted lenses
Sound transmission – e.g. cochlear implant

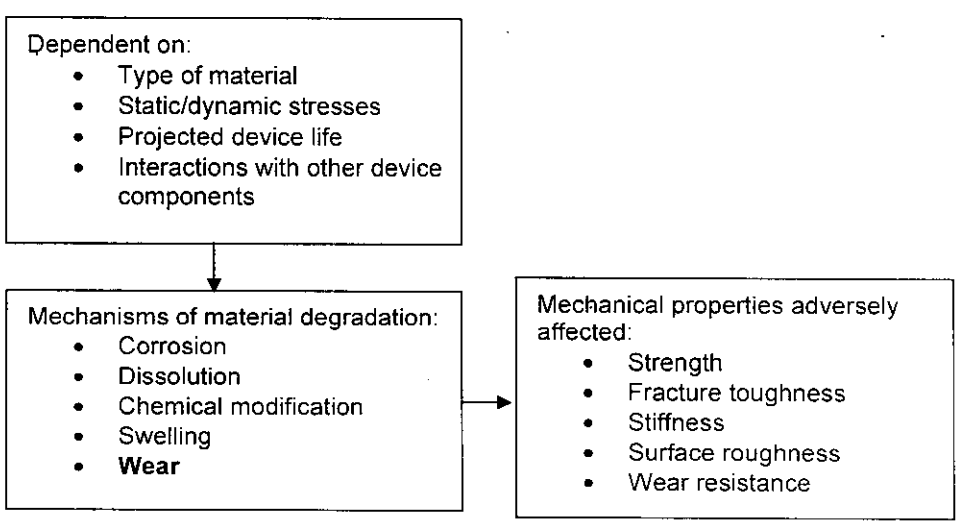


Fig 3.1 The effect of physiological environment on materials/devices

3.2 BIOCOMPATIBILITY:

This concerns the effect of prosthetic device materials (and any degradation product) in the body. The materials must not degrade in its properties within the environment of the body and must not cause any adverse reaction within the host's body.

The main cause of failure of implant in the prosthetic knee joint is wear in the contact area. These wear debris is generated due to surface sliding of two parts of the implant. This phenomenon happened due to the occurrence of wear and joint implant interface and implant bone cement interface. The engineering problems associated with implantation into the human body of prosthetic knee implants and some of the outstanding issues facing engineering designers in the growing sector of orthopedic medicine are wear debris occurrence and component loosening.

It is estimated that currently there are approximately 100 000 knee joint replacement operations conducted annually. There remain significant levels of failure. It is estimated that more than 5 percent of orthopedic implants fail due to poor design, poor material properties of the implanted device or poor surgical procedures. In general the focus is on contact area like sliding surface of femur over polyethylene is concentrated for the study. But in reality it is essential to show concentration on various design aspects like wear in pin, wear in hinge and contact surface area based on what kind of joint it is. More over the fully constrained joint is widely affected by this wear occurrence. The knee joint, however, is significantly more complex in both form and motion than the hip joint and while there has been remarkable success with knee replacement surgery also. The engineering challenges that remain are complex and demanding. Thus here the wear plays a major role and the study of wear on this material becomes important. The scope of this project is that this kind of implant can be referred to a patient with knowing the level of failure rate, the day to day activities they undergo and the impact of load, velocity and considering their million of cycle movement involved.

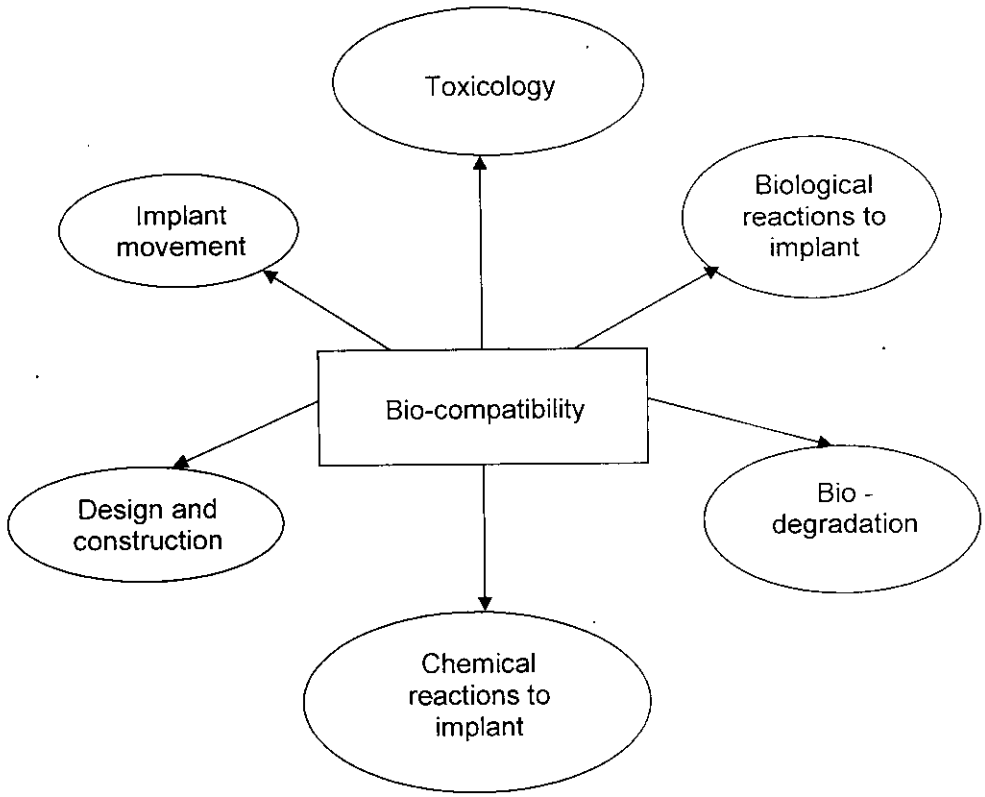


Fig 3.2 Bio Compatibility depending on variety of system parameters

As shown in figure 3.2. various parameters are taken in to account before the compatibility of the material is ensured.

The first important issue is the material's toxic property. A biomaterial should not have any toxic content in its pure state and also it should not produce any toxic substances when reacted with other foreign particles. If any such content has been found, then it should be ruled out in bio-medical application. The next factor is the effect of chemical reactions in the human body. As far as the bio material is concerned any chemical reactions happening inside the human body should not adversely affect the material.

The design and construction factor may also some times affect the compatibility; hence proper design for the implant has to be done based on the patient's body structure. Lack in proper surgical techniques may also some times affect the compatibility of the material; hence care has to be taken to adopt good surgical techniques.

Chapter 4

Introduction to Biomechanics

CHAPTER 4

INTRODUCTION TO BIOMECHANICS

Biomechanics is defined as the application of mechanical laws to living structures specifically to the locomotor system of the body. The findings of the biomechanical research, however, have led to clinical advances that play an important role both in orthopaedic practice and in the design of orthopaedic products. The design of many of today's implants, for example, relates to the biomechanical properties of bone tissue, whole bone behavior, and bone/joint relationships.

4.1 KNEE JOINT:

Although the knee is considered a hinged joint, moving back and forth in one plane, the complicated shapes of the articulating surfaces actually provide a complex interaction of gliding, rolling and rotation around a vertical axis (the vertical axis of rotation extends from the head of the femur of the medial tibial condyle). This complex interaction permits the knee to accommodate two distinct functions:

- It can lock-in or screw home as the femur rotates medially during the last part of extension, providing a high degree of stability.

- It can provide the flexibility and freedom of movement during flexion that permits walking, running or climbing because the femur rotates laterally at the beginning of flexion, unlocking the joint as the femur rolls backward on the tibia.

The knee joint is made up of the distal femur, the proximal tibia, and the patella. Although the proximal tibia and the proximal fibula articulate, the fibula is not a part of the joint; it is important to the knee function, however, because it serves as an attachment site for a knee stabilizing ligament. Between the long medial and

shorter lateral, femoral condyles in the intercondylar notch of fossa. The shallow groove between the condyles anteriorly is called the patellofemoral groove. On the tibial side, there are two expanded surfaces, the tibial plateaus. The medial tibial plateau articulates with the medial femoral condyle; the lateral tibial plateau with the lateral femoral condyle. The two plateaus are separated by a pair of tubercles. These intercondylar tubercles and the spaces between them form the tibial intercondylar eminence.

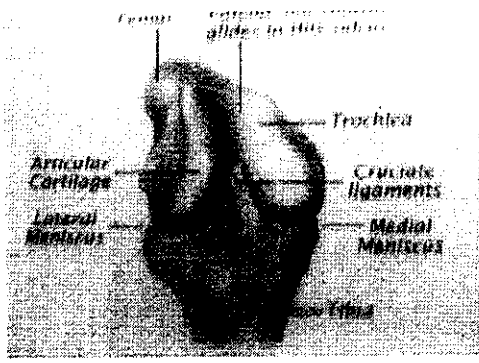


Figure 4.1(a): Artificial Knee Joint

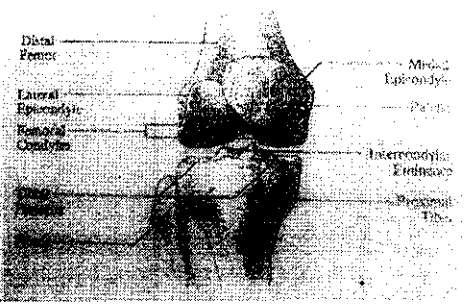


Figure 4.1(b): Human Knee Joint

The paella is a short, irregularly shaped bone - a sesamoid bone – that lies anterior to the tibiofemoral joint. Its posterior aspect, divided by a vertical ridge that fits within the pateellofemoral groove, is its articular surface. The soft tissues of the knee contribute to the joint's stability and motion.

4.1.1 Menisci:

The medial and lateral menisci are attached to each side of the tibial plateau. They aid in distributing the load of body weight, acting as shock absorbers. Their horns are attached to the intercondylar tubercles by ligaments. On the posterior tibial surface, they are joined by a ligament. The medial meniscus is firmly attached to the tibia whereas the lateral meniscus is relatively loose and mobile.

4.1.2 Ligaments:

The transverse ligament joints the menisci posteriorly and the coronary ligament attachs the horns of each meniscus to the intercondylar tubercles. The medial and lateral collateral ligaments contribute to the mediolatral stability of the joint. The criciate ligaments provide anteroposterior stability.

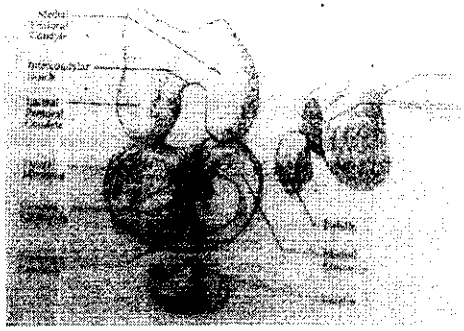


Figure 4.2: Compartments of Knee joints

4.1.3 Muscles:

The flexor and the extensor muscles of the knee provide the primary movement of a hinge joint. The flexors are the hamstring muscles, situated posteriorly (semitendinousus, semi membranes and bicep femoris muscles). The major extensors, situated anteriorly, are sections of the quadriceps, i.e., the vastus muscles and the rectus femoirs (external rotation) and the semimembranosis (internal rotation). Knee joint muscles are inverted by the sciatic nerve.

