

Tuning the formation and dynamics of spokes in magnetron sputtering

M. Rudolph¹, W. Diyatmika¹, O. Rattunde², E. Schüngel², D. Kalanov¹, F. Manke², J. Patscheider², A. Anders^{1,3}

IT

¹ Leibniz Institute of Surface Engineering (IOM), Permoser Straße 15, D-04318 Germany

² Evatec AG, Hauptstraße 1a, CH-9477 Switzerland

³ Plasma Engineering LLC, 708 Avila Place, El Cerrito, CA-94530 USA
martin.rudolph@leibniz-iom.de

Spokes in magnetron sputtering discharges are distinct zones of enhanced excitation and ionization that move along the racetrack. These instabilities create a strongly heterogeneous plasma along the race-track, with bright regions associated with spokes and much darker regions in between them. The mechanisms contributing to the deposition process are highly localized, starting from the production of ions inside a spoke, followed by their acceleration toward the target and subsequent sputtering in the vicinity of a spoke. The released target atoms then deposit onto the substrate, sometimes after being ionized when passing through the discharge. Film growth is thus strongly linked to spokes and their characteristics, such as their emission intensity and velocity.

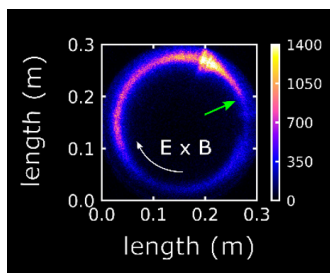


Figure 1: Spoke formation at a strong-to-weak magnetic field strength transition (indicated by the green arrow) on a DCMS magnetron sputtering discharge using a 300 mm aluminum target operated at 10 kW of discharge power. The images is taken with an ICCD camera using an exposure time of 250 ns. The color bar shows light intensity through a bandwidth filter of (480 ± 5) nm.

In this contribution, we demonstrate how spokes can be controlled using standard process parameters. We demonstrate how spokes can

be dimmed or intensified by adjusting the working gas pressure and magnetic field strength [1,2]. The reason is that both parameters affect the electron drift current that is necessary for spoke formation. Moreover, we show that intense spokes can be excited at a defined location along the racetrack by introducing a step in the magnetic field strength [2]. The observation can be explained by an accelerating electron drift velocity as the magnetic field strength weakens. Finally, we show that their velocity can be adjusted using the working gas pressure and discharge current with lower velocities observed at higher gas pressures and lower discharge currents. The controlled manipulation of spokes and tuning of their characteristics may in the future enable spokes engineering allowing thin film properties to be tailored through deliberate tuning of spoke characteristics.

References

- [1] Rudolph, M. et al. J. Appl. Phys. 130 (2021) 24431 doi: 10.1063/5.0075744
- [2] Rudolph, M. et al. Plasma Sources Sci. Technol. 33 (2024) 045002 doi: 10.1088/1361-6595/ad34f7

Financial support was provided by the German Federal Ministry of Education and Research (Grant No. 01QE2116B).