

a controlled release from the glass because its elevated concentrations can have negative effects on the growth of new bone tissue and have a cytotoxic effect. The *in vitro* bioactivity studies showed that ZnO in glass retards the HAP nucleation at the initial stage of SBF soaking, but does not affect the growth of HAP after long periods of soaking (Seyedmomeni et al., 2016; Wang et al., 2015; Anand et al., 2016). The release of Zn ions from a glass into the SBF medium was controlled and it was retained mainly in the ACP or HAP product (Liu et al., 2014; Wang et al., 2015). *In vitro* studies showed that Zn-doped glasses are biocompatible (Coelho et al., 2012; Xiao et al., 2012; Nezafati et al., 2012). The incorporation of 1.5–5 wt% of Zn into the borosilicate bioactive glass was not toxic to hBMSCs when cultured on the glass scaffolds, while the proliferation and the cell viability have been inhibited for the glass with 10 wt% of Zn (Wang et al., 2015). An *in vivo* study showed that the incorporation of 5 wt% ZnO in the borosilicate bioactive glass scaffolds significantly enhances bone regeneration in rat calvarial defects at 8 weeks when compared to the nondoping scaffolds. Zn-doped biomaterials exhibit weak antimicrobial activity as an important feature in the prevention of postoperative infections (Stanić et al., 2010). Anand et al. (2016) synthesized  $B_2O_3$ -MgO-SiO<sub>2</sub>-Na<sub>2</sub>O-CaO-P<sub>2</sub>O<sub>5</sub>-ZnO glasses with different amounts of B<sub>2</sub>O<sub>3</sub>, MgO, SiO<sub>2</sub>, and Na<sub>2</sub>O oxide by the sol-gel technique. All the samples showed antimicrobial activity against almost all the microorganisms tested. There is evidence to suggest that borate-buffered media is a potent antimicrobial (Houlsby et al., 1986).

### 8.3.4 Strontium-Doped Boron-Containing Bioactive Glass

Strontium is an important trace element in the human body, mainly deposit in bone and related tissues, and has a significant impact on bone metabolism. Its compounds such as strontium ranelate and SrCl<sub>2</sub> are currently used to treat osteoporosis (Reginster et al., 2005; Marie et al., 2001). *In vitro* and *in vivo* studies showed that a low dose of strontium ions promotes bone formation, osteoblast proliferation and activity, and decrease in osteoclast activity and resorption (Gentleman et al., 2010; Yang et al., 2011). In contrast, high doses of strontium ions may induce skeletal abnormalities (Marie et al., 2001). The effect of strontium ions on the structure and solubility of several bioactive glasses has been reported. Substitution of strontium for calcium or magnesium ions leads to the expansion of the glass network. The changes in the glass network are associated with the characteristics of metal ions. Strontium has a higher ionic radius, average coordination number (CN), and lower ionic field strength ( $r=0.127$  nm; CN=7.2;  $I=0.24$ ) compared to the calcium ion ( $r=0.100$  nm; CN=6.3;  $I=0.35$ ) and the sodium ion ( $r=0.96$  nm; CN=6.0;  $I=x$ ) (Lu et al., 2017). The increasing Sr<sup>2+</sup> content in the borate compositions induced more NBOs into the glass network and favor of the conversion of BO<sub>3</sub> to BO<sub>4</sub> units (Li et al., 2017; Sinouh et al., 2013; Hasan et al., 2015). Glass transition temperature (T<sub>g</sub>s) increases with the content of Sr<sup>2+</sup> because of the high ionic strength of Sr–O bonding,