

Cutting tools are widespread across all the industrial sectors, from aerospace and automotive to the biomedical and consumer electronics, and are employed wherever material processing is required. Coatings, such as Diamond-Like Carbon (DLC) and Titanium Nitride (TiN), are extensively applied to enhance the durability and cutting efficiency of Hard Metal (HM) and High-Speed Steel (HSS) cutting tools, particularly under demanding machining conditions. Over time, tools inevitably develop defects and wear, becoming dull and losing cutting efficiency. To extend their lifespan through resharpener and recoating, an efficient decoating process is essential. Nowadays, chemical and electrochemical processes are mainly employed in industry for coating stripping, while mechanical and physical techniques are less frequently used. In the present research, the application of vacuum and in-liquid plasma technologies was investigated to tackle the critical issue of cutting tools decoating, aiming at a fast removal of the protective film while avoiding the use of harmful chemicals. Low-Energy High-Current Electron Beam (LEHCEB) was employed to remove DLC coatings from WC-Co2 milling inserts, while Electrolytic Plasma Polishing (EPP) was used to remove TiN coatings from AISI M2 drill bits.

Pulsed electron irradiation by LEHCEB completely removed the carbon coatings (a-C:H and ta-C types of DLC) due to the high surface temperatures reached and consequent evaporation of the thin film. The electron accelerating voltages were 20, 25 and 30 kV, with an associated energy density of 2.5, 3.3 and 4.9 J cm⁻², respectively. The number of pulses was 5, 10 and 20, with a 0.2 Hz repetition frequency. The working pressure (1.8·10⁻⁴ Torr) and the ionized gas (Ar) were kept the same. In the optimized conditions the DLC was stripped from the whole cutting tool in 100 seconds, which was faster with respect to the whole topic literature. After decoating, cutting tools were resharpener, coated again and tested. In particular, the adhesion, the microhardness and the wear behaviour were assessed. LEHCEB treatment was performed also on two different WC-Co grades containing 10 and 20 wt.% of cobalt binder, without any coating. After the surface treatment, the microhardness and the corrosion resistance in acidic environment were measured, and an improvement in both surface properties was observed.

The EPP technique allowed to remove the nitride coating by combining the anodic dissolution, typical of any electrochemical polishing process, with the effect of plasma interactions occurring at the surface of the cutting tool. An initial optimization of the electrolyte was performed, comparing more than 40 formulations. Once the electrolyte has been selected, the influence of the DC cell voltage (75-350 V), of the electrolyte concentration (3-24 wt.%) and of the temperature (20-95°C) was investigated. Coating thickness and mass loss were measured at regular intervals in between 1 and 15 min. In the optimized treatment conditions, the titanium nitride coating was stripped in around 150 seconds. Moreover, the EPP process showed great reproducibility and the electrolyte did not suffer of aging even after six hours of continuous treatment. In the end, a decoating mechanism was proposed combining results of different characterization techniques such as EDS, GDOES and XPS.

In comparison with commercially available techniques, LEHCEB and EPP technologies allowed to remove protective coatings in a shorter time and without the use of any hazardous chemicals.