Tooth—A natural biocomposite

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Abstract. The inorganic content of human tooth is predominantly hydroxyapatite. The content varies in enamel and dentin. A reversible thermal transformation at 157°C is observed and has correspondence in the dielectric measurements. The dental decay is related to the piezoelectric property of tooth, which is similar to a polar glassceramic. The toughness of tooth is higher than hotpressed hydroxyapatite and owes it to the microstructure signifying the importance of a weak, pliable interface. The hardness is graded, higher for enamel in the crown and very much lower for dentin, to suit their function and environment. The relevance of biomimics in designing materials for advanced performance is discussed.

Keywords. Tooth; biocomposite; caries; hydroxyapatite; biomimics.

1. Introduction

In recent years attention has turned on natural materials as they are light and tough. It has been noticed that no man-made material is able to achieve the toughness at such low densities as in shell, wood or tooth. Various approaches have been made to copy them, which encompasses a new subject called biomimics (Calvert 1990). Tooth is nature’s cutting and grinding tool. It is a natural composite consisting of collagen, biopolymers and hydroxyapatite (HAp). Tooth has three major sections called the enamel, dentin and the core pulp, each having a different composition, property and function.

Synthetic HAp is a phosphate of calcium and is often used in restorative dental surgery and in implants. Tests have confirmed that it is bioactive and bonds to the biotissues (Hench 1991). HAp content is different in natural bone, dental enamel and dentin. The tooth enamel is wear-resistant. This paper presents the study of the physical and mechanical properties of teeth with a future aim for (i) designing better implants which can match with the properties of natural tissues, (ii) obtaining composites with higher values of toughness for multivariant applications and (iii) elucidating the problem of dental decay, which is said to relate to the piezoelectricity of tooth (Masi and Masi 1989). The investigation has shown the role of micro and macrostructure in achieving high toughness in tooth compared to synthetic HAp. The relevance of biomimics for enhancing toughness in light materials is discussed.

2. Material and experimental methods

Twelve samples in all of deciduous (MT), normal (NT) and diseased (DT) teeth were examined. They were cleaned and sterilized. X-ray diffraction and infrared (FTIR) measurements were carried out to identify phases and molecular groups.

An impedance bridge was used for measuring the capacitance in the frequency range 1 kHz to 1 MHz and at temperatures from ambient to 400°C. The samples were coated with silver paint for good electrical contact. Dielectric constants were calculated from
measured capacitances. Differential scanning calorimetry (DSC) methods identified the temperatures of transformation. Repeated reruns were taken while heating and cooling to confirm the reversibility of the transformations.

SEM and EDX analyses on carbon-coated fractured surfaces reveal the microstructures, fracture patterns and elemental content.

The Vickers hardness numbers were measured with a Leitz tester at a load of 100 g. The variations of hardness with load in the range 50 to 500 g were also studied to know the initiation of cracks. The toughness was calculated from the initiation of cracks and indentation at 2 kg load. Linear thermal expansion measurements were carried out in the range 20 to 400°C using a dilatometer.

3. Results and discussion

Tooth has three parts—the root, the neck and the enamel (figure 1a). The root is within the gum attached to the tooth-bearing bone. The crown projects into the mouth cavity. It has enamel and dentin. The neck is the in-between area. Forms of teeth reflect their functions—the incisor crowns have cutting edges and the molars have elevations and valleys suited for grinding. The enamel is the hardest of calcified tissues. Dentin grows at the expense of primary pulp as dentinal tubules. It has less mineral as compared to enamel and is more elastic. Cement is formed as layers on the surface of roots—similar in composition and structure to bone. Pulp occupies the central cavity and connects to the root canal. The pulp consists of cells, fibres, blood vessels, nerves etc. The tooth