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Topology of WC/Co interfaces in cemented carbides

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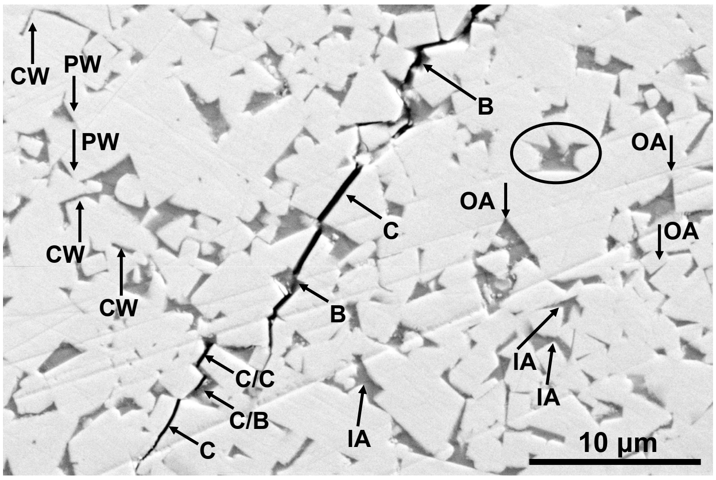
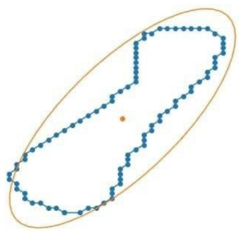
On March 23, 1923, the first patent for cemented carbides based on tungsten carbide with a cobalt binder was registered in Germany [1]. Further development of such alloys requires now the new methods for describing their microstructure, which go beyond the traditional approaches of quantitative metallography. Here we propose a fundamentally new approach to describing the microstructure of these materials, namely, the topology of the WC/Co interfaces in hard alloys based on tungsten carbide with a cobalt binder using computer vision elements (Fig. 1).



(a)



(b)

Fig. 1 (a) SEM micrograph of a WC-Co alloy with various structural elements. Center: crack growth trajectory. The symbol C denotes a transgranular fracture, C/B and C/C, an intergranular fracture, and B, a fracture through a cobalt binder. To the left of the crack the phenomena of grain-boundary wetting are marked. The arrows and symbol CW indicate the boundaries between tungsten carbide grains completely wetted with a cobalt binder. The arrows and symbol PW indicate the boundaries between tungsten carbide grains partially wetted with a cobalt binder. To the right of the crack the structural elements of the "islands" of the cobalt binder are marked. Arrows and the symbol IA indicate kinks at the interface(“incoming angles”), in which the ridges of faceted tungsten carbide crystallites enter the region of the cobalt binder. The arrows and symbol OA indicate kinks at the interface (“outgoing angles”) where the cobalt binder contacts the WC/WC boundaries between tungsten carbide grains. The ellipse denotes, for example, a continuous region of cobalt binder grains. For such areas, an analysis of the contour of the interphase boundary was carried out with the determination of incoming IA and outgoing OA angles. The lengths of the semiaxes of such ellipses, which characterize the dimensions of the continuous regions of the cobalt binder, were also determined. (b) Scheme of an ellipse around the points of the contour.

In this work, model sections of samples imitating conventional commercial hard alloys WC-Co were made. The resulting sections were subjected to microscopic examination using scanning electron microscopy (SEM). The calculation of the angles at the interface between tungsten carbide and cobalt binder was based on the scalar product. For each of the three samples, one hundred micrographs were processed and a histogram of the angles at the interfacial boundary of the cobalt binder and tungsten carbide was plotted in Fig. 2(a). To determine the width and length of the cobalt binder regions (Fig. 2b,c), we describe an ellipse around the cobalt regions using the Khachiyan algorithm [2] (Fig. 1c). Based on the obtained lengths of small and diseased semiaxes, we construct a heat maps of the probability distribution of a two-dimensional quantity for large grains and apply a polynomial on it, passing through the “warmest” pixel (Fig. 3)

