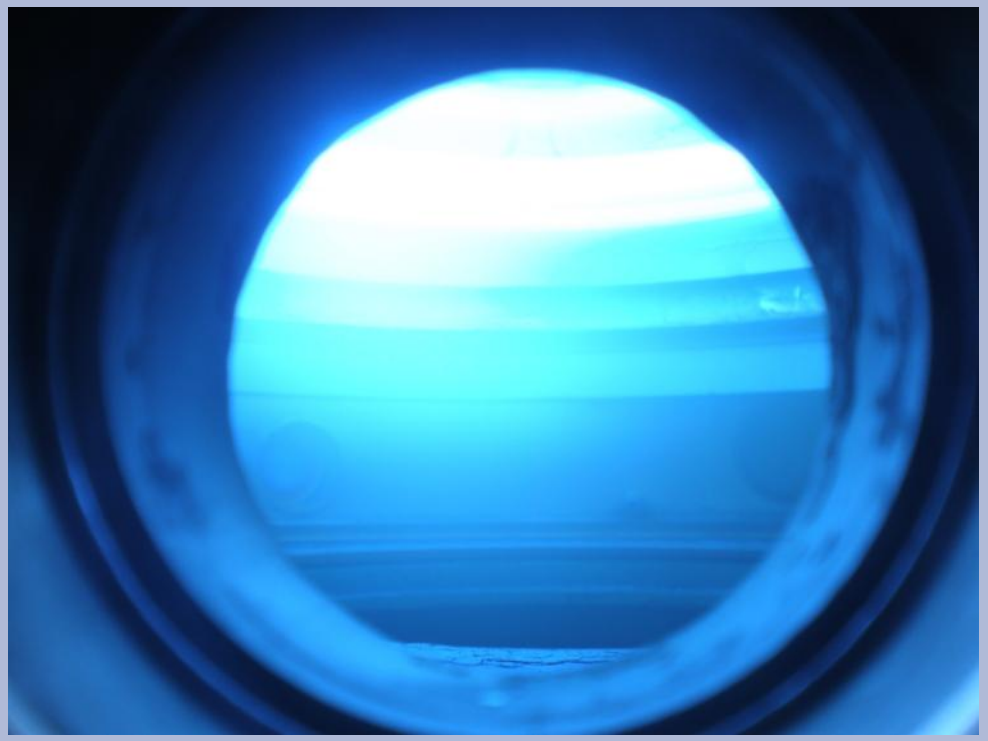
High Power Impulse Magnetron Sputtering / High Power Pulse Magnetron Sputtering (HiPIMS/HPPMS)

Technology, applications and possibilities

Anna Gustafsson

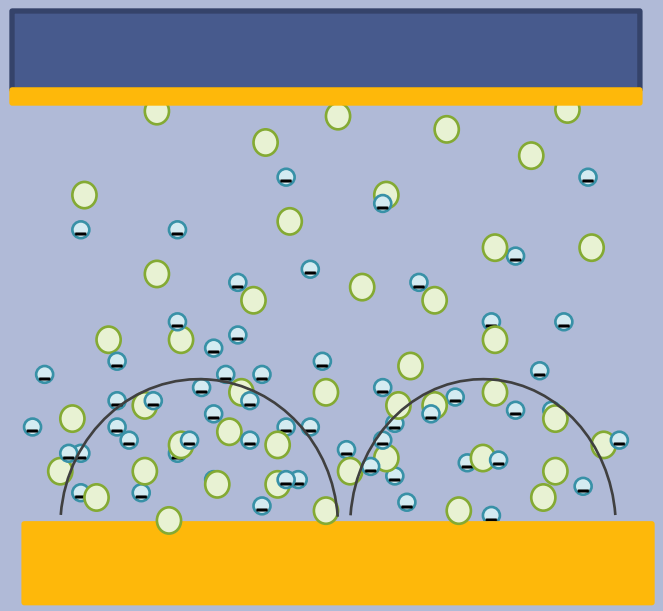
Overview

- Introduction into Magnetron Sputtering
- HiPIMS
  - Physical processes
  - Film properties
  - Applications
- Pro's and Con's
- The HiPIMS Power Supply
- Summary & Outlook



