# Beta-type Zr-Nb alloys with changeable Young's modulus for spinal fixation applications

Beta type Zr-Nb alloys with changeable Young's moduli are developed for spinal fixation applications. Before deformation, the alloys exhibit low Young's modulus to keep the mechanical compatibility. After deformation, the Young's moduli of all the alloys increase with different range. The increase in Zr-15Nb and Zr-17Nb reach 34.3% and 26.5%, respectively. The EBSD and TEM results indicate the significant increase in the Young's modulus of these two alloys is attributed to the deformation-induced ω phase.

For spinal fixation applications, the alloys with changeable Young's modulus are preferred to meet the demands of both surgeons and patients. The alloys should possess a low Young's modulus before deformation to keep the mechanical compatibility, and a high Young's modulus at the deformed part with the deformation during surgery to lower the springback [1].

Each Zr-*x*Nb (*x* = 13, 15, 17, 19, 21, 23 mass%) (200g) were prepared by levitation melting. The ingots were then homogenized at 1373K for 21.6 ks and hot-forged at 1273K (both processes were performed in an argon atmosphere), after which they were quenched in ice water and the air-cooled, respectively. Then the hot rolled plates were solution treated in vacuum at 1123 K for 3.6 ks and quenched in ice-water. Some of the solutionized plates were cold rolled with a reduction ratio of around 10% at room temperature. As the final treatment, the solution treatment and cold rolling were labeled as ST and CR, respectively.

After solution treatment, each of the Zr-xNb (x = 13, 15, 17, 19, 21, 23 mass%) alloys consists of equiaxed β phase and tiny dispersive ω phase, which were observed by TEM. The intensity of the athermal ω phase decreases with increase in the Nb content. In addition, in the Zr-xNb (x = 13, 15, 17 mass%) alloys, some unknown phase with acicular structure is visible. These phases disappear with increase in the Nb content.

Figure 1 shows the Young's moduli variation of each alloys subjected to solution treatment and cold rolling. All the novel designed alloys exhibits low Young's moduli of <70 GPa; this value is much lower than those of SUS 316L stainless steel (SUS 316L), commercially pure titanium (CP Ti), and Ti-6Al-4V ELI alloy (Ti64 ELI) [2], which are currently widely used for spinal fixation applications. The Young's moduli of Zr-15Nb and Zr-17Nb are lower than 60GPa ; this value is much closer to that of human bones compared with the previous developed Ti-30Zr-Cr-Mo [3], Ti-Cr [4], Ti-Mo [5], and TNTZ-Cr [6] alloy. Therefore, the Zr-Nb alloy exhibits excellent mechanical compatibility. After cold rolling, the Young's moduli of all the alloys increase compared with those under ST conditions. The increase in Zr-15Nb and Zr-17Nb reach 34.3% and 26.5%, respectively. The EBSD and TEM results indicate that deformation-induced ω phase exists in both Zr-15Nb and Zr-17Nb alloy, however, the deformation-induced ω phase in Zr-15Nb is accompanied with the deformation-induced {332}<113> mechanical twin, while the deformation-induced twin is not visible in Zr-17Nb alloys. The significant increase in the Young's modulus is attributed to the deformation-induced ω phase.

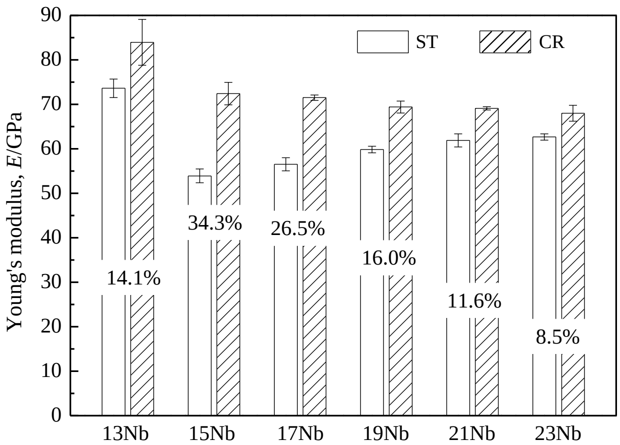


Fig. 1 Young's moduli of Zr-Nb alloys subjected to solution treatment (ST) and cold rolling (CR).

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Xiaoli Zhao (Materials institute, Schools of Materials and Metallurgy, Northeastern University, China)
E-mail: zhaoxl@smm.neu.edu.cn