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# SIMS depth profile analysis of WC-Co composite used in wood materials machining after nitrogen ion implantation

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**Abstract:** *SIMS depth profile analysis of WC-Co composites used in wood materials machining after nitrogen ion implantation.* The paper presents the analysis of depth profiles WC-Co samples obtained using the SIMS method. The surface of samples was modified in the process of nitrogen ions implantation. Secondary ion mass spectrometry (SIMS) is a very useful technique for the analysis of layered systems. It is based on the primary ion beam sputtering of solids and mass analysis of the emitted secondary ions. The results show a high correspondence between the nitrogen depth profiles obtained in the SUSPRE modeling and in the SIMS experiment.

*Keywords:* Secondary ion mass spectrometry (SIMS), depth profile analysis, WC-Co composites, nitrogen ion implantation, machining, wood materials

## INTRODUCTION

Ion implantation is utilized for changing the physical (e.g. hardness, friction coefficient, wear resistance, fatigue resistance, durability) and chemical (e.g. corrosion resistance) properties of the implanted material. During the implantation process, the 'peening' by the ions which penetrate, to a nanometric depth, affects the density, phase composition and microstructure of the layers being formed [Sokolowska et al. 2001].

Usually, the beam diameter exceeds 5 cm, thus enabling the treatment of relatively large surfaces. The applied dose is proportional to ion beam current and implantation time and inversely proportional to the implanted area and the implanted ion charge. The implanted dose, i.e. the planned fluence and the retained dose, i.e. real introduced quantity, strongly depend on the sputtering yield. The unit of the applied dose is ions per $cm^2$, which means the density of the implanted ions [Barlak et al. 2016].

The depth profiles of the implanted materials can be analyzed using SIMS method. Secondary ion mass spectrometry (SIMS) is a very useful surface analytical technique which allows one to analyze layered systems with a very high depth resolution. This technique has many advantages such as: very low detection limit and high signal/noise dynamics [Mišnik et al. 2018, Konarski et al. 2013, 2014].

The aim of this work is to determine nitrogen distribution of near surface layers of WC-Co composite after a process of ion implantation.

## MATERIAL AND METHODS

The WC-Co indexable knives (with dimensions 29.5×12×1.5 $mm^3$) produced by Ceratizit company (Reutte, Austria) were used. Properties of the tested WC-Co composite are presented in Table 1. It is a standard tool material used for machining wood-based panels in the furniture industry.

**Table 1.** Chosen properties of tested WC-Co material

| Material symbol | WC grain size [μm] | Binder content Co [%] | Density [g/cm$^3$] | Hardness HV30 | Fracture toughness $K_{IC}$ |
|---|---|---|---|---|---|
| KCR08 | 0,5-0,8 | 3,2 | 15,2 | 1790 | 12,1 |

The knives were implanted with N+ ions, using the implanters with mass-separated ion beams. The implanted doses were 1e17 and 5e17 cm$^{-2}$. The implantation energy was 50 keV. After the implantation process, the SIMS depth profile was analyzed. The apparatus used in the experiment is shown in Fig.1.

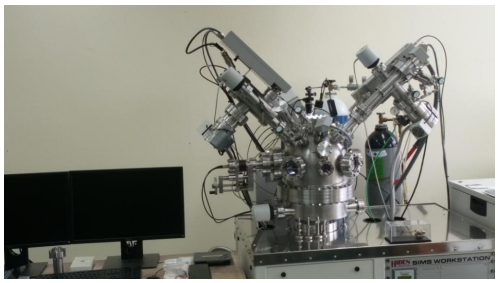

**Figure 1.** The SIMS apparatus at Tele and Radio Research Institute – ITR

The ion depth distribution is roughly given by a Gauss-shape depth profile of implanted element [Barlak et al. 2016]. The depth profile and selected properties of the implanted material can be modelled using several computer codes, e.g. based on a quick ion implantation calculator SUSPRE (Fig.2).

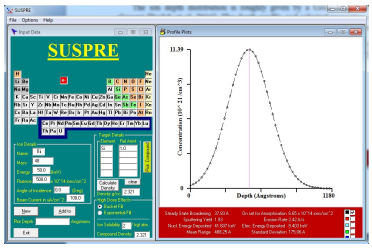


**Figure 2.** The ion implantation calculator SUSPRE (the program interface).

The SIMS tests were performed using of the $O_2^+$ primary ion beam. The measurement parameters are presented in Table 2. The depth of the SIMS craters (Fig.3) was measured using a Tencor A-step 100 profilometer to determine of the sputtering rate.

