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Co drifts between cemented carbides having various WC grain sizes

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ABSTRACT

Functionally graded cemented carbides obtained on the basis of capillarity phenomena can be very important for numerous applications and are expected to substitute conventional WC–Co cemented carbides. Drifts of liquid Co-based binders in couples of model WC–Co alloys with different WC mean grain sizes sintered together were examined. Noticeable Co drifts occur from coarse-grain into fine-grain regions of the model alloys due to different capillary forces. The Co drifts become more pronounced when the difference between WC mean grains sizes of the coarse-grain region and fine-grain region increases.

1. Introduction

Functionally graded cemented carbides obtained on the basis of capillarity phenomena due to creating Co drifts during liquid phase sintering can be very important. They are expected to substitute conventional WC–Co cemented carbides in numerous applications.

Co drifts between parts of carbide articles with various WC mean grain sizes and carbon contents were reported in literature with respect to the possibility of fabrication of functionally graded cemented carbides [1–4]. However, the Co drifts were examined in couples of cemented carbides with various carbon contents containing η-phase and the process of carburisation of η-phase due to carbon diffusion can play a significant role in this case. There are no results in literature on the Co migration between alloys with the same carbon content but very different WC grain sizes varying in a wide range from near-nano to ultra-coarse.

The formation of significant Co gradients in WC–Co articles can be achieved by the selective carburisation of the near-surface layer leading to a noticeable WC grain growth in this layer [5–10]. It is known that the process of WC coarsening occurs at a considerably higher rate in WC–Co cemented carbides with high carbon contents [11]. Therefore, it is expected that Co drifts can occur in this case as a result of different WC mean grain sizes in the near-surface layer and the core region due to various capillary forces.

In the present work Co drifts between couples of model alloys with very different WC grain sizes sintered together were for the first time systematically examined

2. Experimental details

Powders of cemented carbide model alloys containing 10 wt% Co with very similar carbon contents but various WC mean grain sizes were pressed together and sintered at 1420 °C for 75 min in a vacuum for examining Co drifts during liquid phase sintering. The cemented carbides with various grain sizes were WC–Co grades with WC mean grain size of 0.2 μm (near-nano grade), 0.8 μm (ultra-fine grade), 2.5 μm (medium-coarse grade) and 4.8 μm (ultra-coarse grade).

Microstructures of the model alloys sintered separately, and pressed and sintered together as well the interface between two model alloys with various WC grain sizes were examined by light microscopy. The Co distribution in the samples after sintering was measured by EDX on the HRSEM (Philips XL30S) with the precision of roughly ±5%. Before measurements, both the sample with gradient Co contents and a control sample without Co gradient and known Co content were ground, polished and measured by EDX in exactly the same way in order to normalise the EDX results with respect to the model alloys with the known Co content. This is necessary when taking into account that the Co binder regions among WC grains on the surface of polished cross-sections are usually slightly polished away leading to the fact that the Co content measured by EDX on the cross-section surface is typically