The knee joint consists of six articulating surfaces. These are usually paired, and the areas about them are referred to as compartments shown in figure 5.2. The medial compartment includes the articular surface of the medial femoral condyle, medial tibial plateau, and medial meniscus. The lateral compartment includes the articular surface of the lateral femoral condyle, the tibial plateau, and meniscus. The patellofemoral compartment includes the anterior surface of the distal femur (patellofemoral groove) and the posterior surface of the patella.

4.2 HIP JOINT:

Major bony structure of the hip joints is shown in figure 5.3. The hip joint not only permits a very wide variety and range of motion-flexion, extension, abduction, adduction, circumduction, and rotation – but also withstands tremendous pressure, pressure reaching three times body weight, or even more, in one legged stance. The hip joint is most stable in the extended position, when the femoral head is firmly within the acetabublum, articular surfaces are fully congruent, and the ligaments are taut.

The hip joint is a synovial joint of the ball-and-socket type, with the head of the femur serving as the ball, and the acetabalum serving as the socket. The acetablum forms an almost-hemispheric socket. The articular surface of the acetblum is horseshoe-shaped and has a surface area of minimal depth, creating minimal friction and maximum strength. The femoral head is actually ellipsoid, rather than spherical. It is desired up, in, and slightly forward, with most of its convexity at top and front. It is cartilage-covered expect at a posterior ovoid depression that accommodates the ligamentum teres.

The femoral neck is rather flat, pyramidial section of bone connecting the head to the shaft. Although the length and angle of the neck vary at different times of life, the angle portion of the neck has multiple foramina through which blood vessels pass while the posterior portion is smooth, broad and concave. The short, thick superior border of the neck ends at the greater trochanter. The tronchanters provide points of attachment and give leverage to muscles that rotate the femur. The area where the neck joints the shaft, midway between the lesser trochanter and the internal border of the shaft, is vertical plane of compact bone called the calcar.

The femoral head and neck form a sort of beam, placed at an angle to the shaft, which is mechanically ideal for supporting the weight of the trunk. Distally, the femoral shaft becomes, cuboid, flattened from front to back, and divides onto the condyles. The condyles are separated by a smooth depression in front, the patellofemoral groove, and a large depression at the back, the intercondylar notch. The hip joint capsule, reinforced by heavy ligaments, extends in a circle from the edge of the acetablum, going distally around the neck of the femur and inserting at the base of the femoral neck. The muscles that move the hip are innervated by branches of the lumbosacral plexus.

Figure 4.3: The Hip Joint

4.2.1 Cartilage:

The hyaline cartilage covering the articulating surface of the femur is thick at its center and thin at its circumference. The acetabular cartilage is the opposite, thin at the center, thicker at the edges. The acetablum also has a thick labrum (ring of cartilage) at its rim, increasing its depth and providing frimer seating for the femur.

4.2.2 Ligaments:

There are five important ligaments at the hip joint. The ligamentum teres. whose blood vessels supply blood to the femoral head, is not significant in strengthing the joint. The iliofemoral ligament (also called Bigelow's ligament) is the strongest ligament in the body. A Y-shaped bundle of fibres, it extends from the ilium to between the tronchanters, strengthing the anterior of the joint so the femur cannot be overextended.

The pubofemoral ligament extends from the crest bone to the capsule and the lower part of the femoral neck. It strengthens the joint anteriorly. The ischiofemoral ligaments is a broad triangular band on the posterior surface of the joint, attaching to the ischium posteriorly and the acetablum inferiorly. It crosses the capsule. The tansverse ligament crosses the capsule in a transverse plane from its attachment at the margin of the acetablum. It protects the edges of the bone and by surrounding the head of the femur, holds it in place.

4.2.3 Muscles:

The muscles in the hip joint are grouped by function: flexors, exensors, abductors, and external and internal rotors. The ilipsoas is the strongest of the flexors; the gluteus maximus is the major extensor, working with the hamstrings (tendons): the gluteus medius and minimus are abuctors and are also involved in internal rotation; the adductors (bevis, longus, ans magnus) are, of course, the adductors.

4.3 REPLACEMENTS:

A total hip replacement is now a common orthopaedic procedure. It is said that around 80000 joint replacements ate implanted every year in the world with the majority being total hip replacements says E. INGHAM et al. many total hip replacements used these days consist of a metal femoral head and ultra high molecular weight polyethylene acetabular cup. These artificial joints last over 20 years. For more than 35 years ultra-high molecular weight polyethelene (UHMWPE) has been used successfully as a bearing material in total joint replacement component says Kurtz SM, et al.

A total joint replacement system comprises of a pair of material surfaces articulating to each other to stimulate the functions of the human joints figure 4.4. From years of research and development, an artificial joint system consisting of Co-Cr alloy sliding on an ultra-high molecular weight polyethylene (UHMWPE) surface has been proven to function well because of wear resistance, biocompatibility, and durability.

The hip and knee prosthesis must bear stress values that range from the body weight, under condition o slight movement, up to four or five times higher, under condition of quick movement. Thus the articulated joint implies that the surfaces in contact and in motion between each other are subject to remarkable sliding friction. A person weighing 60 Kg ca transmit to the femoral head a maximum force of 2600 N. The time length of a walk cycle is assumed to be about 1 s for a normal step. Each femoral head receives from 1 to 2.5 million impacts in one year. The velocity of slipping of surfaces on one another is about 0.05 m/s. the rotation range for a normal step is 458 due to flexion – extension, 128 due to abduction – adduction, and 148 due to internal – external rotation.

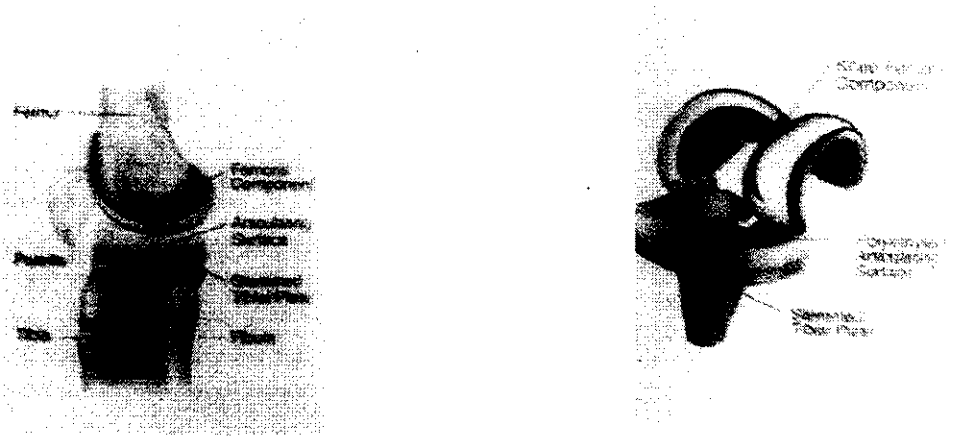


Figure 4.4: Artificial Knee Joint

4.3.1 Joint repair:

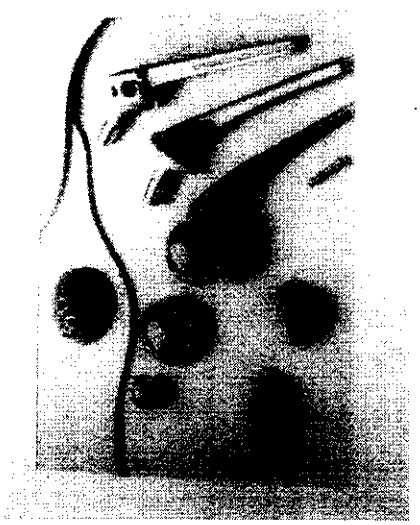
Arthroplasty is the surgical replacement or reconstruction of a joint. Total hip arthroplasty (THA), total knee arthroplasty, etc., are procedures for replacing both sides of joints with prostheses. Segments of bone are precisely excised to accommodate the appropriate size, shape, and orientation of the prostheses.

Hemiarthroplasty is the prosthetic replacement of one side of a joint. Anthroplastics are performed for treatment of fractures, including pathological fractures, and to replace arthritic joints.

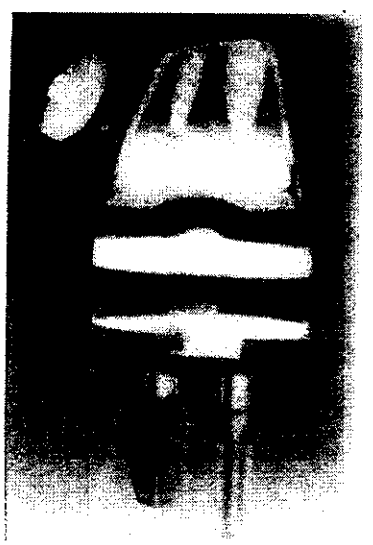
4.4 FUNCTION AND COMPONENTS:

Total joint replacement surgery is one of the most common and successful treatments for all types of arthritis and other painful conditions of the hip or knee. Joint replacement replaces destroyed or worn-out surfaces with new, uniform surfaces. For example, in an arthritic hip, the damaged ball (the upper end of the femur) is replaced by a metal ball attached to a metal stem fitted into the femur, and a plastic socket is implanted into the pelvis, replacing the damaged socket. In an arthritic knee the damaged ends of the bones and cartilage are replaced with metal and plastic surfaces that are shaped to simulate knee movement and function. Although hip and knee replacements are the most common, joint replacements can be performed on other joints, including the ankle, foot, shoulder, elbow and fingers. The materials used in a total joint replacement are designed to enable the joint to move smoothly with low friction says H.W.Fang, et al,

A joint implant is generally composed of two parts that articulate during the joint motion. In a hip, for example a metal ball is usually used to fit closely into a matching counter surface composed of UHMWPE. Several metals are used, including stainless steel, alloys of cobalt and chrome, and titanium. The UHMWPE is durable and wear resistant. It has been widely accepted for its low friction and high wear resistance. Examples of total hip and knee replacements with Co-Cr alloy and UHMWPE parts are shown in figure 5.5 while these materials are mostly used, combinations of ceramic-ceramic, metal-metal and ceramic – UHMWPE total joint systems are some other alternative materials used under special situations Bone cements made by polymers are usually used to anchor the prosthesis into the bone. Joint replacements also can be implanted without cement when a porous surface on the stems of joint replacements is proved to allow bone to grow into it.



