

in humans (Danks, 1988). Copper and its compounds are highly significant as antimicrobial agents in the prevention of postoperative infections (Borkow and Gabbay, 2005; Stanić et al., 2010).  $\text{Cu}^{2+}$  ions act as network modifiers in glass systems and decrease the connectivity of the network structure (Marzouka and Gaafar, 2007). This leads to the formation of a more stable glass structure and less solubility. Liu et al. (Liu et al., 2014) reported that small concentrations of metal ions ( $\text{Cu}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Sr}^{2+}$ , and  $\text{Fe}^{3+}$ ) had little effect on the degradation of borate13-93B3 microfibers and their conversion to an ACP product in SBF, but they did inhibit the crystallization of the ACP to HAP. Approximately 75%–85% of Cu was released from the borate 13-93B3 bioactive glass microfibers into the SBF at 2 weeks. Wang et al. (Wang et al., 2016, 2014) made the boron-containing glass scaffolds doped with Cu ions from 0 to 3 wt%. Incorporation of copper ions in scaffolds resulted in a transformation from  $\text{BO}_3$  into  $\text{BO}_4$  groups. The scaffolds have not shown cytotoxicity to human bone marrow derived stem cells (hBMSCs) and the alkaline phosphatase activity of the hBMSCs increased with an increase in Cu in the glass. An in vivo study showed that Cu-doped scaffolds significantly enhanced blood vessel formation in rat calvarial defects at 8 weeks postimplantation.

### 8.3.3 Zinc-Doped Boron-Containing Bioactive Glass

Zinc is an essential trace metal found in all living organisms and is necessary for a lot of biological processes. It plays a physiologically important role for the skeletal system, proliferation of bone cells, enzyme regulation, and DNA replication (Brandao-Neto et al., 1995; Hadley et al., 2010; Yamaguchi and Matsui, 1996). Zinc deficiency results in a retardation of bone growth, indicating that the element is required for the growth, development, and maintenance of healthy bone (Park et al., 1986). Excess zinc may have adverse and serious effects on health such as reduced bone formation, anemia, hypertension, as well as systemic cytotoxicity (Salgueiro et al., 2000; Gonzales et al., 2011; Kasai et al., 2012). ZnO in the structure of bioactive glass might act as a divalent network modifier and/or network former depending on the composition and its content (Colak et al., 2016). ZnO acted as a network former in borate glasses, having more than 5% (wt%) incorporated. When ZnO acts as a network modifier, it breaks B–O–B bonds and leads to the formation of NBO atoms. However, ZnO, when played a network former role,  $\text{Zn}^{2+}$  ions in glass adopt a tetrahedral coordination ( $\text{ZnO}_4$ ) and participate in the copolymerization (Colak et al., 2016; Brow, 1996). The addition of Zn ions to boron-containing glasses enhances its chemical durability and improves the thermal and mechanical strength of glass (Kaur et al., 2014; Abdelghany et al., 2014). The increase in ZnO content leads to a decrease in the solubility of glasses (Abdelghany et al., 2014). The bioactivity and biocompatibility of Zn-doped glasses were not only strongly associated with the apatite forming ability but also related to the release of zinc ions, which have a stimulatory effect on bone cells proliferation and differentiation. Zinc ions must have