Applications of IBA methods for biomineral research

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Biomineral structures include teeth, bones, antlers, dental composites and implants, restorative and prosthetic materials, etc. In the last decades remarkable progress took place in the field of dental and ortopaedic materials, as well as of dental tissues' and bones' treatments aiming at the prophilaxy and therapy of various dental and bone impairments. On the other hand the new materials bring foreign elements in the organism and may present toxicologic and occupational risks. At the same time many aspects of mineral tissues pathology are poorly understood. Research in this field requires detailed characterization of the surface composition and structure and of their changes due to physical and chemical factors involved in interactions of medical relevance. Therefore, surface characterization methods are needed for new developments in biomineral research. Ion beam analysis (IBA) methods such as PIXE, PIGE, ERDA and RBS may help a deeper insight of the pathology of mineralized tissues like teeth, bones and antlers, aimed at various applications ranging from disease prevention and therapy to biodiversity conservation.

In our recent measurements at the 3 MV Tandetron we made a preliminary survey of the potential offered by this new instrument for biomineral samples, using teeth and dental materials. The main advantages of the 3 MV Tandetron for biological studies in general and for biomineral structures in particular are the following: 1) the visualization of sample's surface and precise positioning of the beam; 2) the windowless detectors which allow e.g. detection of light elemets by PIXE; 3) the simmultaneous detection of PIXE, PIGE and RBS spectra; and 4) the automated control of experimental parameters.

Hydroxyapatite (HA), dental enamel and calculi, acrylate and metallic alloys from extracted dental works, and dental nanocomposites were analyzed at the 3 MV Tandetron. We used 2 MeV/amu α particles for comparison with spectra previously recorded with 3 MeV protons. With 2 MeV/amu alphas the yield of characteristic X-rays above 12 keV is lower. We detected light elements not seen before (Mg, Al, Si) while other were better analyzed (P, S, Cl). Natural HA and HA-rich dental enamel contained also Al and Si (probably Al silicates). Acrylate from dental works and dental calculus from teeth with dental works showed accumulation of light elements (Mg, Al, Si, P, S, Cl, Ca, K) and traces of metals with catalytic activity (Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ru, Ag) and with toxic action (Cd) which may be relevant for medical history, environmental and occupational contamination and forensic applications. A metallic Cr-Fe-Ni alloy (Wipla) extracted from a dental work showed also Al, Si, Ti as minor components. Although the alloy presented a shining surface, the presence of P, S, Cl, K, Ca suggested incipient corrosion invisible to the eye. PIGE detected nuclides which were already observed in the PIXE spectra (^{27}Al, ^{39}K, ^{40}Ca, ^{47}Ti, ^{67}Zn, ^{114}Cd)

but also some in addition (^{19}F, ^{79}Br, ^{127}I) – of which F is essential in biomineral tissues – while other (like ^{77}Se) need further confirmation. The PIGE spectra are complicated also by the elements of the natural background. In the dental composites Al and Si detection suggested quartz and glass particles in addition to the components containing F, Ca, Fe, Sr, Ba, Yb. However the use of 2 MeV α failed to detect Zr (seen with 3 MeV protons). Thus the 3 MV Tandetron offers a high potential – previously inaccessible – for studies of teeth, bones, and other biomineral structures, which may be approached from many perspectives.

On this basis of present and previous results, a cooperation with Prof. S. Gomez (Univ. Cadiz, Spain) and Prof. T. L. Castillejos (Univ. Albacete, Spain) is planned, together with the approach of subjects which extend our study. On short and medium term we propose the fpllowing investigations using mainly 3 MeV protons:

1. Applications of IBA methods in the study of hard dental tissues affected by pathological conditions (hipophosphatasemia, periodontal disease, heavy metal contamination) – cooperation Spain.
2. Applications of IBA methods in the study of mineral elements from deer amtlers in relationship with ecological conditions – cooperation Spain.
3. Dental calculi and dental polymers as accumulators of trace elements from the oral environment studied by IBA methods.
4. Studies by IBA methods of periodic structures generated on dental enamel surface by high power laser ablation.
5. Comparative potential of IBA and other metods (LIBS, Raman spectroscopy, SIMS) in the surface characterization of biomineral materials.
6. Studies by IBA and other methods of damage produced by the ion beam during the analysis of dental composites as a function of cummulated electric charge density.

For the next 6 months we request for the IBA experiments at the 3 MV Tandetron 10 days (30 shifts) grouped in two separate shifts of 5 days each, with one shift of 5 days starting in the period ... [to be specified a.s.a.p.], when Prof. S. Gomez intends to come in a visit in our institute. He wants to participate during the IBA measurements on pathologicasl teeth and deer antler samples, for selecting on the samples' surfaces the biologically most relevant areas for the beam analysis.

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