Components of Total Hip Replacements



Components of Total Knee Replacements

Figure 4.5: Components of Total Hip and Knee Joint Replacement

Chapter 5

Introduction to Implants

CHAPTER 5

INTRODUCTION TO IMPLANTS

5.1 UHMWPE (Ultra High Molecular Weight Polyethylene):

U.H.M.W.P.E is a tough resilient, low friction type of plastic that provides a smooth surface for joint articulation. These characteristics make it an ideal material for prostheses. It is, however, much weaker than bone in tension and compression, has much lower modulus of elasticity than bone, and has a tendency to migrate (move under stress) and to crack when subjected to cyclic loading (fatigue cracking). When added to UHMWPE metal backing helps the plastic withstand stresses and transmit those evenly to cement and underlying bone.

UHMWPE ($-CH_2-$ 1 $_n$ monomer) is an interesting polymer useful in different fields such as medicines, engineering, microelectronics and biology. A special application of this polymer in medicine concerns the interface of mobile joints, such as hip and knee prostheses, where the friction can be significantly reduced using intermeddled sheets of polyethylene says Wright TM, Goodman SB.

Ultra-high molecular weight polyethylene is widely used as the bearing material in total hip and knee replacements. Polyethylene has the repeating unit chemical structure:

$$- (CH_2-CH_2)_n -$$

There are several kinds of polyethylene (LDPE, HDPE and UHMWPE) that are synthesized with different relative molecular mass and chain architectures. LDPE refers to low-density polyethylene with a relative molecular mass of less than 50,000M_r. High density polyethylene (HDPE) is a linear polymer with a relative molecular mass up to 200,000 M_r.

The molecular chain of UHMWPE can be visualized as a tangled string of wires. The chain is not static and its arrangement is a function of temperature. The molecular chain becomes mobile at elevated temperatures. When the temperature is lower than the melting temperatures, the molecular chain of UHMWPE tends to rotate along the C-C bonds and create chain folds. The chain folding leads to an ordered arrangement of molecules so as to form a crystalline region. The degree and orientation of the crystalline regions depends on its molecular weight, processing conditions and environment conditions.

UHMWPE has been used as a biomaterial for replacing failed hard tissue because of its greater impact resistance, greater wear resistance and superior biocompatibility. For example, in most advanced structure of artificial hip joint, UHMWPE is used for the socket contacted with the ceramic bone head composed of alumina or zirconia attached to the stem made of titanium alloys. Those parts are usually operated under the cyclic loading due to walking for a long time. Understanding its characteristics of UHMWPE is, therefore very important to prolong the life of the instrumentations like artificial hip joints used in the body.

UHMWPE has been widely used as an insert for one of the load-bearing, articulating surfaces in orthopaedic implants, such as the acetabular cup in hip prosthesis or tibial tray insert in the knee. This particular type of polyethylene is used because it has excellent biocompatibility and has a lower wear rate and coefficient of friction than other polymers. Gamma sterilization of UHMWPE improved the wear properties, which is important parameter for implant materials. However, its strength is low as compared to the human bone and cannot be used in other non-load bearing joint or as a possible bone substitute materials. We developed alumina ceramic particle reinforced UHMWPE composite whose mechanical properties are close to human bone. High purity alumina is a bio-inert material and widely used as load bearing articulating component designed for its excellent wear and corrosion resistance, excellent biocompatibility. In this composite, ceramic will provide the strength, like the mineral part of bone, and polymer the resilience and flexibility similar to the collagenous part of the bone. We developed an indigenous technology for producing such composite and tested the materials for its vitri stability. This type of composite will be suitable for non-

weight bearing joints replacement, bone reconstruction, vertebral bodies, temporo-mandibular joints and in plastic surgery, related to maxillofacial and craniofacial parts of human body.

5.2 METALS:

Metals used for any implant must be able to withstand varying amounts of stress and load, be biocompatible in tissue (no harmful or toxic effects), and be able to retain their characteristics in the presence of the body fluids. To achieve these goals, most of the metals used in implants today are alloys (mixtures of metals). The strength of the alloy relates to its crystalline structure, which can be modified by various techniques to prevent deformation and cracking of implants. Metal failure may be the result of overloading (too much stress) or, more commonly, metal fatigue due to cyclical stress (load applied and removed repeatedly). The varieties of laboratory tests have been developed to measure metals resistance to different types of loads; for example, tensile testing measures a metal response to axial load; testing of the metal's modulus of elasticity measures the metal's rigidity/elasticity. In prostheses, particularly, these measurement of strength are a significant part of the orthopedist's concern and therefore, should be a significant part of sales presentation; as we have indicated, stress on joint prostheses can be immense and the various parameters of metal strength are clearly very important.

Corrosion is the deterioration of metal due to an electrochemical reaction between the metal and its environment. Corrosion can manifest itself as galvanic corrosion, in which the least corrosion-resistant metal in an alloy corrodes, crevice corrosion at tight interfaces (for example, at a screw/plate interface), or pitting isolated corrosion due to break down of a corrosion-resistant film on the surface of the metal. The ideal biocompatible metal is one neither damaged by the host body nor induces a response in the host. Although modern implant metals come close to this ideal, the problem is not totally solved. Placing a material in the body is akin to placing it in a sea water-worse yet, in warm water. Body fluids contain the same corrosion-inducing minerals as sea water, only in different proportion, and corrosion process is accelerated by normal body salts, a metal implant tends to shed particles that have the potential for inducing a tissue tissue reaction. Many modern total knee or hip-joint replacements include a metallic (usually a cobalt-

chromium alloy) articulating component and a polymeric (usually UHMWPE) counter component. Among the metals used in today's implants are:

5.3 STAINLESS STEEL

Stainless Steel (type 316 LVM) in an alloy containing chromium and molybdenum, elements that retard the corrosion or rusting characteristics of iron/carbon alloys.316 LVM stainless steel is widely used in short-term trauma applications.

SS 316 L

- The addition of nickel causes the austenite structure to be maintained at room temperature. Thus, this steel is known as austenitic steel.

- Used in early hip implants for its good strength, ability to work harden pitting corrosion resistance.

- However due to potential long-term release of Ni and Cr in to the body, stainless steel are restricted to temporary devices, now used as screws, fittings and wires for orthopedics.

5.4 Vitallium

It is a cobalt/chrome alloy containing cobalt,chromium, molybdenum and carbon. It has excellent corrosion resistance. Biocompatibility, and wear resistance and makes it suitable for long –term implantation.. Vitallium implants are generally produced by a casting process that is well suited for complex geometries of orthopedic implants. Recent advances in metallurgy have made it possible to forge vitallium into an alloy called vitallium –FHS which has increased strength without loss of its corrosion resistance or biocompatibility.

5.4.1 CoCrMo Alloys

- Similar tot Co alloys used for turbine blades in early gas turbine engines (satellite)

- Used in both cast condition and wrought condition. However, the wrought condition provides superior mechanical and chemical properties due to finer grain sizes and a more homogeneous microstructure

- Coherent stable passivation layer (10 nm) gives excellent corrosion resistance

- Excellent wear resistance

- Problem: potential release of harmful Co, Ni and Cr ions in to the body

5.5 Titanium

It is another metal with good corrosion resistance and biocompatibility. It can be processed to achieve relatively high fatigue strength. It has low elastic modulus.

- Commercially pure Ti used in dental implants

- Ti6A14V - Investment cast hip and knee implants

- Coherent stable passivtion layer (10 nm) gives excellent corrosion resistance

- Resistant to stress corrosion cracking and corrosions fatigue in body fluids

- One of few materials that permits bone growth at the interface

- However, titanium has unsatisfactory wear resistance and may reduce wear debris

5.6 BONE CEMENT:

Polymethyl-methacrylate (PMMA), or bone cement evolved from arcrylics used originally in dentistry, in the 1930s. cementing system provide high strength and an easyto use procedure. However, bone cement continues to be the most frequent cause of prosthetic failure for a number of reasons, which include its;

- Relative lack of strength in comparison to both bone and implant materials

- Improper use of cement as a substitute for inadequate bone, rather than as a filler between bone and prostheses;

- Improper preparation of the cement or of the bony area receiving the cement;

- Inadequate application of pressure to insert the cement
- Use of too thin or too thick a cement mantle, which affects the stress response of the material.

5.6.1 GENERAL CHARACTERISTICS OF BONE:

a. Brittleness:

Compared to other body tissue, bone is brittle, that is, after bending relatively slighter, it breaks. Within the small area of bend, however it is elastic and assumes its original shape without deforming. Blackboard chalk is similar to bone in terms of brittleness (although it is more brittle than bone); it breaks primarily as a result of tension stress during bending or twisting.

b. Poor shock resistance:

Because bone will bend only slightly before fracturing, it is poor at absorbing a shock load in comparison to material such as spring steel, which is otherwise similar to bone in terms of its elasticity and its tendency to break when it bent beyond its elastic limits.

c. Weak Resistance to Tension Stress:

It is the pressure exerted on a substance by stretching it; its opposite would be compression stress. Bone withstands a compression stress about one-third better than tension.

d. Good Shear Resistance:

Resistance to shear force, that is, force that causes a parallel sliding motion of bone planes in opposite directions, is good in bone.

e. Not Homogeneous:

The presence of vascular (blood supply) channels in bone, such as in the haversian system of component bone, means that bone is not uniformly dense. Vascularity reduces bone's ultimate breaking strength.

These are the characteristics of the bone. The prosthetic device that is replacing this bone should satisfy the respective functionalities. The bone which is placed in our body is serving so many functions out of which the implant material which are replacing their position of the bone should have the two main functionalities which have been said above.

Chapter 6

Surface Engineering

CHAPTER 6

SURFACE ENGINEERING

6.1 Definition

An engineering component usually fails when its surface cannot adequately withstand the external forces or environment to which it is subjected. The choice of a surface material with the appropriate thermal, optical, magnetic and electrical properties and sufficient resistance to wear, corrosion and degradation, is crucial to its functionality. Sometimes technological progress and manufacturing efficiency may be constrained solely by surface requirements. For example, the fuel efficiency and power output of gas turbines or diesel engines are limited by the ability of key components to withstand high temperatures. However, it is often impractical, inefficient or uneconomical to manufacture components from a bulk material simply for its surface properties - far better to use a cheaper, more easily formed underlying material and coat it with a suitable high performance film. The resulting product conserves scarce material resources, performs better than the original and may well be cheaper to produce.

Improving the functionality of an existing product is only one aim of surface engineering. New coatings and treatment processes may also create opportunities for new products which could not otherwise exist. For example, satellites could not function, nor could modern power plants operate safely, without the application of advanced surface engineering techniques.