Introduction: Magnetron Sputtering

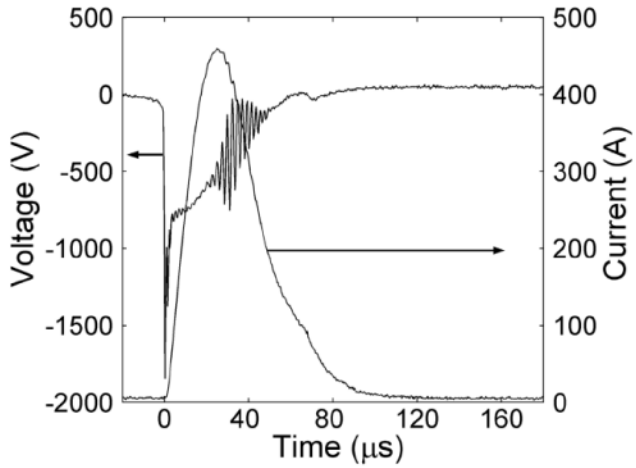
- Buffer-gas atoms (e.g. Ar or Kr) are ionized. The buffer-gas ions are then accelerated towards the target and sputter atoms out of the target.
- The target atoms fly towards the substrate by the kinetic energy received in the sputter process.



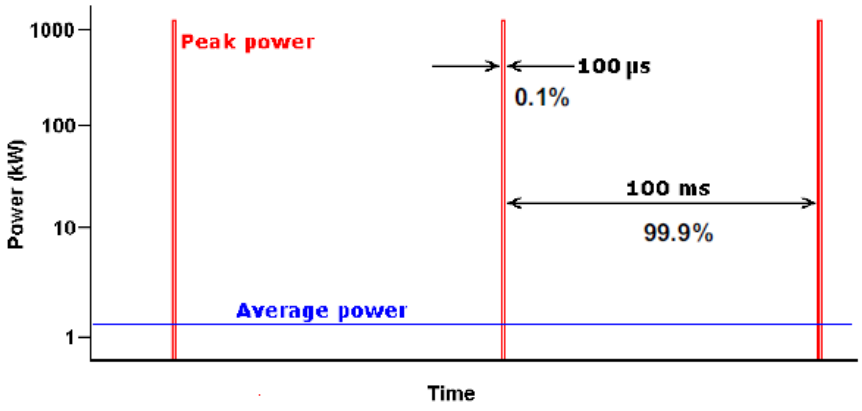
For more details on the spectrum of dcMS see Wil's talk (13.11.09)

HiPIMS: Physical processes

- By applying pulses of high power the sputtered target material atoms are ionized



Typical voltage and current trace from a high power pulsed magnetron discharge.



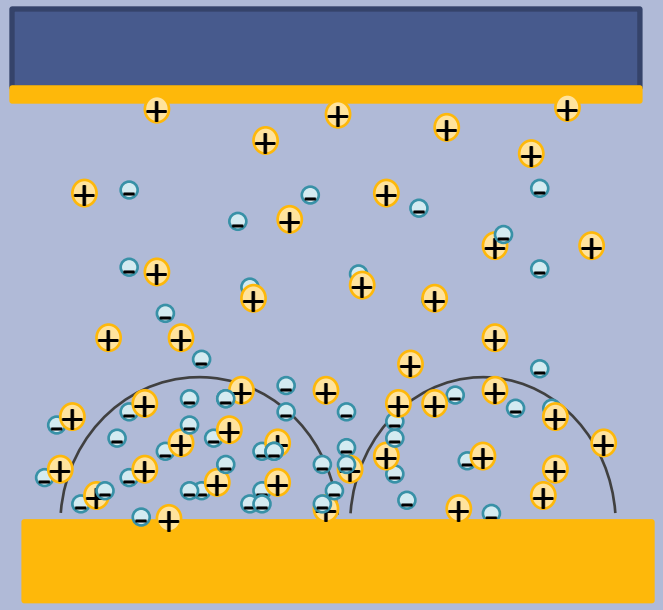
Example of a duty cycle.