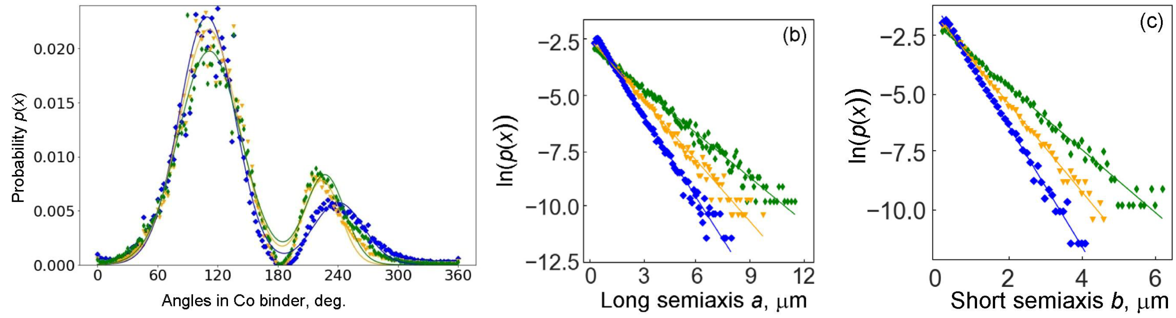


Fig. 2. (a) Distribution of angles on the contour of cobalt binder regions for three samples with different WC grain sizes. Blue is for small grains, orange is for medium grains, green is for large grains. The distribution of the lengths of the semiaxes of such ellipses for the cobalt binder for three samples with different grain sizes WC. (b) long axis, (c) short axis. The vertical axis shows the logarithms of the distribution probability Blue is for small grains, orange is for medium grains, green is for large grains.

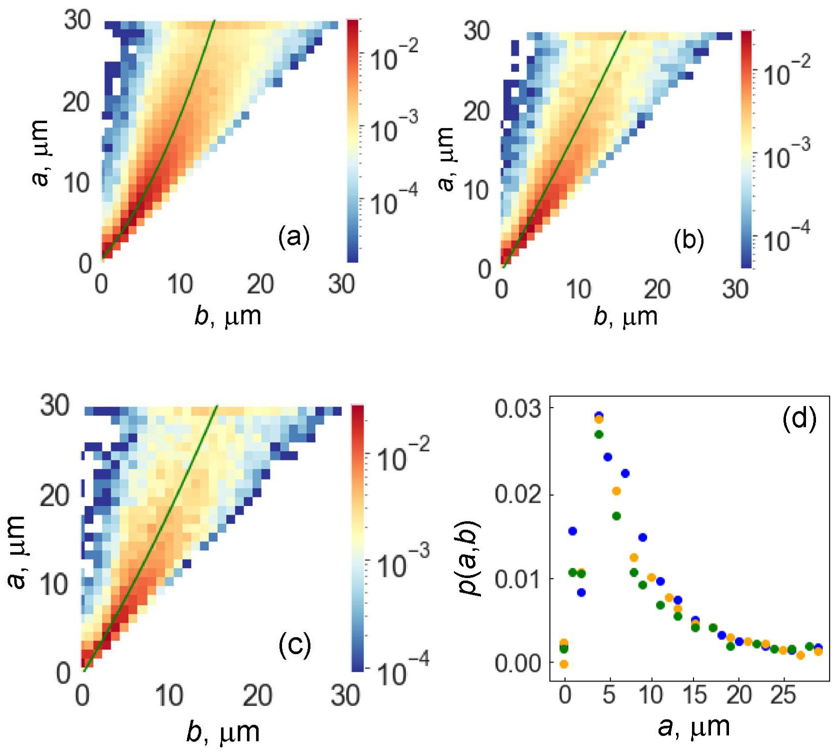


Fig. 3. Two-dimensional distribution densities $P(a,b)$ of the lengths of the semiaxes a and b. (a) small grains, (b) medium grains, (c) large grains. The color scale on the right represents the values of $P(a,b)$. The solid lines are for the distribution ridge. (d) The value of $P(a,b)$ on the distribution ridge as a function of the major semiaxis: blue is for small grains, orange is for medium grains, green is for large grains.

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