The economic benefits of surface engineering are enormous. According to a report by RCSE staff, in 2005 the value of the UK coating market is approximately £21.3 billion, and those coatings critically affect products with a value greater than £143 billion (Source: "2005 Revisited; The UK Surface Engineering Industry to 2010", A Matthews)

In brief, surface engineering is relevant to all types of products. It can increase performance, reduce costs and control surface properties independently of the substrate, offering enormous potential for:

- Improved functionality
- The solution to previously insurmountable engineering problems
- The possibility to create entirely new products
- Conservation of scarce material resources
- Reduction of power consumption and effluent output

6.2 Classification

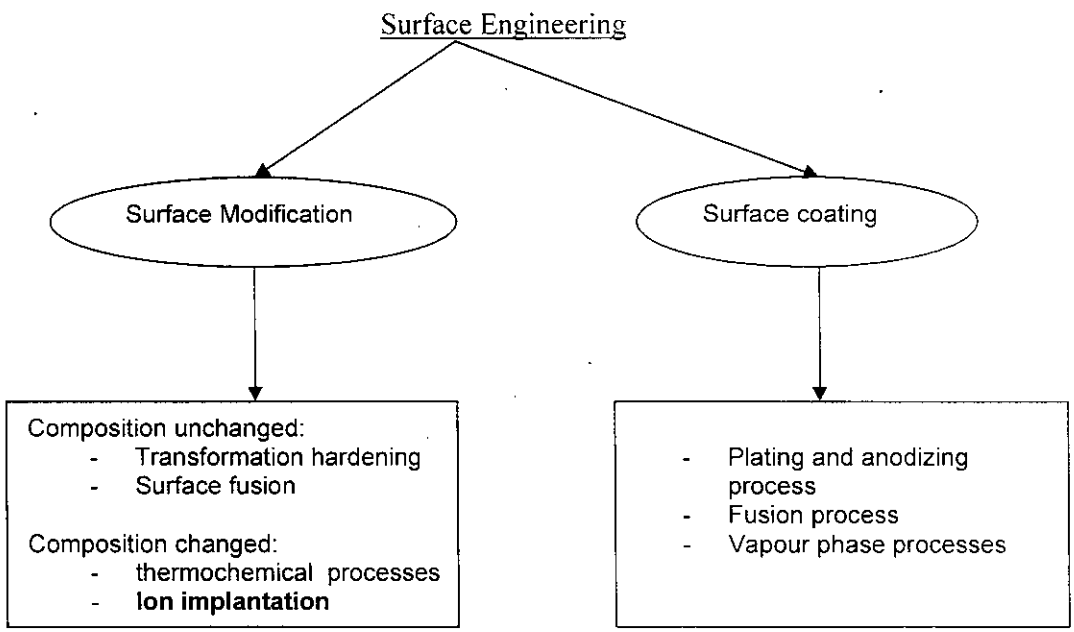


Fig 6.1 Classification chart

Chapter 7

Ion Implantation Techniques

CHAPTER 7

ION IMPLANTATION TECHNIQUES

7.1 Conventional ion implantation

Ion implantation is a high technology approach for modifying surface properties of materials. It is similar to a coating process, but it does not involve the addition of a layer on the surface. Originally developed for use in semiconductor applications, and still used extensively in that capacity today, ion implantation uses highly energetic beams of ions (positively charged atoms) to modify surface structure and chemistry of materials at low temperature. The process does not adversely affect component dimensions or bulk material properties.

Many surface properties can be improved with ion implantation including hardness and wear resistance, resistance to chemical attack, and reduced friction. The process can be applied to virtually any material, including most metals, ceramics and polymers; however, the effects of the process are typically material-specific. Examples of components treated with ion implantation are Ti and Co-Cr orthopedic prostheses, which are made harder and more wear resistant with the process and silicone rubber catheters, which are made less tacky and more water wettable for improved insertion and biological compatibility.

The ion implantation process is conducted in a vacuum chamber at very low pressure (10^4 -10^5 torr). Large numbers of ions (typically 10^{16}-10^{17} ions/cm^2) bombard and penetrate a surface, interacting with the substrate atoms immediately beneath the surface. Typical depth of ion penetration is a fraction of a micron (or a few millionths of an inch). The interactions of the energetic ions with the material modify the surface, providing it with significantly different properties than the remainder of the material. Specific property changes depend on the selected ion beam treatment parameters, for instance the particular ion species, energy, and total number of ions that impact the surface.

Ion implantation offers numerous advantages for treating component surfaces. A primary benefit is the ability to selectively modify the surface without detrimentally affecting bulk properties, largely because the process is carried out at low substrate temperatures. The process is also extremely controllable and reproducible and can be tailored to modify different surfaces in desired ways. Although it is a line-of-sight process, specialized fixturing can be used to uniformly treat complex geometries. Fig 7.1 shows the schematic diagram of conventional ion implantation set up.

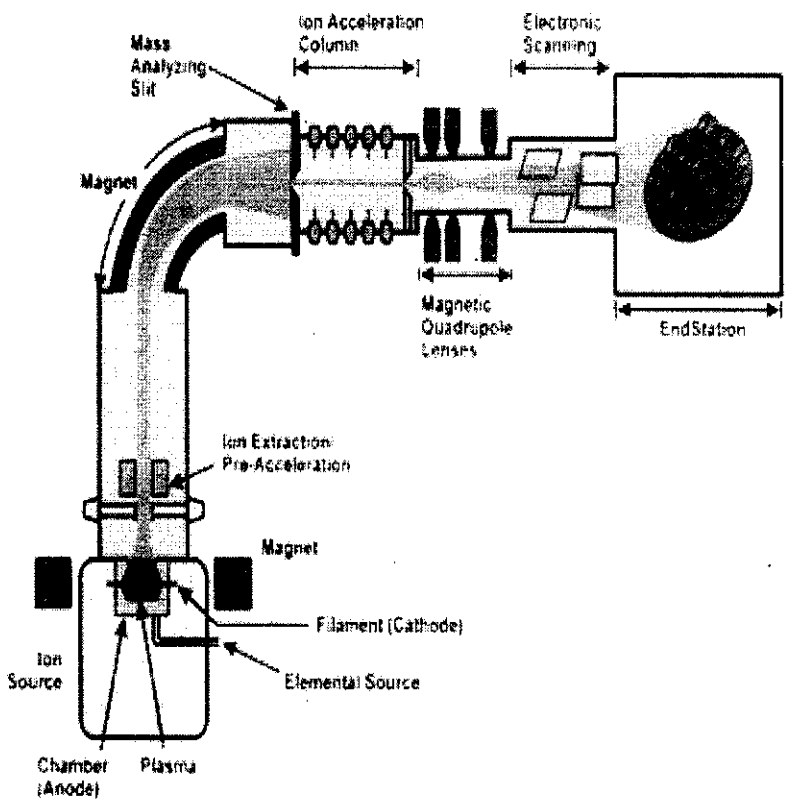


Fig 7.1 Schematic diagram of Ion Implantation set up

7.2 Plasma source ion implantation

Plasma source ion implantation method is a room temperature plasma-based, surface enhancement technology that uses an ionized gas surrounding a target and high-negative voltage, high current pulses to accelerate ions into a target surface from all directions. Ion implantation can modify the target surface in beneficial ways, making it harder, reducing the co-efficient of friction and enhancing the resistance to corrosion.

This process was originally patented by John Conrad of university of Wisconsin, Madison, and has been further developed and demonstrated at industrially relevant scales by researchers at Los Alamos in collaboration with the University of Wisconsin and General Motors Research.

Advantages:

1. Ions are accelerated into the target through a plasma sheath that surrounds the target, so there is no requirement of an unobstructed path from a singles ion source to the surface being treated

2. This process allows treating multiple target surfaces without the need for in-vacuum manipulation of the target assembly.

3. The average ion current to the target surface can be more than the order of magnitude larger than using conventional technique.

Fig 7.3 shows the block diagram of plasma source ion implantation. The apparatus consists of a vacuum chamber where the material to be treated is placed at right position. The desired gas is allowed to flow in to the vacuum chamber. The plasma generator is a mechanical device which converts the gas in to plasma state. The high voltage pulser makes sure that the positive ions are implanted in the target material. The cooling chamber maintains the whole process to take place at low temperature.

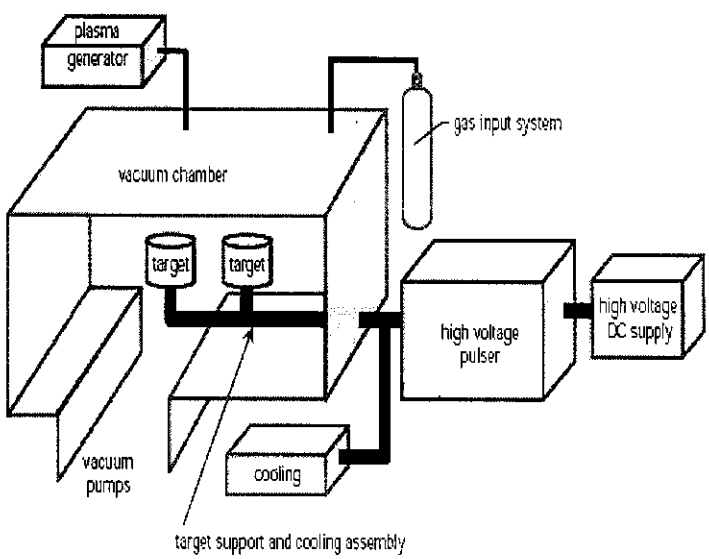


Fig 7.2 Block diagram of typical PSII system

7.3 Ion Beam Assisted Deposition

Ion Beam Assisted Deposition (IBAD) is a thin film deposition process that combines evaporation with concurrent ion beam bombardment in a high vacuum environment. The evaporant (or coating) material is produced using a high power electron beam. Components are placed in the vapor, and individual coating atoms or molecules condense and stick on the surface of the component to form the coating. Simultaneously, highly energetic ions (100-2000 eV) are produced and directed at the component surface. The component is situated at the intersection of the evaporant and ion beam

The concurrent ion bombardment differentiates IBAD from other thin film deposition techniques. It significantly improves adhesion, and permits control over film properties such as morphology, density, stress level, crystallinity, and chemical composition. Ion bombardment intermixes coating and substrate atoms and eliminates the columnar microstructure often observed in conventional, low temperature physical vapor deposition to create very dense, adherent film structures.

IBAD is capable of depositing many different types of metallic and ceramic coatings. Examples of metallic coatings include silver, gold, platinum, and titanium. These films are typically used for increasing biocompatibility and providing conductivity, or for increasing radiopacity. Silver coatings are also used to create antimicrobial surfaces on percutaneous and implantable medical devices. Representative ceramic coatings include aluminum oxide, silicon dioxide, titanium nitride, and aluminum nitride. These coatings are used primarily for improving wear resistance.

The schematic diagram of ion beam assisted deposition is shown in the fig 7.3. this process also can be one of the optimal treatment to improve the wear resistant property of bio materials.

