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# Metallurgy and thermochemistry of cermet/hardmetal laminates

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ABSTRACT

Laminates of Ti(C,N)–WC–(Ta,Nb)C–Co/Ni cermets with WC–Co hardmetals were studied with respect to liquid-phase formation, bulk microstructure and microstructure evolution at the various interfaces. To adapt the cermet to the sintering behaviour of the hardmetal, investigations on mass change, influence of nitrogen pressure, as well as Cr and C doping on liquid-phase formation temperatures were performed. In addition, shrinkage and CO and $N_2$ outgasing were studied.

The bonding of cermets (CMs) to hardmetals (HMs) and that of 1:1, 1:2 and 2:1 mixtures of cermet/hardmetal (CM/HM) is tight, i.e. no pores occur. No major distortion or bending was observed although the shrinkage of each of the alloys was quite different. At the interfaces an intermixing occurred because of diffusion. At the CM/HM 2:1/1:2 interface a graded diffusion zone with more than 100 μm thickness formed.

In a bi-layer cermet/hardmetal laminate the interface microstructure was dependent on the nitrogen pressure in the sintering chamber. Enrichment of Co and nitrides occurred at lower than equilibrium pressure, whereas WC precipitated in the cermet at high nitrogen pressure.



## 1. Introduction

Hardmetals, also called cemented carbides (i.e. WC–Co based alloys) and cermets (i.e. Ti(C,N)–Co/Ni based alloys) are well known as cutting materials. Cermets have higher hardness but lower fracture toughness than hardmetals [1,2] so they are employed only for specific finishing applications. Hence, cermet production amounts only to a few percent of the total production of hardmetal cutting tools in the Western hemisphere, but to about 25% in Japan. Considering the raw materials, an advantage of cermets is the substantially lower supply risk of cermet constituents compared to that of hardmetals. Due to geostrategic peculiarities, tungsten is one of the highest ranked materials in the risk list [3,4].

Due to the inherent material properties, a total replacement of hardmetals by cermets seems impossible. In order to reduce the total W consumption in a cutting body, one method is to prepare only the edge and near-edge positions of a cutting body out of a hardmetal, whereas the rest of the body could be fabricated out of a cermet of substantially lower W content (or even without W). For this purpose, cermet composition and sintering technology has to be adapted in order to be compatible with optimum hardmetal properties. The challenge is to combine these two materials in such a way so as to provide tight bonding without pores or cracks between the layers and minimise mechanical stresses arising from different shrinkage behaviours, reducing any distortion or bending of the sintered body.

Ishida et al. [5] demonstrated that WC reduction of cutting tools with almost the same wear and fracture resistance comparable to cemented carbides is possible. They combined a Ti(C,N)-based cermet body (5 wt.% WC) with WC–TaC–Co cemented carbide layers. Previous tests with higher tungsten carbide content (17 wt.%) in the cermet formulation failed because of distortion and partial loss of cemented carbide layer ("flaking") [6]. They observed a convex or concave distortion, depending on the sintering temperature.

We have studied intermediate hardmetal/cermet compositions for a better matching of the differences between hardmetals and cermets in order to avoid distortion and bending [7], some of these results are condensed in the present paper. In addition, we report here on a detailed thermochemical analysis of Ti(C,N)-based model alloys and cermets to study the influences of composition and nitrogen pressure. The final aim was to obtain cermet/hardmetal bi-layer laminates.

## 2. Experimental

### 2.1. Starting materials and green body preparation

A cermet (CM) model system with 60 wt.% Ti(C,N) with different C/N ratios, 16 wt.% WC, 10 wt.% (Ta,Nb)C, 13 wt.% Co/Ni(1:1) and 1 wt.% Cr was chosen [7]. Alloys without Cr contained 61 Ti(C,N). A tungsten carbide grade FD0.6, $Cr_3C_2$, (Ta,Nb)C and submicron Ti(C,N) were employed from Treibacher Industrie AG, Austria. In a latter optimisation, the binder phase content of the cermet was varied.

The hardmetal formulation was 90 wt.% WC and 10 wt.% Co. For the hardmetal (HM), a submicron DS50 (BET 2.0 $m^2/g$) powder from H.C. Starck, Germany, was employed. In a final stage, this hardmetal was

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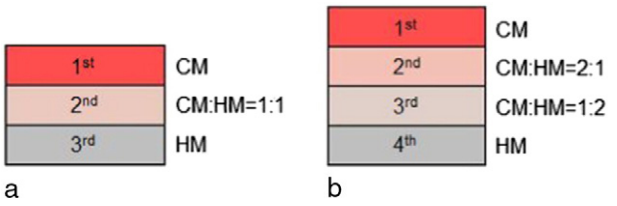


**Fig. 1.** Arrangement of powders for laminates with layers of intermediate composition: (a) three-layer laminate 3L and (b) four-layer laminate 4L.

**Table 1**
Designation of laminates with intermediate layers. CM: Cermet, HM: Hardmetal.

| Laminate name | 1st layer | 2nd layer | 3rd layer | 4th layer |
|---|---|---|---|---|
| HM 3L | CM | CM:HM 1:1 | HM | – |
| HM 4L | CM | CM:HM 2:1 | CM:HM 1:2 | HM |

doped with $Cr_3C_2$ and VC for uniform grain size distribution. After weighing, the powder mixtures were ball milled in drums with a hardmetal lining with hardmetal balls in cyclohexane for 72 h (cermets) or 24 h (hardmetals). The powder-to-ball mass ratio was 10:1. For the preparation of individual bodies and layers with intermediate composition, hardmetal and cermet powders were dry mixed with hardmetal balls in a tumble shaker for 3 h with a mass ratio of CM:HM = 2:1, 1:1 and 1:2. All green bodies were pressed uniaxially with 150 MPa without pressing aids to laminates (Fig. 1). The designation of the prepared laminates with intermediate mixtures is given in Table 1.

