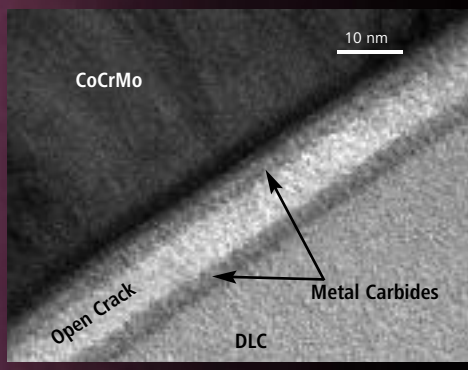
Can implants last forever?

Extra-hard coatings made from diamond-like carbon extend the operating lifetime of tools and components. In artificial joints, however, these coatings often fail because they detach. Empa researchers studied the coatings and found out why.

TEXT: Rémy Nideröst / PHOTOS: Empa, iStock



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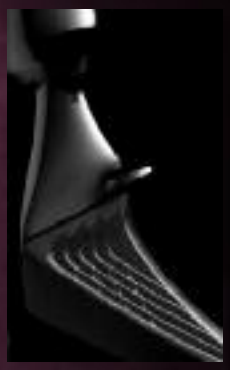

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The failure mechanism has been discovered – coatings made of diamond-like carbon (DLC) can detach from implants if cracks and crevices (the light area) build up in the reaction layer between the implant material and the DLC substrate.

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Together with several partners from industry, Empa developed a method to predict the expected operating lifetime of a DLC-coated implant in the human body.

Whether on computer hard discs, saw blades, embossing tools, razor blades or fuel-injection nozzles, extremely hard coatings made of diamond-like carbon (DLC) have long proven their value. They reduce wear and thereby give tools and components a longer operating lifetime. What could be more logical than to apply DLC to medical implants such as artificial joints? After all, wear is a problem here, too.

DLC has withstood endless *in vitro* tests in manufacturer's laboratories and has shown itself to be well tolerated by human tissue, extremely hard wearing, and resistant to the relatively aggressive environment in the human body. Despite this, when DLC-coated joints were first implanted into human patients, serious problems arose after a few years. The coatings were not worn away, but rather they detached from the implant material for no apparent reason.

Boundary layers under study

In a project financed by the Swiss Innovation Promotion Agency (CTI) and the medical technology company Synthes GmbH, Empa sought out the cause of this detachment. For this, the researchers conducted detailed studies of the boundary layers between the implant material and the coating. When two materials are placed in contact with each other, the result is a reaction layer at the interface between them which is only several atomic layers thick – and thus a new material is formed. The researchers showed that the so far barely considered reaction layer, which is not corrosion resistant, is responsible for the detachment of the DLC layer.

On the one hand, stress corrosion cracking occurred in the reaction layer. The mechanical load in conjunction with the penetration of body fluids led to slow-growing cracks, which in turn caused the DLC substrate to detach little by little. In other cases, crevice corrosion was responsible for the damage. Over time, an aggressive, acidic medium develops in fine crevices, and it slowly dissolves the reaction layer, likewise leading to detachment.

Procedures to determine operating lifetime

In addition to a corrosion-resistant reaction layer, Empa worked together with Synthes and the coating company Ionbond to develop a process which can determine a crack's growth rate under conditions similar to those experienced in the human body. This then allows scientists to calculate the expected operating lifetime of the coated implant in the human body. For crevice corrosion, too, the test process makes it possible to predict the expected operating lifetime of the implants. //