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Material coatings used in mechanical heart valves: A critical review

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Mechanical heart valves are considered more durable than bioprosthetic tissue valves. The major components of an artificial heart valve are the valve frame usually made up of hard materials like titanium, cobalt, chromium alloy etc., the occluders made up of either pyrolytic carbon or titanium coated with pyrolytic carbon, and the sewing ring cuff which is made from Teflon (PTFE), polyester or dacron. It is estimated that a human heart undergoes around 10^6 cycles per year and undergoes more fatigue loading than most of the engineering materials. The procedure of re-operating the patient repeatedly again for replacing the heart valve in itself is not a healthy process. So, coating materials have been developed which will reduce the wear and tear and improve the life and properties of the existing heart valves.

The choice of material plays a very important role, as it should be able to withstand the harsh and corrosive environment of the body and should not lead to rejection. Pyrolytic carbon (PyC) is a major component in heart valves. It is an isotropic turbostratic form of carbon and has high bio-inertness because of its ability to interact with proteins without denaturing it. Until recently silicon was also added, which increased the wear resistance, stiffness etc. but it had inclusions like silicon carbide which inturn affected the thromboresistance of carbon. Recently, On-X developed pure carbon material that showed higher biocompatibility and is chemically inert. Diamond-like carbon (DLC) is an attractive material for biomedical applications, which can be used as a coating that gives the valve wear resistant properties. Here atoms of carbon are deposited on the substrate and bonded together strongly [2]. There are reports, which state that DLC has a better hemocompatibility than pyrolytic carbon, and a higher wear resistance. Surface energy of the coating also played an important part, as it was instrumental in deciding the platelet activation. Since adhesion of this material into the biomaterial substrate is difficult, interlayers are developed which lead to the Ti-TiN-TiC-DLC multilayer structure. Usually the interlayers are TiN and TiC when the substrate used is Titanium. DLC can also be used as a base material wherein it can be functionally alloyed with other biocompatible materials like titanium, silicon etc. Carbon Nitride (CN) coating have also been developed and the properties like wear resistance and hardness are comparable with that of DLC. An important criterion is that smooth surfaces are needed so that blood-clotting process is not activated. The amorphous nature of the coating provided the material with surface finish comparable with the base substrate [3]. Many titanium based coatings like TiO, TiN and also Tantalum Nitride (TaN) have been prepared by the energized vapor deposition process [4]. Nanocrystalline titanium oxide can be used as another coating material, which has high hemocompatibility, and the oxide layer can be produced by many techniques like laser deposition, ion implantation etc. but sol-gel method provides an easy and cost effective production route.

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