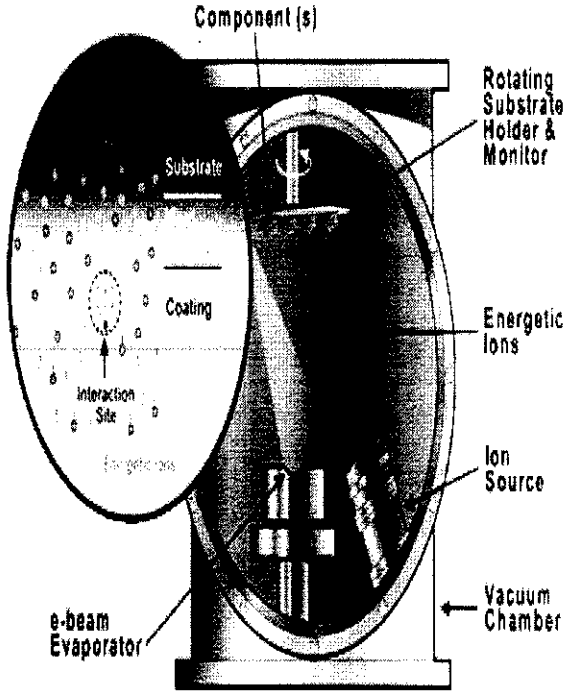


Fig 7.3 Ion beam assisted deposition

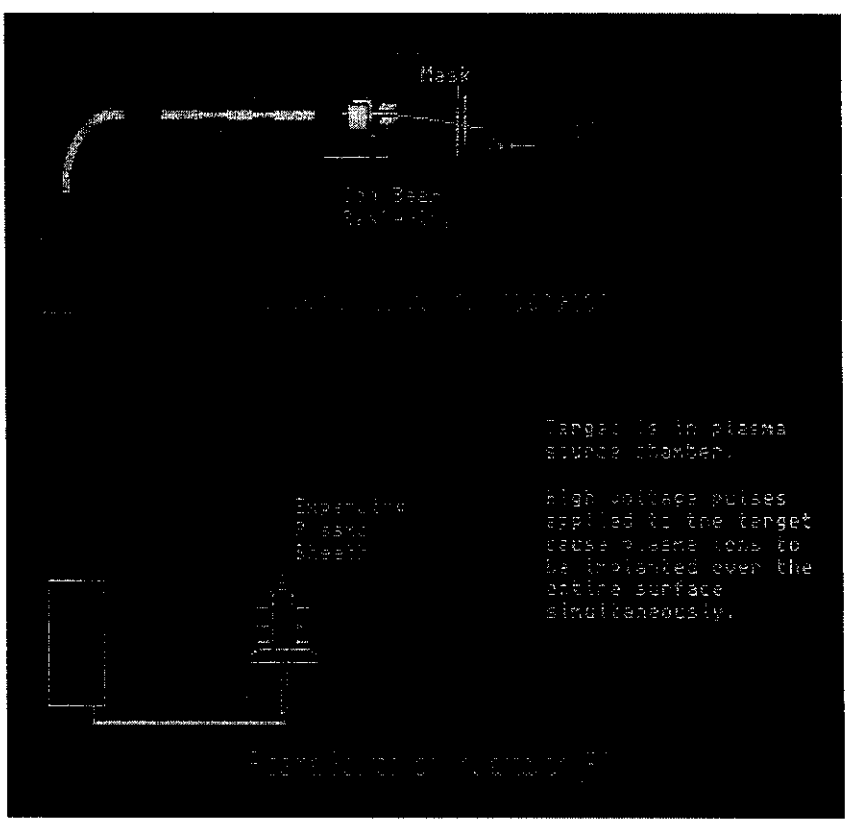


Fig 7.4 Comparison between conventional and plasma source ion implantation

7.4 Comparison between conventional and plasma source ion implantation

1. As clearly shown in figure 7.4, the target material is placed in a different chamber in conventional ion implantation method, but where as in plasma source ion implantation the target material is placed in the same chamber where plasma is produced.

2. Since the target material is placed in the plasma chamber, 3D ion implantation is possible in case of plasma source ion implantation, but in case of conventional ion implantation 3D irradiation is not possible.

3. In plasma source ion implantation, more number of target materials can be treated at one shot, but in case of conventional ion implantation more number of target materials cannot be treated at the same time.

4. When time comparison is taken in to account, plasma source ion implantation technique is more efficient than conventional ion implantation technique.

Chapter 8

Material procurement and specimen preparation

CHAPTER 8

MATERIAL PROCUREMENT AND SPECIMEN PREPARATION

The material was supplied by Stann Bio-med Engineering Pvt ltd., coimbatore. M/S Stann Bio-med Pvt Ltd is a TUV company, which was established during the year of 1983. The company is located at coimbatore and they are leading manufacturers of implants and general surgery instrument. They are successful in making Hip and Knee implants. They are also manufacturing surgical beds and X ray C frame bed. The material was prepared by ram extrusion method from the UHMWPE (Ultra High Molecular Weight Polyethylene) powder. Fig 8.1 shows the photographic image of the raw material.

The raw material purchased is in two forms (rod and sheet). The diameter of the rod is 10 mm and height is 1 feet. The length of the sheet form is 22 mm, width of the sheet form is 22 mm and its height is 1 feet. The raw material purchased is machined to the desired dimension at High Line Engineering Works, Coimbatore. The final dimension of the sheet material is 20*20*25 mm and 10 pieces are obtained. The final dimension of rod material is Ø 10 mm, height 16 mm and 12 pieces are obtained. Then all the pieces are rubbed with emery paper of grade 400. 600 and 800. fig 8.2 and fig 8.3 shows the photographic image of specimens.

Fig 8.1 photographic image of raw material

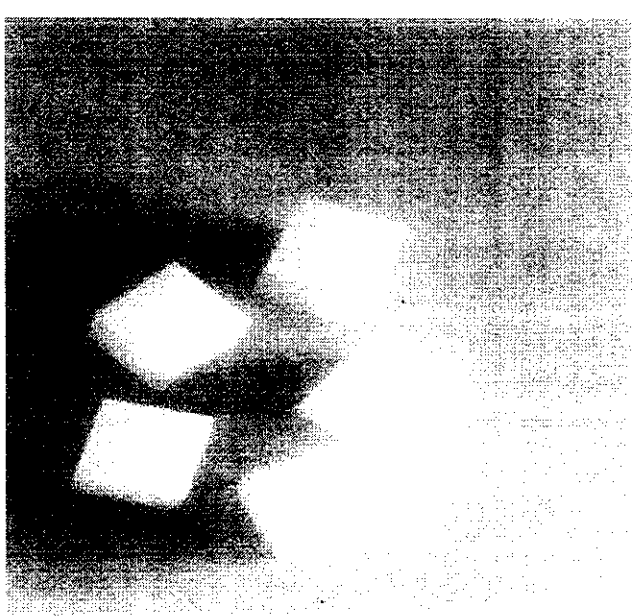


Fig 8.2 photographic image of rectangular form specimen

Fig 8.3 photographic image of rod form specimen

Chapter 9

Treatment Details

CHAPTER 9

TREATMENT DETAILS

The experiment was conducted at IGCAR in Kalpakkam, Chennai. The machine used for the experiment is 150 KV ACCELERATOR. The photographic image of the machine is shown in the fig 9.1 and fig 9.2.

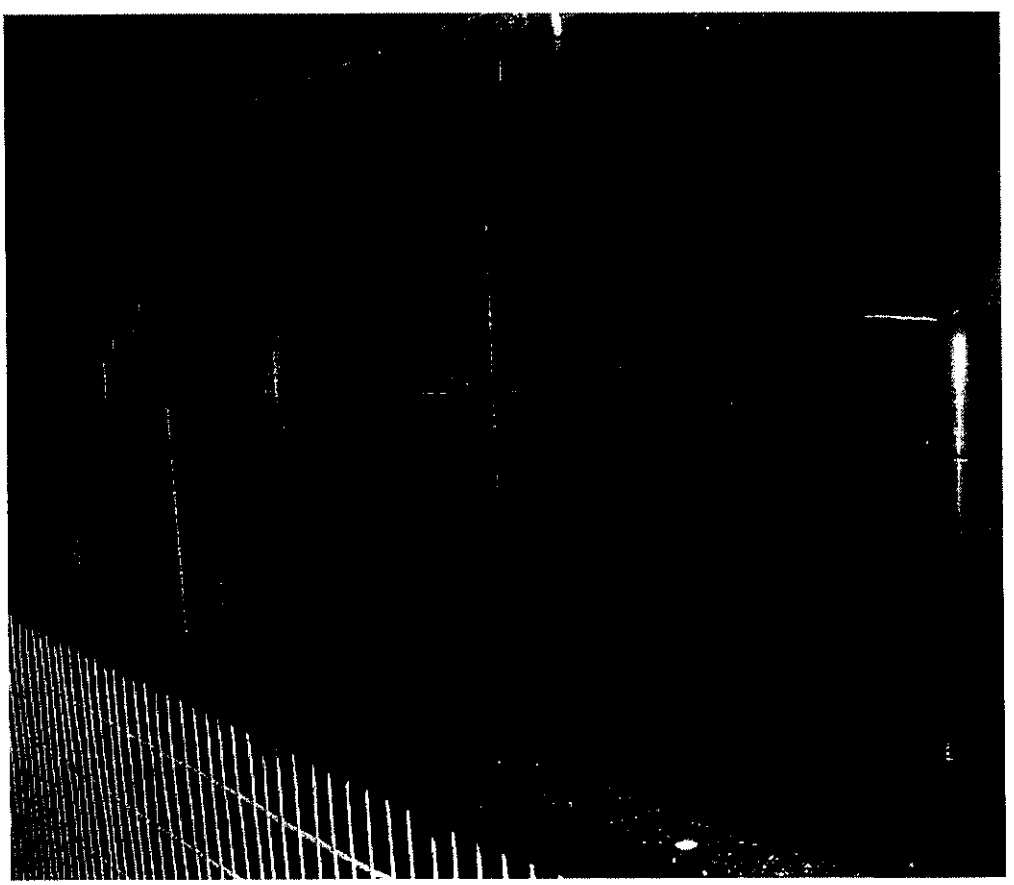


Fig 9.1 150 KV ion accelerator

Fig 9.2 Phase view of 150 KV ion accelerator

9.1 Machine components

The four major components of 150 KV ion accelerator are

1. High voltage power supplier
2. Ions generation area
3. Accelerating tube
4. Mass analyzer magnet
5. Target chamber

The ions generation area consists of a gas bottle, plasma tube, RF oscillator and gas line which are all placed inside an aluminium dome. There is also a separate line which connects the HV power supply device with the ion source.

The next component is the accelerating tube which maintains the potential gradient and hence allows the increase in velocity of ions. Mass-analyzing magnet selects only those ions of a desired species, isotope, and charge state and allows to pass through it. The target chamber is the area where the target material is fixed. The material holder in the target chamber is rotatable.

9.2 Working principle

The desired gas is fed into the gas bottle which will be placed inside the aluminium dome and this gas will be directed to the plasma tube through a needle valve. The plasma of the gas will be generated in the plasma chamber using the RF oscillator. The plasma of the gas will be in the neutral state.

One end of the plasma tube will be connected to the positive charge and the other end will be grounded. When high voltage is applied with the help of high voltage power supply device, the positively charged ions will gain energy and move towards the ground side of the plasma tube into the accelerating chamber. The potential gradient will be maintained throughout the tube. The

Mass-analyzing magnet selects only those ions of a desired species, isotope, and charge state and allows passing through it and striking the target material. The beam of ions will be guided through the series of lens and will be allowed to strike the target material.