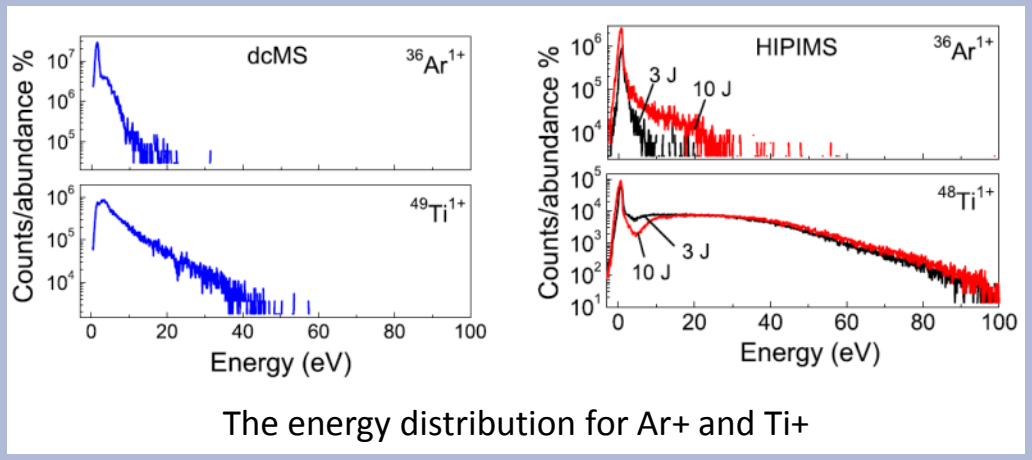
J. Böhlmark et al., J. Vac. Sci. Technol. A 23 (2005) 18

HiPIMS: Physical processes

- By applying pulses of high power the sputtered target material atoms are ionized

→ target material ions can be accelerated towards the target, higher kinetic energy upon arrival





The energy distribution for Ar+ and Ti+

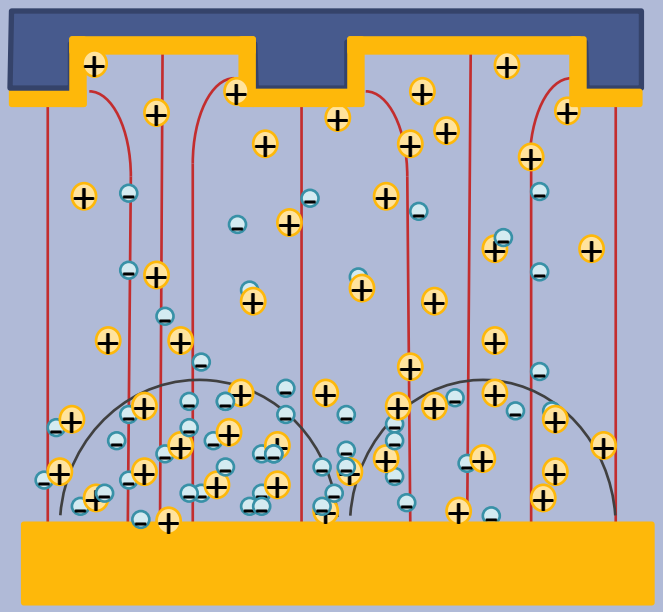
U. Helmersson et al., Thin Solid Films 513 (2006) 1-24

HiPIMS: Physical processes

- By applying pulses of high power the sputtered target material atoms are ionized

