

10.3.2 Magnetic Bioactive Glasses for Hyperthermia Treatment

Magnetic bioactive glasses (MBGs) have been evaluated as potential materials for hyperthermia treatment of malignant tumors, especially for deep-regional cancers such as bone cancer. During the past decade, the development of bioactive ferromagnetic glass-ceramics has attracted considerable interest. Bioactive glass forms a biologically active bone-like apatite, augmenting the formation of new bone tissue and reinforcing the bone structure (Lin et al., 2016; Kaur et al., 2014a,b). It can be used as a material for cancer treatment if a magnetic phase, such as ferromagnetic particles (Fe_3O_4), is added in the glass matrix to be as a hyperthermia thermo-seed. (Aspasio et al., 2016a) The dual effect of magnetic properties and bioactivity makes these glass-ceramics extremely attractive for the treatment of bone cancer.

The magnetic phase of the MBG can be obtained through heat treatment into the glass system through the magnetic phase crystallization or by the incorporation of magnetic nanoparticles in the glass matrix (Baeza et al., 2013). Various SEM images of magnetite crystals after glass-ceramic etching are shown in Fig. 10.5 (Allia et al., 2009). The advantage of magnetic nanoparticles incorporation is the higher surface area and porosity, which comes along with a better magnetization than the magnetic phase crystallized by ceramming. Since nanoparticles have a tendency to aggregate, it is challenging to incorporate magnetic nanoparticles uniformly in the glass matrix for the sol-gel process (Aspasio et al., 2016a; Kaur et al., 2016). In addition, the combination of desired bioactivity with enough magnetization is another main challenge in the MBG research field, because a higher concentration of magnetic phase diminishes the bioactivity behavior of the bioactive glass (Aspasio et al., 2016a). After hyperthermia treatment, there is a possibility that the remaining malignant cells around the tumor site can lead to tumor recurrence (Li et al., 2011a). In this case, these malignant cells can be destroyed to prevent the tumor recurrence through reheating the implanted material when necessary.

Various magnetic bioactive glass-ceramic systems have been synthesized since it was shown to be an excellent material for magnetic hyperthermia treatment of cancer. The earliest magnetic glass-ceramics were reported in the 1980s by Luderer et al. (1983). He reported that nonbioactive ferrimagnetic glass-ceramics containing lithium ferrite LiFe_5O_8 could cause significant tumor regrowth delay and a permanent control of murine breast adenocarcinoma. Ferrimagnetic glass-ceramics containing magnetite in a CaO-SiO_2 glassy matrix were obtained by crystallization of $\text{CaO-SiO}_2\text{-Fe}_2\text{O}_3$ glasses. Lee et al. prepared ferrimagnetic glass-ceramics in the system $\text{Fe}_2\text{O}_3\text{-CaO-SiO}_2$ by a controlled two-step crystallization method (Lee and Choi, 1996). B_2O_3 and P_2O_5 were added to reduce the glass viscosity and the crystallization temperature. Glasses were covered by carbon powders and then heat-treated at temperatures between 650°C and 1000°C to prevent magnetite decomposition. During the crystallization process, magnetite, hematite, and β -wollastonite were formed. The cytotoxicity evaluation showed that those glass-ceramics were biocompatible.