**Table 2.** Parameters of the SIMS profile analysis

| Energy [keV] | Beam current [nA] | Raster [µm x µm] | Sputtering rate [nm/s] | Time of one cycle [s] |
|---|---|---|---|---|
| 2 | 120 | 500x500 | 1.12 | 31.4 |

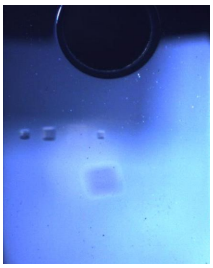

**Figure 3.** View of the polished surface of the WC-Co sample with SIMS craters (the sample to determine of the sputtering rate).

RESULTS AND DISCUSSION

The depth profiles of implanted WC-Co material based on the calculator SUSPRE are presented in Fig.4. The modeled profiles shows the range of nitrogen ions in the WC-Co composite to a depth of about 120 nm.

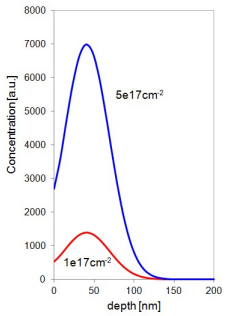


**Figure 4.** Simulated distribution function of N atoms implanted into WC-Co material (dose of 1e17 $cm^{-2}$ and 5e17 $cm^{-2}$).

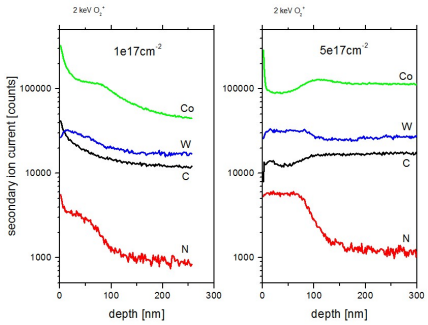


**Figure 5.** SIMS depth profile analysis of the WC-Co samples after nitrogen implantation.

Quantified data of depth profile analysis are shown in Fig.5. The results show a dependence of ion current intensity on sample depth. The values of these currents, however, are different for different samples. This effect results from changes of SIMS sensitivity for individual samples. In order to limit this effect, Fig.6a presents the results plotted in the form of the ratio of $N^+$ to $C^+$ ion current. Fig.6b shows the same result in a logarithmic scale.

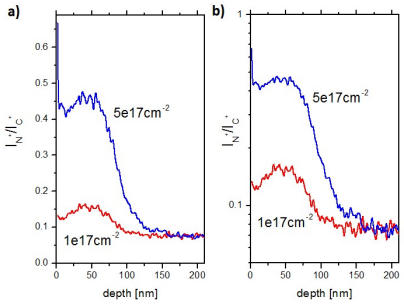


**Figure 6.** The ratio of $I_N^+/I_C^+$ for the tested samples (a) and in logarithmic scale (b).

The profiles of nitrogen depth in the SIMS experiment, similar to the SUSPRE modeling, reached a depth of about 120 nm (Fig.6). A model increase in the $I_N^+/I_C^+$ ratio was also observed along with an increase in the dose of ions (from 1e17 to 5e17 $cm^{-2}$).

CONCLUSION

The results show a high correspondence between the nitrogen depth profiles obtained in the SUSPRE modeling and in the SIMS experiment.

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**Streszczenie:** *Analiza SIMS profilu głębokościowego kompozytu WC-Co wykorzystywanego w obróbce materiałów drzewnych po implantacji jonami azotu.* W artykule przedstawiono analizę profili głębokościowych rozkładu pierwiastków składowych i zaimplantowanego azotu w materiale WC-Co. Wykorzystano analizę SIMS. Wtórna spektrometria masowa jonów (SIMS) jest bardzo przydatną techniką analizy układów warstwowych. Oparta jest na trawieniu jonowym warstwy wierzchniej próbek i analizie masy wyemitowanych jonów wtórnych. Wyniki pokazują wysoką zgodność między profilami głębokości uzyskanymi w modelowaniu SUSPRE i w eksperymencie SIMS.

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