### 2.2. Sintering, metallographic preparation

All samples were sintered on alumina plates in a graphite crucible placed in an induction furnace. The basic sintering profile is shown in Fig. 2, and modification of this profile was made for the sintering temperature, length of the dwell and for the nitrogen pressures. By change of nitrogen pressures, nitrogen loss and diffusion of various constituents at the interfaced can be influenced. After sintering, the samples were cut, ground and polished with 1 μm diamond paste for optical and scanning electron microscopy investigation.

### 2.3. Dilatometry

For the shrinkage investigation of cermets, hardmetals and cermet/hardmetal mixtures dilatometry was performed under vacuum with a heating rate of 50 K/min up to 500 °C, then with 10 K/min to 1500 °C.

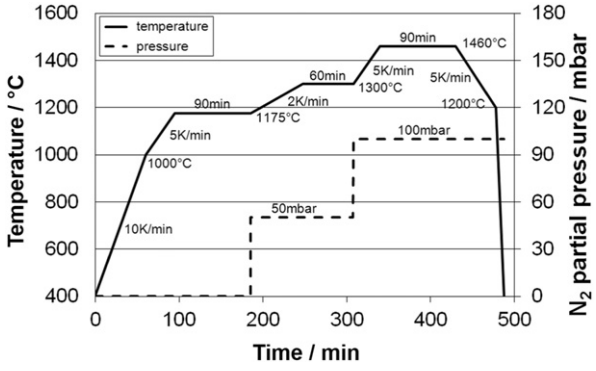


**Fig. 2.** Basic sintering profile for laminates and cermets.

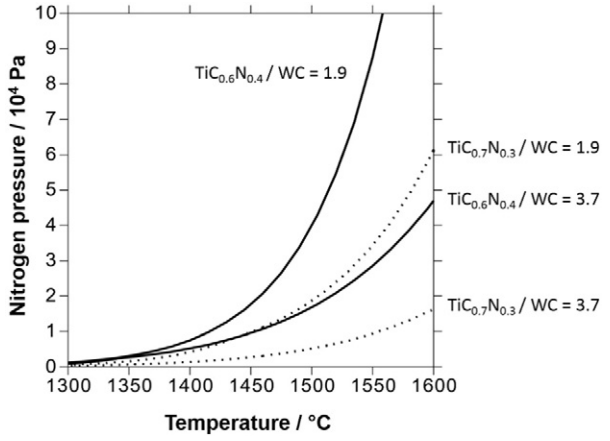


**Fig. 3.** Nitrogen equilibrium pressure (up to 1 bar) of $TiC_{0.7}N_{0.3}$–WC–Co/Ni and $TiC_{0.6}N_{0.4}$–WC–Co/Ni which two different Ti(C,N)/WC ratios (by weight) in a starting formulation with 13 wt.% Co/Ni binder (Co/Ni = 1:1 by weight) as a function of temperature.

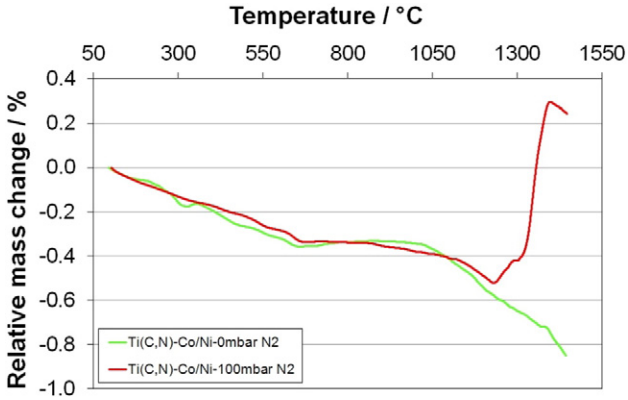


**Fig. 4.** Mass change of $TiC_{0.6}N_{0.4}$–37.5 wt.% Co/Ni, 0 and 100 mbar $N_2$ atmosphere. Error of mass change below 0.02%.

### 2.4. DSC/TG

For further thermoanalytical investigations of cermets, hardmetals and cermet/hardmetal mixtures, Differential Scanning Calorimetry (DSC) was performed in a Linseis STA 1750 DSC/TG apparatus of powders pressed into $Al_2O_3$ crucibles with zig–zag temperature profile (usually two heating and two cooling ramps). Heat flow and mass change were recorded under various Ar and $N_2$ pressures and Ar/$N_2$ ratios.

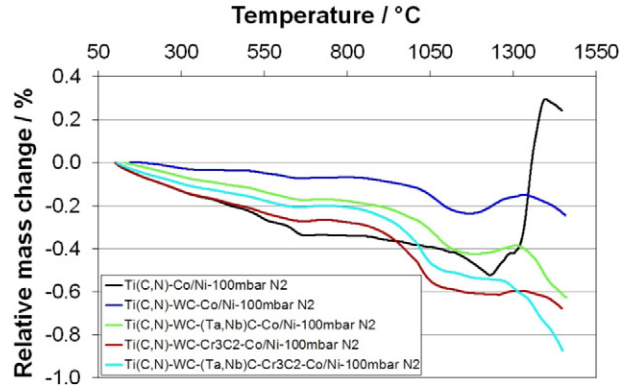


**Fig. 5.** Mass change of cermet model alloys with $TiC_{0.6}N_{0.4}$ and 13 wt.% binder compared to $TiC_{0.6}N_{0.4}$ with 37.5 wt.% Co/Ni, 100 mbar $N_2$.