

Focused magnetron sputtering (FMS):

Combining HiPIMS-level plasma density and DCMS deposition rates on large industrial targets

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■ Cathodic Arc Evaporation (CAE) is the dominant deposition technology for producing hard protective coatings in the machining industry. The process is characterized by a high ionization degree of the evaporated material and fast growth of highly dense coatings. The main drawback of CAE is the formation of more unwanted metallic droplets than competing technologies. For applications sensitive to droplets and pinholes, Direct Current Magnetron Sputtering (DCMS) and High-Power Impulse Magnetron Sputtering (HiPIMS) are the main alternative deposition technologies. Sputtering comes with its own set of challenges, particularly related to achieving sufficient plasma density to deposit high-quality coatings over a large substrate area at an industrially practicable growth rate.

PLATIT has recently developed a novel patented^[1] coating deposition technology achieving high plasma power densities across industrial-scale targets: a mobile magnetron is shuttled between the ends of a cylindrical sputtering cathode, effectively scanning a dense plasma across the length of the target. This concept is being commercialized as Focused Magnetron Sputtering (FMS) technology and is depicted in *figure 1*. By using a DC power supply with a total output power of up to 30kW and a target measuring $\varnothing 110\text{ mm} \times 510\text{ mm}$, peak sputter power densities of 840 W/cm^2 are attained. This approaches the range characteristic of HiPIMS, yet with considerably higher deposition rates^[2]. Its integration into PLATIT's PVD industry-leading coating unit, the $\pi 411$, represents a significant advancement in hard protective coatings for industrial applications.

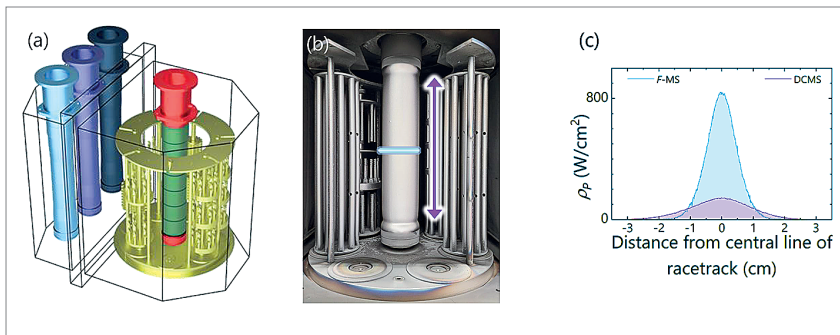


figure 1

Overview of Platit $\pi 411$ cathode configuration – FMS cathode in red (a); chamber with schematized annular blue plasma generated by the movable focused magnetic field (b); the power densities achieved in the FMS and DCMS modes at 25 kW (c)

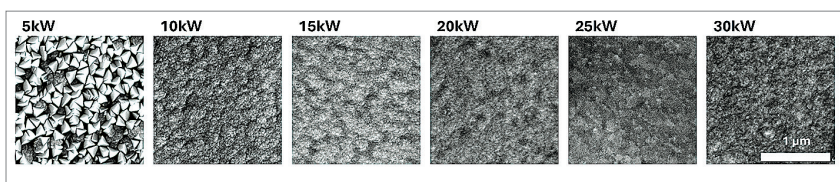


figure 2

Surface features observed at 5kW disappear above 10kW, accompanied by a significant decrease in surface roughness; densified coatings are observed above 10kW due to enhanced ion bombardment

High plasma densities in magnetron sputtering facilitate intense ion bombardment during thin film growth. This ion bombardment enhances film adhesion by promoting interfacial bonding and removing surface contaminants. It also compacts and densifies the film, resulting in a uniform, dense structure with reduced porosity. Moreover, by adjusting ion energy and flux during deposition, the film's composition, microstructure and texture can be tailored (*see figure 2*). This enables optimization of film properties for specific applications, such as protective coatings for a wide range of components and tooling^[3].

To evaluate the performance of FMS technology relative to conventional methods, AlCrN coatings deposited by CAE, HiPIMS and FMS technologies were compared in two cutting test applications: side milling and fly cutting (a single-tooth cutting test simulating gear hobbing^[4]).

