A TEM investigation of twinning in ZnO nano-spikes

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In recent years, the synthesis of various ZnO nano-structures has been extensive carried out using different methods. Due to its simplicity, vapour-liquid-solid (VLS) mechanism of crystal growth is widely used for the synthesis of various nanostructures. Defects like twin boundaries are frequently observed in ZnO nano-structures after the VLS growth [1]. In the present work the transmission electron microscopy (TEM) investigations of twinned regions observed in ZnO nano-spikes are presented. The ZnO nano-spikes were synthesized by a modified VLS setup, where Zn powder was heated together with graphite in a vacuum furnace, compare [2]. Instead of using gold as a precursor, particles of Zn with a size of about 5 µm were used as catalysts for the ZnO nano-spikes growth. This method is similar to the approach described in Ref. [3]. TEM investigations were performed in a Philips CM 30 STwin microscope equipped with precision electron diffraction (PED).

Figure 1 shows a scanning electron microscopy image of ZnO nano-spikes grown from particles of Zn. Figure 2(a) gives a TEM bright-field image of a single ZnO nano-spike. The image shows that the spike consists of two areas. Figure 2(b) presents a PED patter taken from the ZnO nano-spike shown in Figure 2(a). The pattern has three sets of spots in $[2\bar{1}\bar{1}3]$ viewing direction of ZnO which are produced by the coexistence of twinned domains. The examination of many ZnO nano-spikes confirms the twinning as the characteristic feature. Two sets of spots in Figure 2(b) are from a twin structure of ZnO with the $(10\bar{1}\bar{1})$ twin plane. The third set is from double diffraction based on the overlap of twinned domains of ZnO. Such phenomenon was frequently observed, like for (111) twins of cubic SiC [5]. Noticeably, a similar electron diffraction pattern was observed for the ZnO whiskers grown by isothermal annealing of wurzite-type ZnO/Zn composites [4]. Figure 2(d) is a high-resolution TEM (HRTEM) image of the ZnO nano-spike presented in Figure 2(a). The image shows more clearly that the spike consists of two different areas (see also fast Fourier transforms in Figures 2(d) and 2(e)). From the HRTEM image it was found that the ZnO nano-spike grows in $[01\bar{1}0]$ direction. It should be noted that the $(10\bar{1}\bar{1})$ twins of ZnO are usually imaged along the $[01\bar{1}0]$ or $[2\bar{1}\bar{1}0]$ directions [6]. However, due to limitations of the experimental setup, it was not possible tilting to the appropriate viewing direction. In order to explain more accurately the lattice plane contrast of Figure 2(d), simulations of the HRTEM contrasts are in progress.

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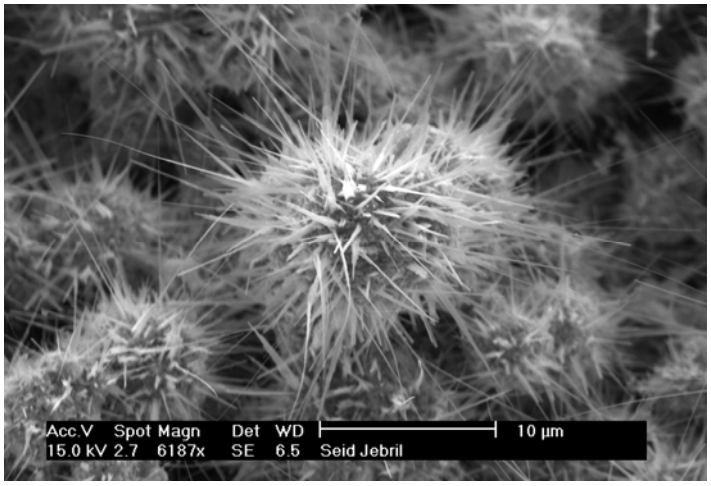

Figure 1. Scanning electron microscopy image of the ZnO nano-spikes.

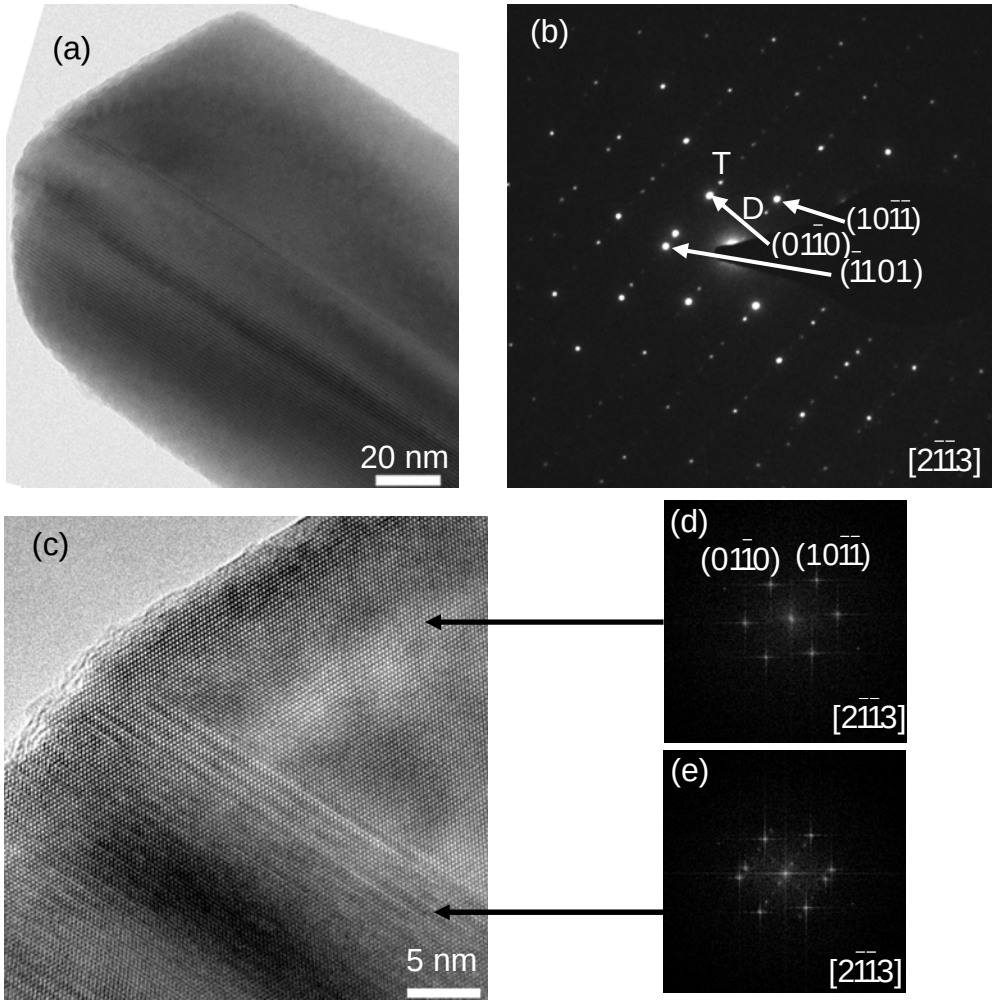

Figure 2. (a) TEM image of a ZnO nano-spike. (b) PED pattern taken from the ZnO shown in (a). Twin spot is denoted by 'T' and double diffraction spot is denoted by 'D'. (c) HRTEM image of the ZnO nano-spike. (d) and (e) Fast Fourier transform images of areas noted in (c).

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