Experimental studies on fundamental mechanisms leading to fatigue crack initiation

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Introduction. The knowledge of fatigue crack initiation mechanisms is one of the basic but, unfortunately, still only partially answered questions in the study of fatigue damage of materials. The damaging process starts preferentially at the sites of cyclic strain localization, now usually called persistent slip bands (PSBs) and results in the formation of sharp surface slip markings (called persistent slip markings – PSMs). PSMs consist of local elevations and depressions of the surface, known as extrusions and intrusions, which develop on the initially flat surface at emerging PSBs. Although it is generally accepted that PSMs represent incipient fatigue crack sites, the exact mechanism of fatigue crack nucleation has not been yet clarified completely [1]. Some theoretical models highlight an important role of *point defects* in the process of fatigue crack initiation and predict temperature dependence of surface relief evolution (see e.g. [2,3]). For their verification it is desirable and crucial to obtain detailed experimental data on the PSM formation at elevated and particularly at depressed temperatures.

Experimental study. In the present work two advanced microscopic techniques – AFM (atomic force microscopy) and high-resolution scanning electron microscopy (SEM–FEG) were adopted to study surface relief and its evolution in individual grains of 316L austenitic stainless steel fatigued at depressed and elevated temperature. Cylindrical specimens with a shallow notch were mechanically and electrolytically polished. The specimens were cyclically strained with constant plastic strain amplitude of 1×10^{-3} at 93, 173 and 573 K to different early stages of fatigue life. To reveal true qualitative and quantitative information on the surface relief topography of individual PSMs, AFM images were taken in identical areas on the specimen surface and on its inverse copy obtained via plastic replica. In this way characteristic features of the surface relief topography evolution have been documented and quantitative data on the extrusion growth kinetics were obtained for all temperatures. Experimental findings are compared with those obtained recently in room temperature cyclic straining and they are discussed in relation with recent *point defect models* of surface relief formation and fatigue crack initiation.

[1] J. Man, K. Obrtlík and J. Polák: Phil. Mag. 89 (2009) 1295–1336.
[2] U. Essmann, U. Gösele and H. Mughrabi: Phil. Mag. 44 (1981) 405–426.
[3] J. Polák and M. Sauzay: Mater. Sci. Eng. A 500 (2009) 122–129.