Bone-like apatite formation on titanium and silica glass

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If a material induces apatite formation in SBF (simulated body fluid) it is likely to exhibit bioactive behavior and form a stable interface with bone tissue. Apatite formation kinetics can help to estimate bioactivity of material and also to describe the formation mechanism. In present study, apatite formation on the surface of titanium and silica glass was investigated using microscope image analysis and by weighing the precipitated apatite. The titanium surface was chemically treated in sodium hydroxide before the interaction with SBF.

A microscope image analysis of the sample surface was used to describe apatite formation kinetics during the initial stages of precipitation, when isolated apatite spherullites were formed. These are parameters evaluated by the image analysis: mean and maximum diameter of apatite spherullites, their number per unit area and the percentage of apatite covered surface. The time dependence of maximum diameter was the most reproducible one and it could be used to determine the apatite growth rate and to estimate the induction times for different supersaturations of the SBF solution. It was found that not immediate but continuous nuclei formation occurs. It was shown that it is possible to characterize the initial stages of apatite precipitation by the induction times evaluated using extrapolation of the linear time dependence of spherullite maximum diameter. This method was used to characterize apatite formation on chemically treated titanium and silica glass.

The induction times could be used to determine the apparent interfacial energy (S_{CL}) for nucleation according to modified Gibbs-Thomson equation:

$$\ln(1/t) = \ln(A) - \frac{16\pi {s_{CL}}^3 v^2}{3k^3T^3} \cdot \frac{1}{(\ln S)^2}$$

where t is induction time, v -molecular volume, k –Boltzman constant, T absolute temperature and S –supersaturation ratio.

The obtained apparent interfacial energy value for apatite precipitation on chemically treated titanium was 3.7 mJ/m^2. This value could serve as a measure of a substrate's ability to induce apatite formation and thus it could help to estimate the bioactivity of a material on the basis of in vitro tests.

Because during the interaction of titanium with SBF no significant release of any component occurs, the apatite growth rate can be evaluated by weighing the precipitate. It is possible to describe the growth rate using equation $R=k(S-1)^n$, in which S is the supersaturation and n is the effective order of reaction indicating the rate controlling mechanism. The calculated value of n≈2.8 indicates that the rate controlling process of apatite formation on the surface of chemically treated titanium is polynucleation.

The apatite precipitation on the surface of silica glass occurred only in SBF solution with increased supersaturation ratio.

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