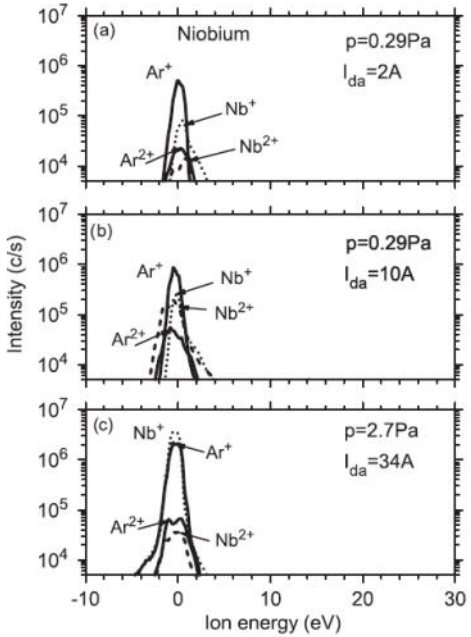
→ target material ions can be accelerated towards the target, higher kinetic energy upon arrival

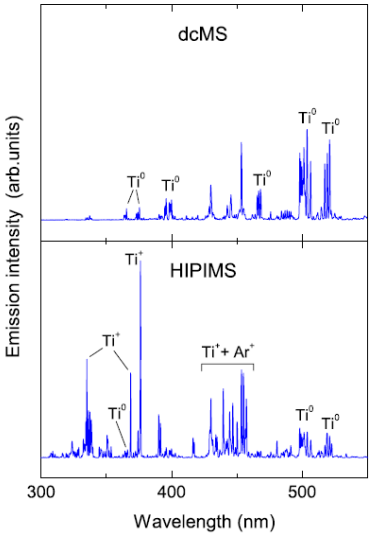
→ ions are directed to the surface, thus non-flat surfaces can be sputtered with good conformity of the film



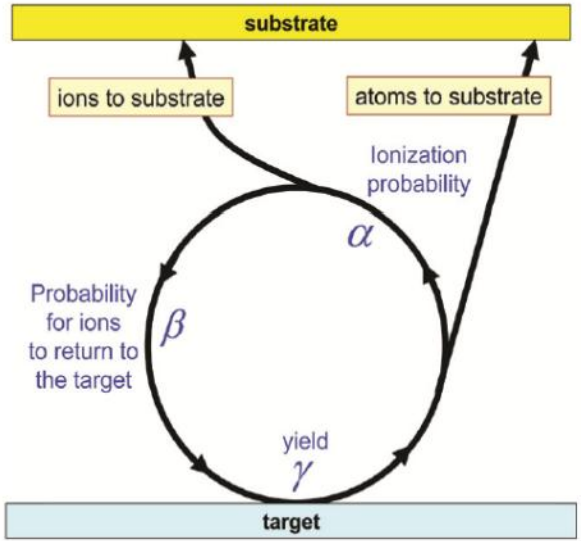
HiPIMS: Ionization

- High ionization percentage
- Typical values: > 90 % ionization of Ti, for Nb ~ 60 %. Nb and Ti have comparable ionization energies (6.88 eV and 6.83 eV).
- Ionized target atoms can return to the target and cause self sputtering