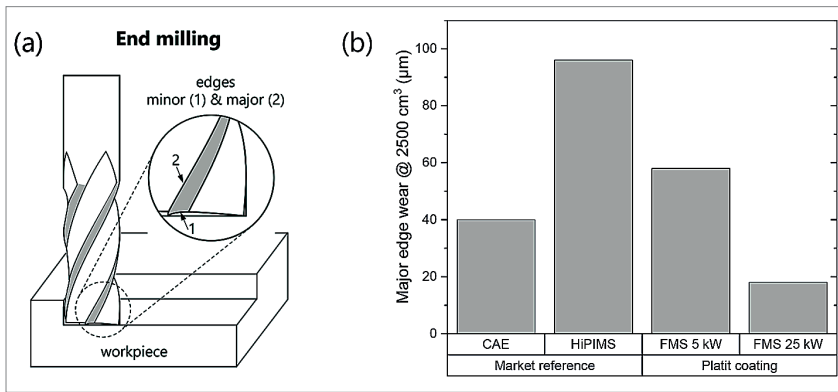


figure 3

Schematic illustration of the side milling test setup (a) and wear evaluation of the major cutting edge for CAE, HiPIMS, FMS coatings (b)

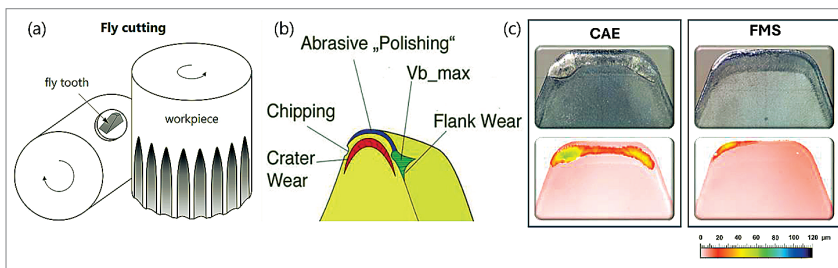


figure 4

Fly cutting test setup (a), typical wear patterns on cutting teeth (b), and the evaluation of crater wear on the rake face of the cutting tooth (c)

Side milling:

The side milling tests with minimum quantity lubrication were performed using a Fehlmann Picomax 60-M. The selected coatings were deposited on end mills (MB-NVDS, Fraisa AG) which were then used to machine a C45 steel plate (HB200). The cutting speed and feed rate were set to 200 m/min and 0.32 mm/rev, respectively, with radial and axial cutting depths of 4 mm each. Total tool wear was assessed after removing 2400 cm³ of material from the steel plate.

FMS demonstrated significant wear reduction on the major edge while minor edge wear was comparable to CAE AlCrN. The HiPIMS market reference had the highest wear of all three coatings. Overall FMS provides superior abrasive resistance and performance in side milling tests especially for the version with increased ion bombardment using average sputter power of 25 kW.

Gear hobbing (fly-teeth):

The fly cutting analogy test is performed by using a single cutting tooth alone to perform a gear cutting operation. This effectively concentrates all the wear ordinarily distributed across the hob onto one sole tooth, permitting wear behavior to be assessed after milling only a few gears (see figure 3, [5]).

The dry fly cutting of 20MnCr5 gear blanks was carried out on a Liebherr LC180 gear cutting machine using the teeth removed from an original PM-HSS hob with modulus 4. Cutting speed and feed rate were set to 220 m/min and 6.9 mm/rev, respectively. The wear was evaluated every 0.8 m cutting distance, and the test was stopped once the flank wear exceeded 130 µm or the crater wear exceeded 100 µm.

The fly cutting tests demonstrated a significant reduction in crater wear on the rake face for AlCrN coatings deposited by FMS compared to those deposited by CAE. For teeth coated by CAE, significant crater wear was observed after 7.8 m/tooth, while teeth coated by FMS show no crater wear even after a cutting distance of 9.4 m/tooth. Just a small amount of abrasive polishing damage was observed near the cutting edge for the teeth coating using FMS. Closer inspection of the worn teeth revealed improved fracture toughness in the FMS coatings as evidenced by enhanced crack-deflection.

In conclusion, FMS offers a viable alternative to conventional sputtering and CAE for depositing tough, wear-resistant coatings. This is achieved using a powerful magnetron to achieve plasma densities comparable to those encountered in HiPIMS processes. The reciprocating magnetron prevents the target from overheating locally beneath the dense plasma. Side milling and gear cutting tests confirm the excellent properties achieved for AlCrN coatings while provisional results indicate that FMS technology will provide similar advantages for a host of other common coating materials.

References:

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