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EFFECT OF LONG-TERM HOLDING UNDER CONTACT LOADING ON THE SPECIFIC FEATURES OF PHASE CHANGES IN SILICON

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It is shown that the long-term holding under the peak load during the indentation of Si (100) leads to the creep of material even at room temperature. This becomes possible due to the phase transition into a more plastic metallic β-Sn phase. The end structural phases in the indentation zone were studied by the micro-Raman spectroscopy. It was discovered that they are affected by the longer holding under the load. Thus, more intense peaks were detected for the amorphous (a-Si) phase in the depth of indentation, as compared with those observed for short-holding indentations. It is suggested that this effect is caused by the activation of the dislocation mechanism in the a-Si formation as a result of the longer action of shear stresses under long-term holding. This fact induces some changes in the kinetics of the events of unloading, which reveal a trend to the formation of "kink pop-out" events instead of the typical "pop-out" and "elbow" events.

Keywords: indentation, silicon, phase transformation, amorphous phase, unloading events, creep, holding time.

Although numerous new materials for micro- and optoelectronics were created within the last years, silicon remains the principal component of the major part of semiconductor devices and has numerous industrial applications. Parallel with electrical and optical properties, the mechanical behavior of Si, especially under local loading, is of especial interest in view of the specific features of its structural phase transformation in nano- or micro-volumes of the deformed material. High pressures created by nano/microindentation lead to the phase transformation of the initial diamond cubic structure (Si-I) into a highly conductive β-Sn structure (Si-II) under loading. If the pressure is released, then Si-II transforms into the body centered cubic (Si-III), rhombohedral (Si-XII) and amorphous (a-Si) structures depending on the rate of unloading [1, 2], value of the load, and the type of indenter [3–5] (or on the deformation temperature [6, 7]).

Recently silicon has found wide applications in microelectromechanical systems (MEMS) whose reliability strongly depends on the mechanical durability of the used material. In the course of exploitation, the Si MEMS components may undergo the influence of long-lasting constant loads. The nanoindentation technique proves to be the most suitable procedure for the investigation of the time-dependent mechanical response of the material under these conditions and to study various aspects of the process of creep on nano- and microscales.

It seems likely that, despite numerous works dealing with the mechanical behavior of Si under nano/microindentation for various loading conditions, such as cyclic loading [3, 8] or scratching [5], there is a gap in the investigations of indentation creep for Si. Thus, the data concerning the characterization of creep in silicon were mostly obtained by using uniaxial compression or bending tests for relatively low stresses (from 2 to 150 MPa) and elevated temperatures (from 800 to 1300°C) [9, 10]. The main deformation mechanism during

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