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Research paper

On the role of oxygen vacancies, aliovalent ions and lattice strain in the *in vivo* wear behavior of alumina hip joints

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ABSTRACT

We have visualized at the nanometer scale the topological, chemical and mechanical characteristics of long-term *in vivo* exposed bearing surfaces of femoral heads made of monolithic alumina. Four self-mated alumina retrievals were studied, which were exposed in the human body for relatively long periods of time ranging between 7.7 and 10.7 yrs. Besides conventional morphological features, monitored by atomic force microscopy, the topographic distributions of point defects and lattice strain on the surface of the heads were systematically probed by collecting high spatially and spectrally resolved cathodoluminescence spectra from zones of different wear severity. Three types of optically active point-defect site could be detected: (i) oxygen vacancies; (ii) substitutional (aliovalent) cations; and, (iii) interstitial aluminum cations. These luminescent sites represent the main defects progressively developed in the alumina lattice during exposure in human hip joints. A clear evolution toward (environmentally driven) off-stoichiometry was found with progressing wear. Moreover, the shallow electro-stimulated optical probe also detailed the presence of lattice strain fields (of both elastic and plastic nature) stored in the very neighborhood of the bearing surface. The present spectroscopic characterizations enable substantiating important tribochemical interactions between bearing surfaces and *in vivo* environment as pivotal parts of progressive events of wear degradation.

1. Introduction

Monolithic alumina (Al_2O_3) is the most widespread ceramic material for bearing parts in hip joints because of its high bioinertness and biocompatibility (Christel, 1992), and a conspicuously low-friction coefficient (Khanna and Basu, 2006). However, scientists and technologists nowadays believe that its wear resistance could be further improved provided that fundamental aspects of its tribological behavior *in vivo* (partly unfolded or standing under debate) could be clarified at the nanometer scale. According to the basic principles of contact mechanics (Gao et al., 2006; Jamari et al., 2007), one could evince that the strong (ionic) lattice bond should ultimately preserve oxide ceramic surfaces from experiencing plastic flow under the moderate temperature/stress conditions of low-friction sliding developed in the human hip joint,

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