9.3 Experimental Procedure

1. The Helium gas was filled in the gas bottle and it was placed inside the aluminium dome.

2. The vaccum was created inside the chamber with the help of vaccum pump.

3. The helium gas was allowed to pass through the needle valve into the plasma tube.

4. Ultra high molecular weight polyethelene specimen was fixed in the target chamber.

5. Initially the energy level was set to 80 KeV and the dose of $5x10^{16}$ ions/cm^2 was allowed to strike the target material.

6. 1 KeV stands for 1,000 electron volts. An electron volt is a measure of Energy used in atomic and nuclear physics. It is the amount of energy that an electron gains when it moves through a potential difference of 1 volt.

7. It is a very small unit of energy in everyday terms, but it is large enough to accelerate ions to very high speeds.

8. Similarly the experiment was conducted at 100 KeV and 120 KeV for the dose of 5x1016 ions/cm^2 and the treatment was done.

9. The parameters used for the treatment of material are shown in the table 9.1.

Table 9.1 – Treatment Parameters

MATERIAL	**ENERGY LEVEL** (KeV)	**DOSE** (ions/cm^2)	**VACCUM PRESSURE** (torr)	**TEMPERATURE** (°C)
UHMWPE	80	$5x10^{16}$	$2.8x10^{-7}$	40
UHMWPE	100	$5x10^{16}$	$2.8x10^{-7}$	40
UHMWPE	120	$5x10^{16}$	$2.8x10^{-7}$	40

Chapter 10

Wear test and result analysis

CHAPTER 10

WEAR TEST AND RESULT ANALYSIS

10.1 Pin on disc wear test

Many different experimental arrangements have been used to study sliding wear. Laboratory investigations of wear are usually carried out either to examine the mechanisms by which wear occurs or to simulate practical applications and provide useful design data on wear rates and coefficients of friction. For both purposes, control and measurement of all the variables, which may influence wear, are very important. It is vital to appreciate that wear rate and friction are often critically dependent on the sliding conditions; apparently minor changes in conditions can lead to radical changes in the dominant mechanism and associated rate of wear. Close control and monitoring are essential if the results of the test are to be useful either as a simulation of practical application, or for wider scientific purposes.

The pin on disc wear tests used in our study cannot replicate all the tribological conditions found in the artificial hip/knee. For example, there is no simulation of real-time degradation of UHMWPE, a multidirectional friction force and time dependent loading, all of which can accelerate the wear of UHMWPE. As a result the wear in these simplified simulations is often lower than is found clinically. The most common asymmetric test rigs employ a pin pressed against a disc, either on the flat face or on the rim, a block loaded against a ring or a pin on a flat. In these cases the contact may initially be over an extended nominal contact area, or only at a point or a line.

In asymmetric arrangements one component of the mating pair, commonly the pin or block, is usually treated as the specimen, and is the component for which the

wear rate is measured, while the other; often the disc, flat or ring is called counter face.

10.2 Technical details of the equipment

The technical specifications of the equipment used for conducting the wear test is shown in table 10.1

Table 10.1 Technical details of the equipment

S. No.	Description	Units	Size
1	Sample disc size	mm	168 x 8
2	Disc rotation speed	rpm	31-2000
3	Pin dimension	mm	6,8,10,12
4	Normal load	N	5-200
5	Test duration	hrs	0-99.59.59
6	Electrical	VAC	230/1/50
7	Power	Kva	2
8	Motor	Seimens, 6 terminal, 1415 rpm, 1.5kw flange mounted	

10.3 Experimental procedure

- Make sure that the electrical connections to the equipment are rightly connected. Before switch ON the main supply, confirm it with the circuit map provided by the manufacturer. Once the machine is ON, LED on the control panel started displaying its own values as said above in DAS.

- Check whether the loads in the lever arm are in the removed stage. Should be in unloaded condition if not that is to be done.

- The Allen screws in the slide ways are to be loosed to fix the disk in the disk holder and to keep the track diameter.

- Linear LVDT shows the wear; its displacement range is ±2000μm about mean position of its plunger. The display of the wear always should be with ±20μm. this can be achieved through the mild adjustments of the knurled cylinder near the LVDT. These things are to be done after loading.

- The sliding velocity can be fixed up with its corresponding rpm values having a constant track diameter. The speed can be adjusted by rotating the threaded knob.

- Sliding distance of the specimen can be fixed up by giving duration for carry out the experiment by setting the required hours and starting the timer. Having pressed the small reset button and enter button, the values can be set by increasing mode.

- The pin can be fixed up now with its respective sample holders independent of its specimen size by means of Allen screws. Pins are to be clamped in a gentle manner that it should have more than 85% contact with its counter surface.

- After fixing up the knobs, switches, and in the lever arm the screw is to be adjusted so the pin comes in contact with the counter surface (here the case is stainless steel) completely indicating the load applied on the other side is acting on the surface through the pin. This is considered to be normal load.

- Finally once overcome the things done to it the machine can be started by pressing the START button on the control panel. And the countdown starts from the fixed time.

- Emergency STOP is in the equipment in case of any emergency this can be used.

- The motor can be stopped anytime before auto shut off by pressing MANUAL STOP. Timer, however, will continue. Pressing, START, may restart it.

- It will display "SET" if timer is set at 0000 RPM indicator is based on measurement of period of revolution. At very low RPM, display is held for many seconds if motor is stopped suddenly.

10.4 Experimental method and parameters used

The materials pin and the disk are made in the required form and this has to be fixed into the correct position in the equipment holder mainly the pin and disk holders. Before the specimens are to be fixed up onto the holders the initial weight of the pin is to be found out. The pin should be in the firm position so that it should not be slipped due to the vertical load. The test is carried out as per the procedure mentioned in the above part.

The parameters used in for conducting the experiment are shown in the table 10.2.

Table 10.2 Parameters used in the experiment

Parameter	Unit	Value
Sliding distance	m	1000
Contact stress	MPa	2.5
Sliding velocity	m/s	2

After testing has been done the samples are removed and the weight loss of the specimen is measured. Then the difference in the weight loss has to be found out by comparing the initial and final weight. The volume of the wear is calculated from the mass loss of the sample and density of the sample.

The results from the wear tests can be presented in three forms- the volume of material lost due to wear, the wear rate or wear factor. The volume of the material lost due to wear is simply the primary data from the experiment and does not account for the experimental conditions. The wear rate can be defined as the volume of material lost due to wear per unit of sliding distance.

Wear rate = volume loss due to wear/ sliding distance (mm^3/m)

The wear factor is derived from the wear rate but also accounts for the magnitude of the applied load.

Wear factor= volume loss due to wear/sliding distance x load (mm^3/Nm)

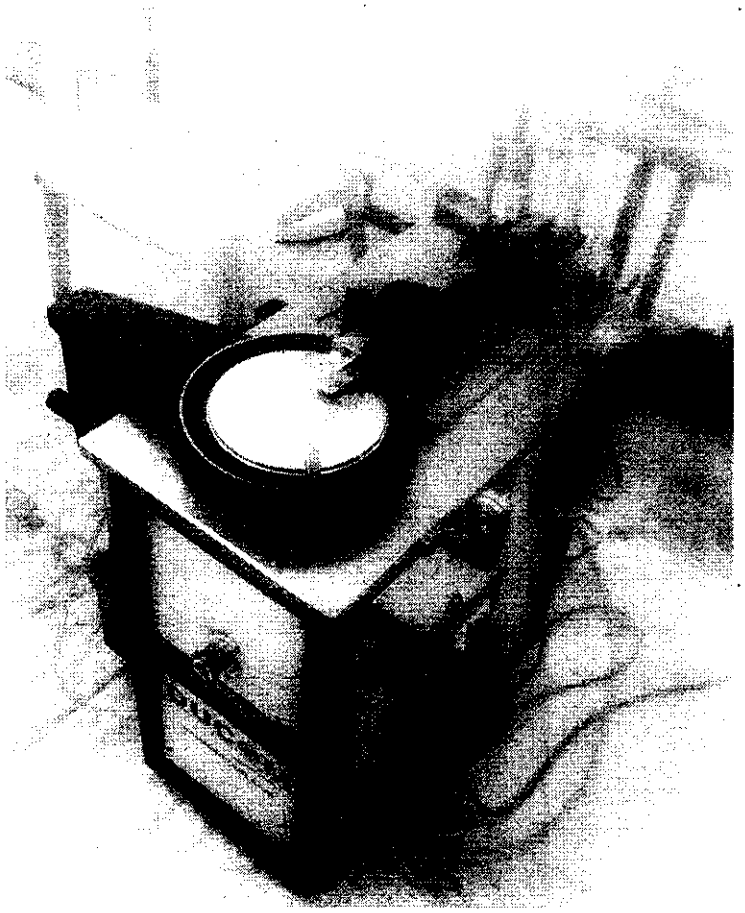


Fig 10.1 Pin on disc test rig

10.5 Results and discussions

Set of UHMWPE after treatment at three energy levels are taken along with untreated samples for the wear test. The comparison of the weight before and after wear for the virgin material and the treated material is shown in table 10.3.

Table 10.3 Weight of samples before and after wear

Material condition	**Energy levels** (KeV)	**Weight before wear** (gms)	**Weight after wear** (gms)	**Weight loss** (gms)
Virgin	-	1.2271	1.2240	0.0031
Treated	80	1.2372	1.2368	0.0004
Treated	100	1.2506	1.2490	0.0016
Treated	120	1.2513	1.2489	0.0024

From table 10.3 it is very clear that the wear is more in virgin material than in the treated samples. When the treated samples are compared, it is clear that the wear occurring in the treated sample of 80 KeV is less compared to the treated sample of 100 KeV and 120 KeV. Hence we can say that the sample treated at 80 KeV has got more wear resistance characteristic than the sample which was treated at 100 and 120 KeV.

Fig 10.2 shows the graph which is plotted showing the relation between the weight loss at various energy levels of the treated samples. From this graph it is clear that the weight loss is very less in the sample treated at 80KeV.