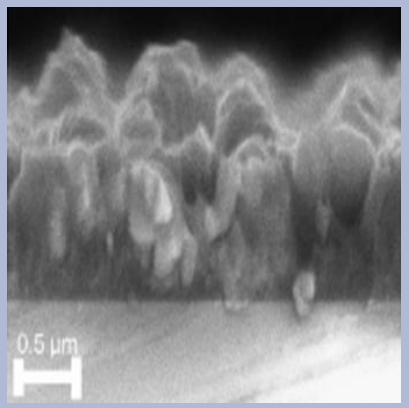
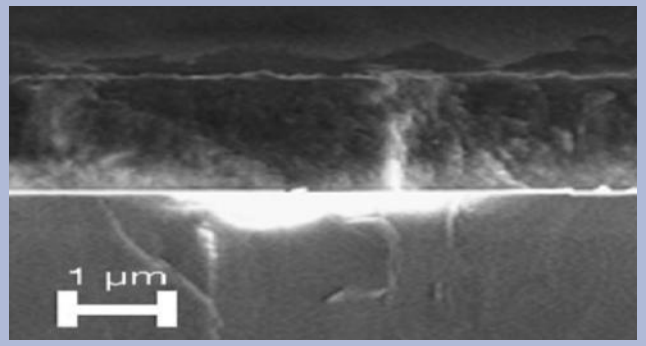
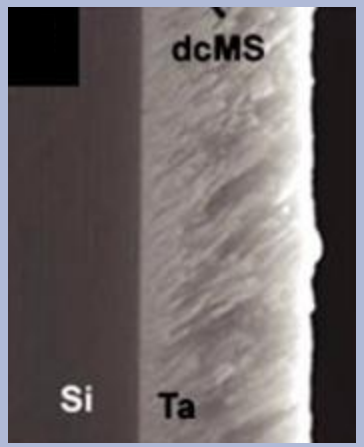
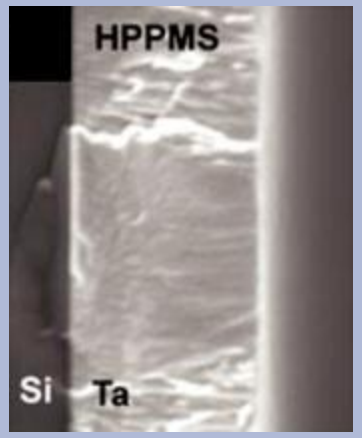
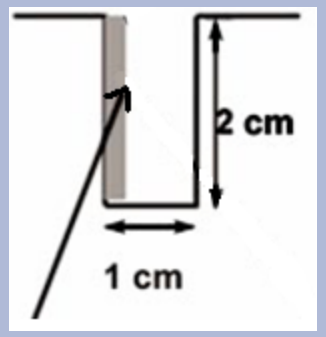
Optical emission spectra of dcMS and HiPIMS discharge



Courtesy: A. Anders, LNL

A. Anders, AVS 56th International Symposium 2009, SE2-MoM8
K. Burcalova et al., J. Phys. D: Appl. Phys. 41 (2008) 115306
U. Helmersson et al., Thin Solid Films 513 (2006) 1-24

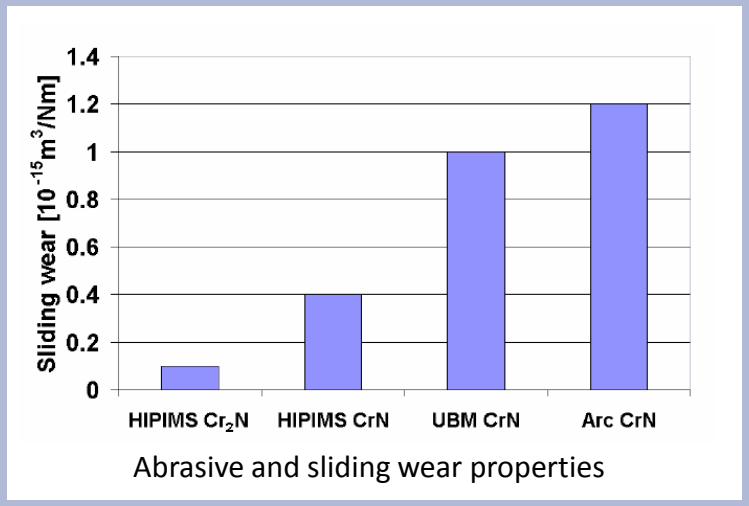
Enhanced properties of films with HiPIMS

dcMS	HiPIMS	Comment
		SEM image of a Ti-Si-C film
		SEM image of a Ta film grown on Si. 

