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Surface modification of implants by sol-gel coating technology: Advantages and Applications

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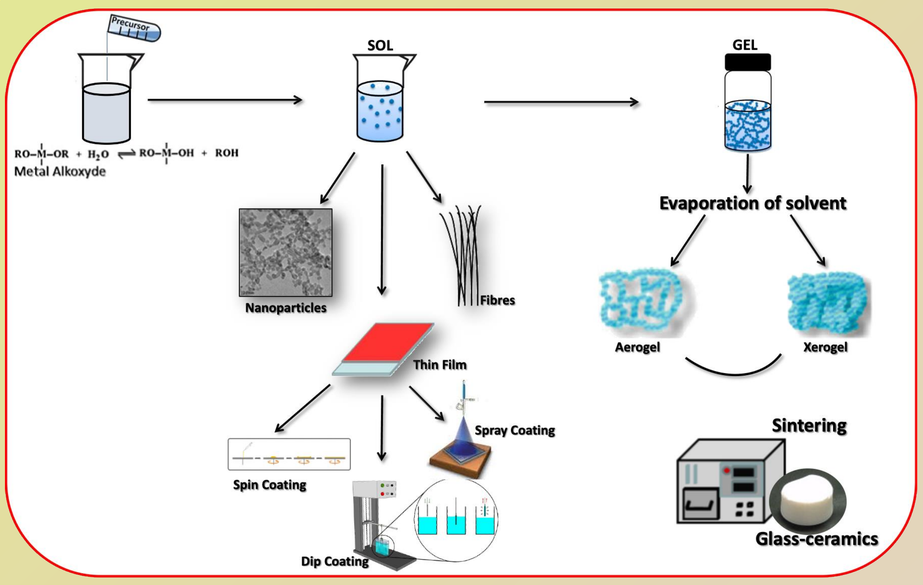
OBJECTIVE

Nowadays, approximately 1.5 million joint replacements are performed annually in Europe, while 7 million in the United States. Despite the advances made in the biomaterials field over the last 50 years, still today the average lifetime of an implant is about 20 years. This entails the need for subsequent prosthetic device replacement, especially in young patients, resulting in an increase in patients' health risks as well as clinical and economic burdens for the public health service. The failure of the implants can be caused by several reasons, such as adverse immune system reaction, biofilm formation or mechanical, chemical, tribological, surgical, manufacturing and biocompatibility problems. An alternative and useful strategy used to overcome this limitation is the modification of the implants' surface by sol-gel coating technology.

SOL-GEL METHODS



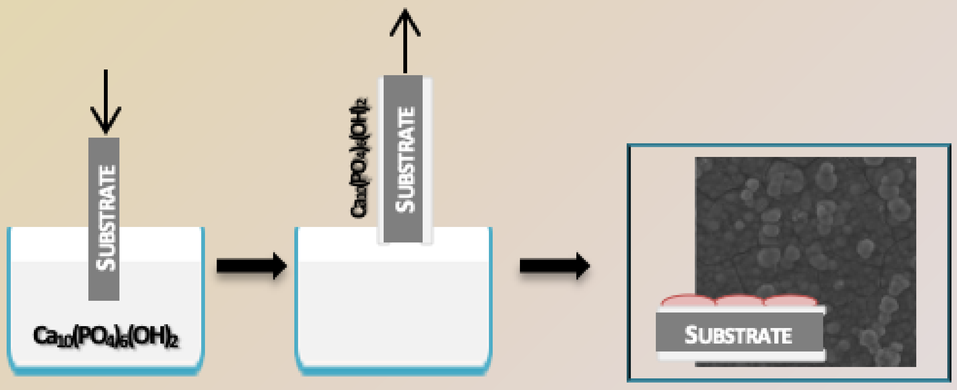
Sol-gel is a method used to produce inorganic and organic-inorganic hybrid materials at relatively low temperature starting from a colloidal solution (namely "sol") where hydrolysis and condensation reactions take place leading to the formation of a 3D rigid network (namely "gel"). The process is easily coupled to some coating techniques, such as dip coating, spin coating and spray coating. Sol-gel coating technology allows the production of coatings with a wide range of properties on substrates of different nature and shape, due to the fine control of the coating composition and microstructure.

Sol-gel coatings were successfully proposed in the biomedical field to inhibit wear, reduce corrosion and ion release, modify lubricity, hydrophilicity/hydrophobicity, and biocompatibility of several substrates. This is ascribable to the presence of residual hydroxyl groups on coating materials' surface, able to induce easier nucleation of the hydroxyapatite, to their mesoporosity and, thus, the large specific surface area.

THE APPLICATION OF SOL-GEL COATING TECHNOLOGY IN BIOMEDICAL FIELD

BIOCOMPATIBLE COATING TO IMPROVE OSSEOINTEGRATION

The use of bioactive hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) coatings promotes bone formation, adhesion and fixing of metal substrates.



The sol-gel method allows obtaining a thin hydroxyapatite film on a titanium substrate, with a good chemical homogeneity. In addition, the coating amount and layer thickness too can be controlled by adjusting the concentration of suspension and number of dips.

ANTIMICROBIAL COATING

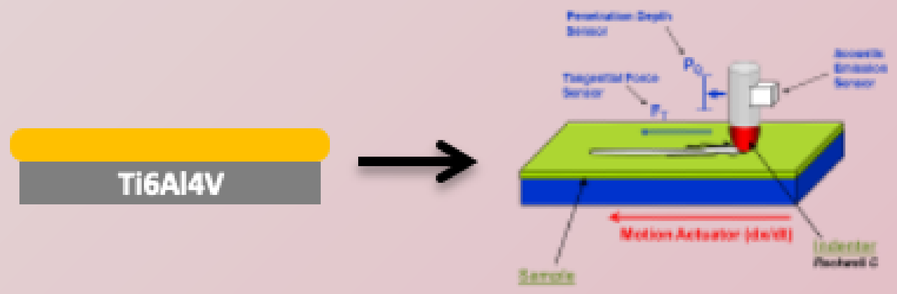
Sol-gel technology represents an alternative and useful technique for implant surface modification to prevent biofilm formation.

The sol-gel coatings are able to minimize bacterial adhesion, inhibit biofilm formation to protect implanted biomaterials.

The low processing temperatures allow the use of the sol-gel coatings to integrate a wide variety of antibacterial natural or organic compounds destined to be locally delivered at a controlled rate

COATING FOR CORROSION PROTECTION

A further cause of early failure of the metallic medical device is their low resistance to corrosion processes which take place in the aggressive body environment. Corrosion reduces strength and leads to the release of debris and metallic ions in the implant site which can cause the onset of inflammation processes and, thus, of harmful effects on the surrounding tissues. Therefore, to extend the prostheses lifetime and, thus, to avoid the premature failure of the implant due to wear and corrosion, the surface modifications of the implant by sol-gel coatings to obtain protective layers were proposed



BIOCOMPATIBLE COATINGS IMPROVE MECHANICAL PROPERTIES AND CORROSION BEHAVIOR OF IMPLANTS

CONCLUSIONS

Therefore, the application of the sol-gel coatings provides an excellent chemical modification of the materials' surface allowing protective barrier layers production.