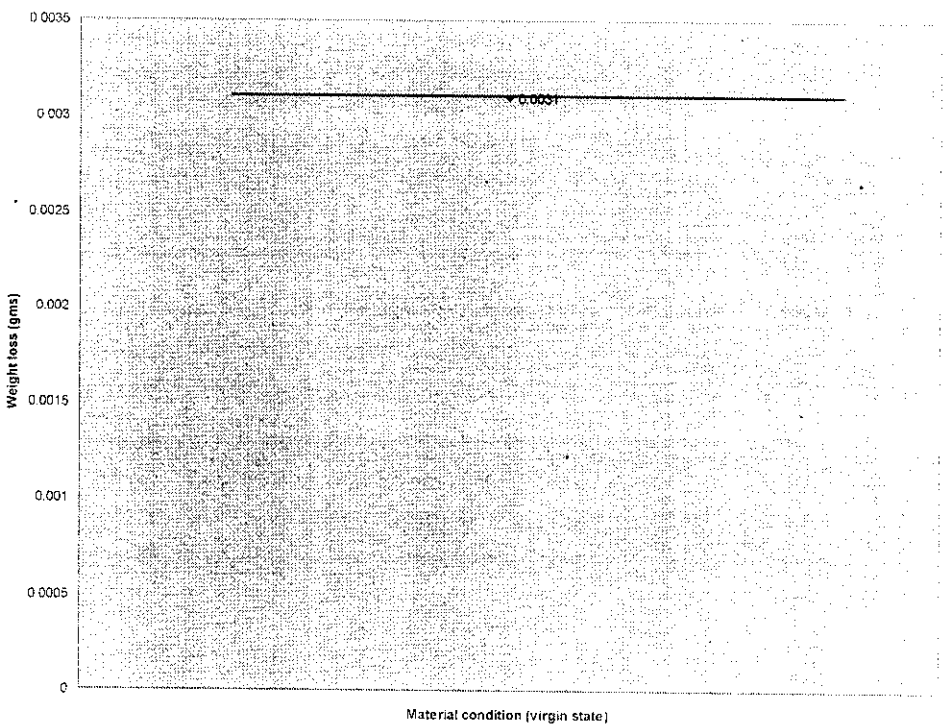


Fig 10.2 Graph showing the weight loss of the virgin sample after wear

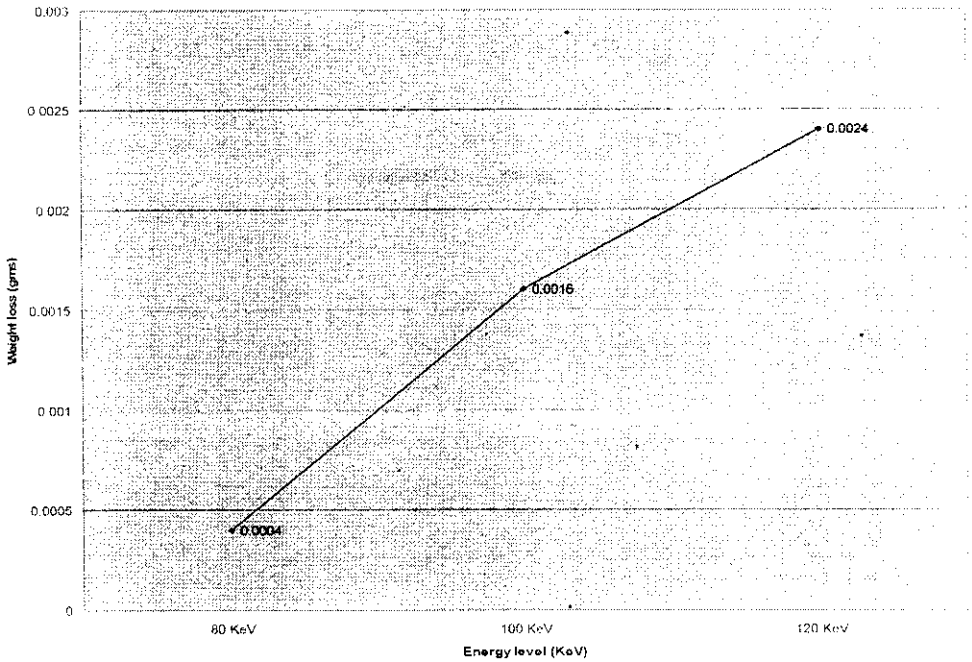


Fig 10.3 Graph showing the weight loss of treated samples after wear

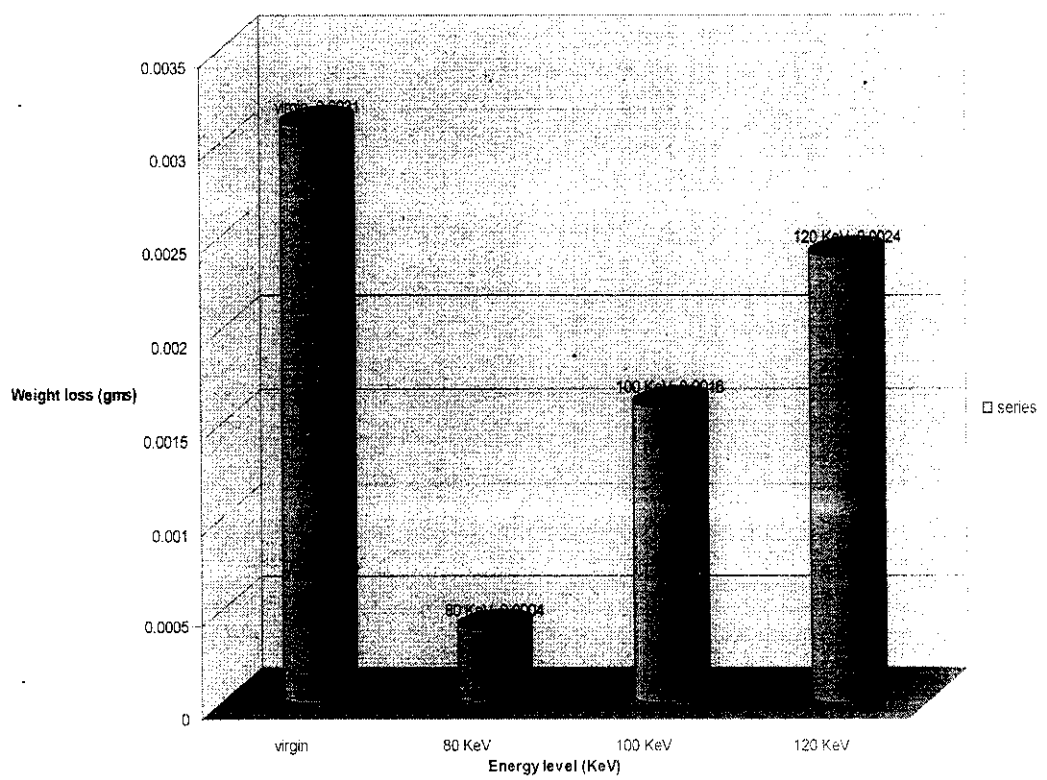


Fig 10.4 Column chart showing the difference in weight loss of samples after wear

The wear can be represented in terms of volume loss. The volume loss of the sample material can be found out by knowing the weight loss and the density of the material. Table 10.4 shows the volume loss of the un-treated and treated samples. Figure 10.4 shows that the wear is less in case of the sample treated by ion implantation at 80 KeV.

Table 10.4 Volume loss of the treated and untreated samples

Material condition	**Energy level** (KeV)	**Density** (g/cm^3)	**Weight loss** (gms)	**Volume loss** (mm^3)
Un- treated	-	0.945	0.0031	3.280
Treated	80	0.945	0.0004	0.4232
Treated	100	0.945	0.0016	1.6931
Treated	120	0.945	0.0024	2.5396

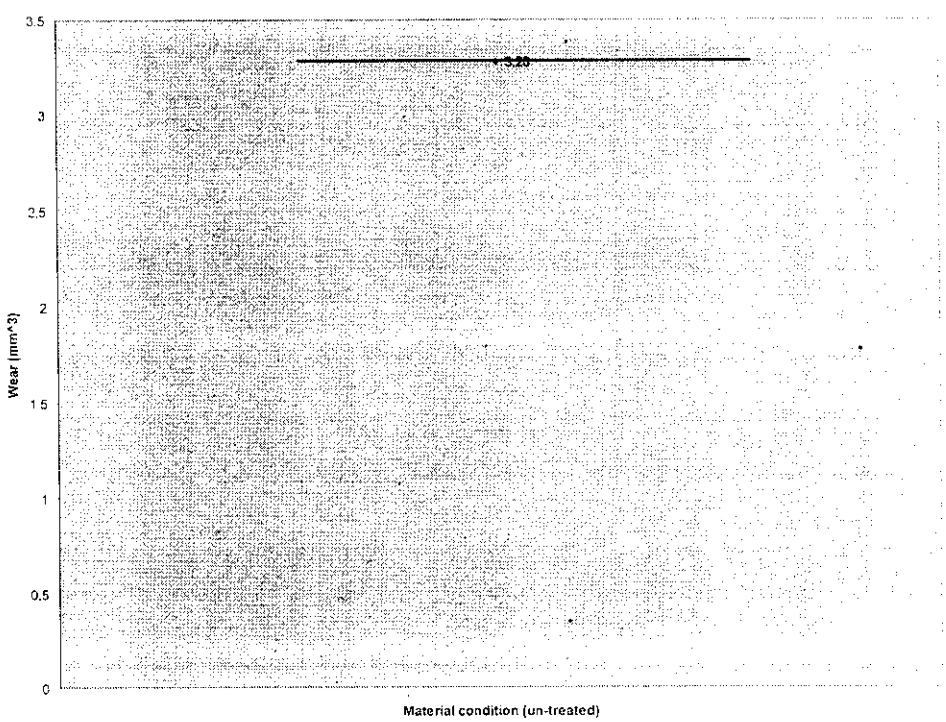


Fig 10.5 Graph showing wear of untreated sample

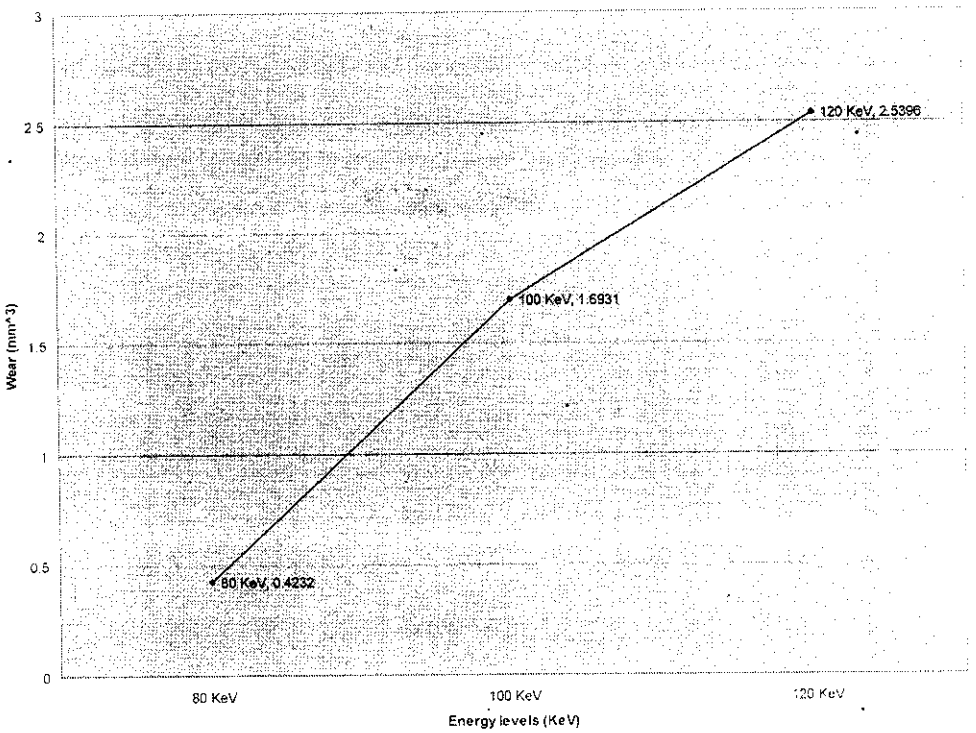


Fig 10.6 Graph showing wear of treated sample

Chapter 11

Conclusion

CHAPTER 11

CONCLUSION

- Bio Materials should ensure two aspects to be fulfilled, (ie) Bio-compatibility and Bio- functionality. If any one of the above mentioned aspects are disturbed, then it loses its fame to be a Bio-material.