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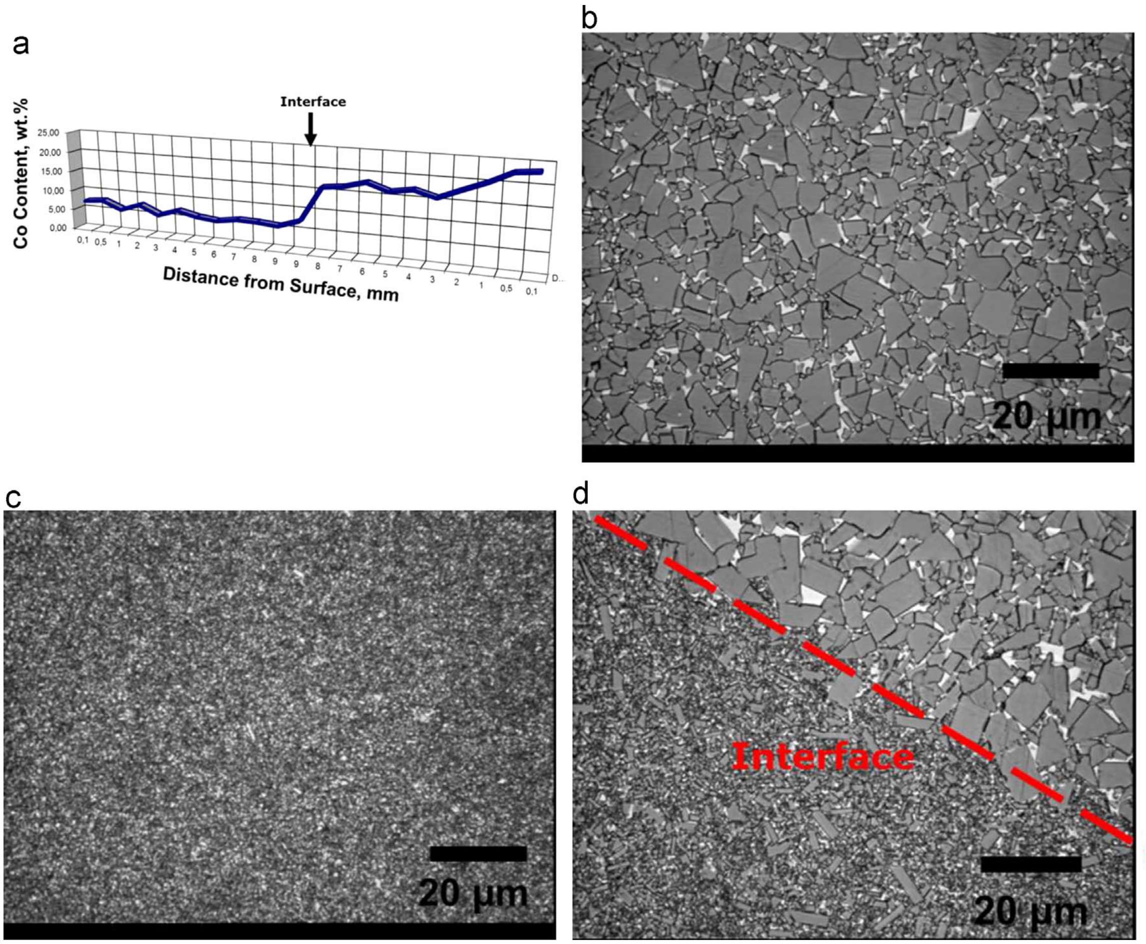

Fig. 1. Curve indicating the Co distribution after sintering a couple of model alloys with various WC mean grain sizes: ultra-coarse alloy with WC mean grain size of 4.8 μm on the left hand size and near-nano alloy with WC mean grain size of 0.2 μm on the right hand size (a). The initial interface between the two model alloys is indicated by an arrow. Microstructures of the model alloys: (b) ultra-coarse alloy with WC mean grain size of 4.8 μm; (c) near-nano alloy with WC mean grain size of 0.2 μm; and (d) interface between the two model alloys sintered together.

nearly 30% lower than the real Co content in the bulk sample.

3. Results and discussion

Fig. 1 shows a curve indicating the Co distribution between the cemented carbide with the ultra-coarse structure (WC mean grain size of 4.8 μm) and that with the near-nano structure (WC mean grain size of about 0.2 μm) as well as their microstructures. It can be seen that Co migrates from the ultra-coarse-grain part into the near-nano part as a result of very different capillary forces and the difference in Co contents between these two parts becomes roughly 10 wt% after sintering. The microstructure of the near-nano carbide region close to the initial interface becomes noticeably coarser than in the region distant from the interface. This is a result of the significantly higher Co content in the region of the near-nano carbide adjacent to the interface.

Fig. 2 shows a curve indicating the Co distribution between the cemented carbides with the ultra-coarse structure and WC mean grain size of 4.8 μm and that with the ultra-fine structure and WC mean grain size of nearly 0.8 μm and their microstructures. It can be seen that Co also migrates from the coarse-grained part into the fine-grain part as a result of different capillary forces. However, the difference in Co content between these two parts is lower than in previous case shown in Fig. 1 and equal to nearly 6 wt%, which is related to the less significant difference in capillary forces between these two alloys. As in the case of the near-nano carbide, the microstructure of the ultra-fine carbide in the region close to the interface becomes coarser than in the region distant from the interface due to the enrichment of the region by the binder.

Fig. 3 shows a curve indicating the Co distribution between cemented carbide with ultra-coarse structure and WC mean grain size of 4.8 μm and that with medium-coarse structure and WC mean grain size of nearly 2.5 μm and their microstructures. In this case, the difference in WC mean grain size is relatively insignificant, so that the difference in capillary forces is noticeably lower than in the two previous cases. As a result, the difference in Co contents between the parts with the ultra-coarse and the medium-coarse microstructure is much lower than in the two previous cases and equal to only about 4 wt%. There is also some coarsening of the microstructure of the medium-coarse grade near the initial interface after sintering.