- The failure of UHMWPE happens due to the formation of wear debris caused due to friction and this formation of wear debris leads to the loss in Bio-functionality.

- Since the melting point of UHMWPE is 135°C surface treatments are more applicable than heat treatments to improve the property of the material.

- There are various surface treatments available such as ion implantation, plasma source ion implantation, plasma immersion ion implantation, ion beam assisted deposition, etc....

- In this work the UHMWPE material has been treated with ion implantation technique and this technique proved to be an effective technique enhancing abrasive wear performance.

- Obtained results indicate that UHMWPE polymer suffers strong modifications when subjected to ion implantation treatment.

- The treatment has been done at three energy levels (80KeV, 100KeV, 120KeV) and the results show that all the three treated samples have got more wear resistance when compared to un-treated sample of UHMWPE.

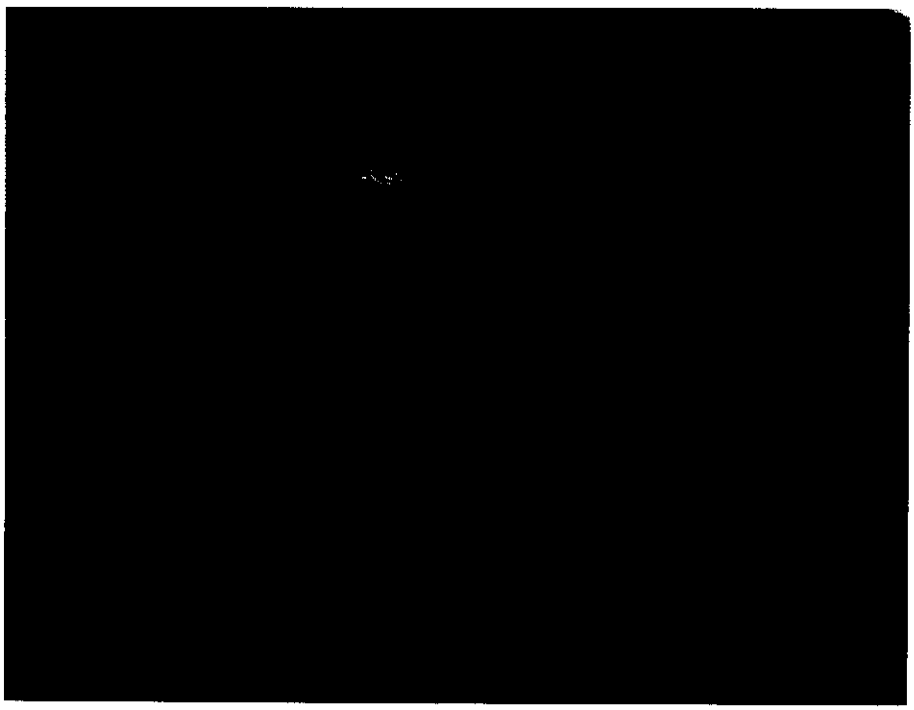
- Further when the results have been compared between the samples done at three energy levels, it shows that the sample which was treated at 80KeV has more wear resistance than the other two energy levels.

- The analysis of the wear test results shows that at lower energy levels the treated material exhibit better performance.

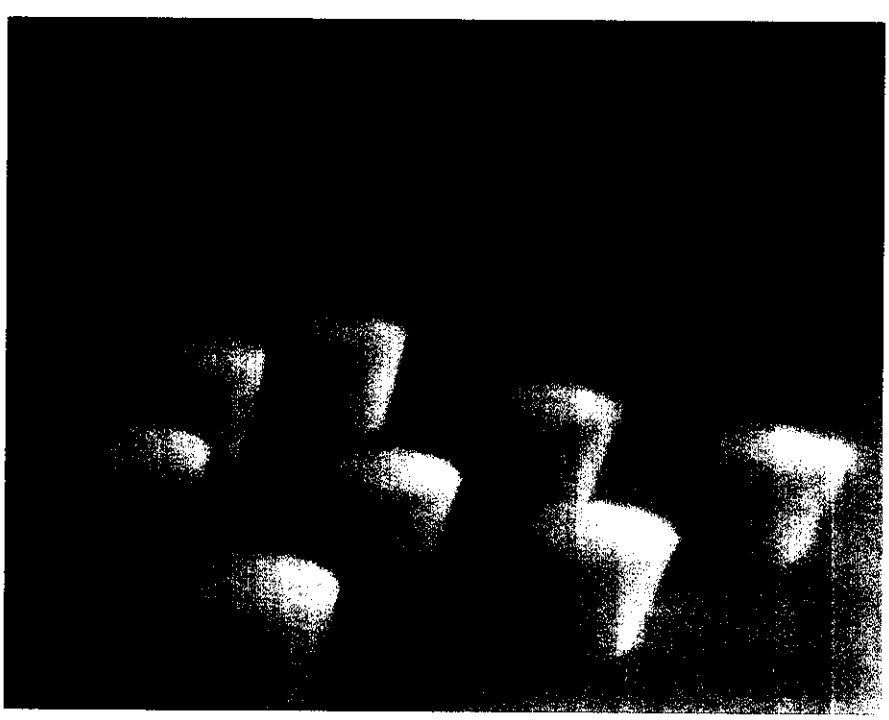
In conclusion, the new properties given to the UHMWPE surface by ion implantation treatment are very interesting to improve the functionality of mobile prostheses. Ion implantation treatment reduces the wear and hence a better performance of the material is achieved.

Appendix 1

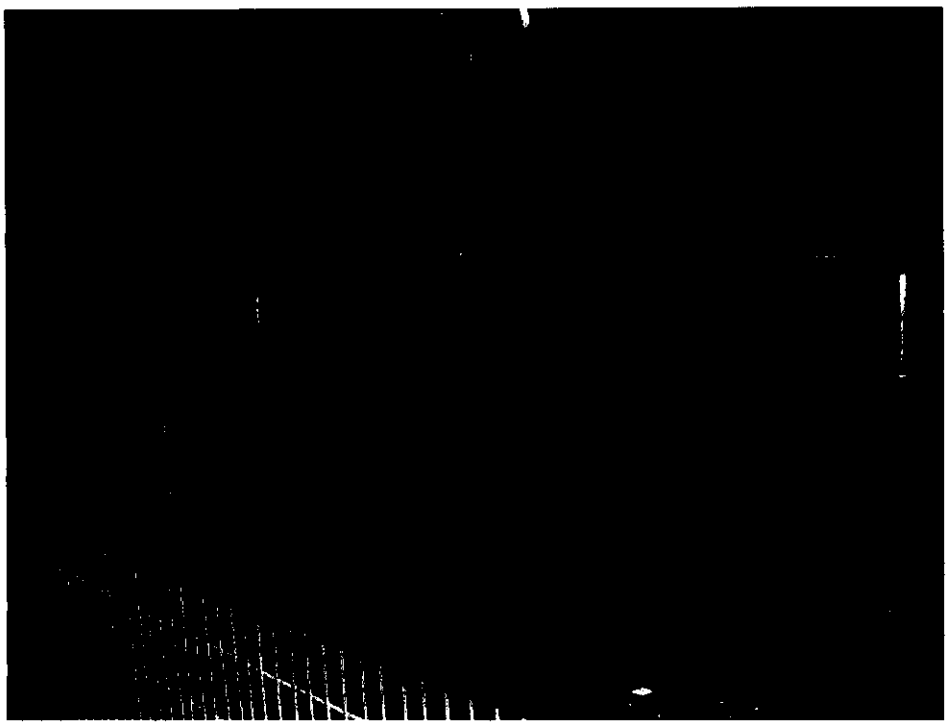
Appendix 1



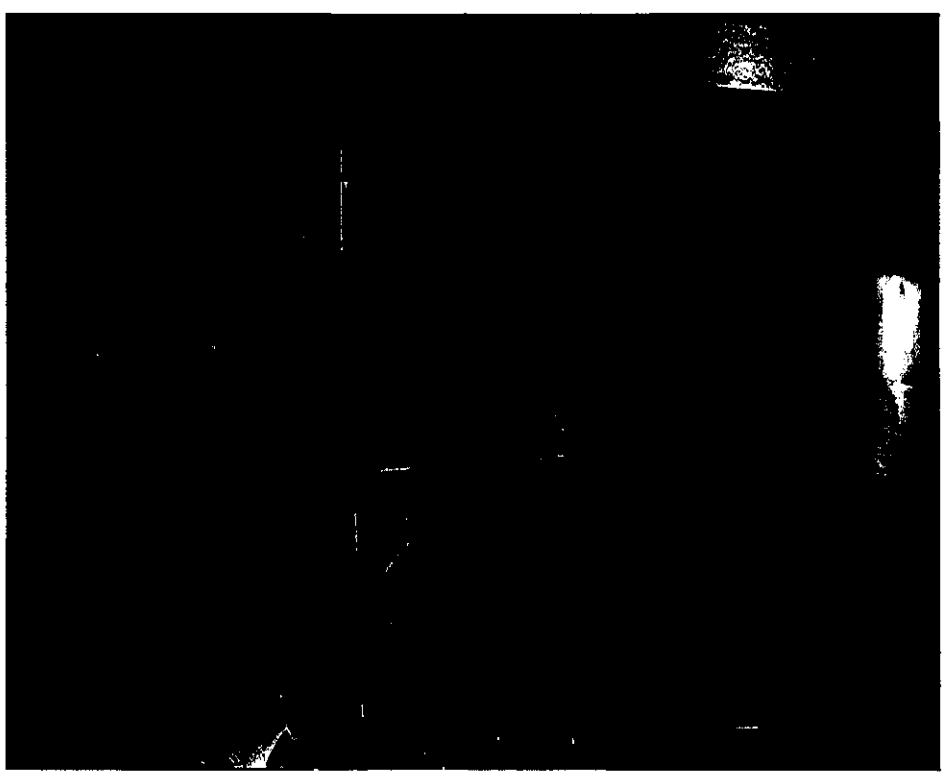
UHMWPE (RAW MATERIAL)



UHMWPE (SPECIMEN)



150 KV ION ACCELERATOR



PHASE VIEW OF 150 KV ION ACCELERATOR

WEAR TEST RIG PIN-ON-DISC

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