J. Alami et al., J. Vac. Sci. Technol. A 23 (2005) 278
J. Alami et al., Thin Solid Films 515 (2006) 1731

Industrial applications of HiPIMS

- HiPIMS can be used on large cathodes (up to 1 m length).
- Semiconductor applications (trench filling).
- Sputter etching and implantation of Cr and Nb for enhanced adhesion of hard coatings.
- Improved wear behaviour of HiPIMS coatings of e.g. CrN and Cr_2N coatings.



Abrasive and sliding wear properties

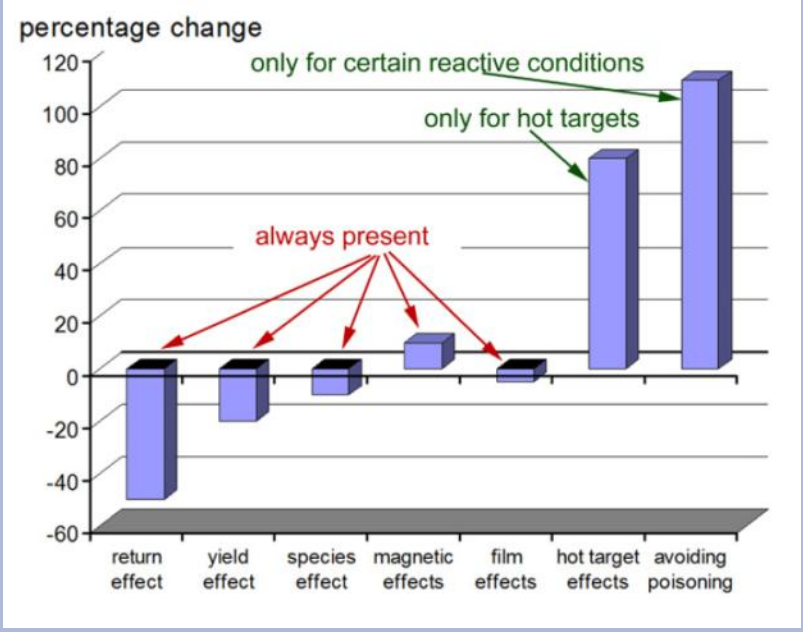
W.-D. Münz et al., J. of. Phys: Conf Series 100 (2008) 082001

Benefits

- **Any existing magnetron sputtering system can be used for HiPIMS by connecting a HiPIMS power supply instead of the DC power supply.**
- Low average power at the target due to a long duty cycle.
- High ionization factor. Ionization dependent on many factors. Typical values: > 90 % ionization of Ti, for Nb ~ 60 %. Nb and Ti have comparable ionization energies (6.88 eV and 6.83 eV).
- HiPIMS can be used on large cathodes (up to 1m length)
- **Improved film quality**: better adhesion, higher density, decreased roughness, good conformity, increased (normal) conductivity have been reported.
- Applicable to non-flat surfaces.

Drawbacks

- (Usually) lower deposition rate than with dcMS
- More expensive power supply
- Cathode size limited (HIE-ISOLDE)



A. Anders, AVS 56th International Symposium 2009, SE2-MoM8

The power supply

HÜTTINGER Elektronik is the only available manufacturer of HiPIMS power supplies suitable for our systems and purposes

- Average/Peak power: 20 kW/ 2 MW
- Peak current: 1 kA
- Peak voltage: 2 kV
- Output frequency: up to 500 Hz
- Pulse length: up to 200 µs

Outlook

- Establish a HiPIMS coating system for small samples by use of the DMS in Building 101, understanding the different parameters and optimize the system.
- Produce Nb films on Cu samples to investigate superconducting properties as well as RF properties.
- Investigations of the so-called Q-drop mechanism to possibly improve the performance of Nb film cavities by this new sputtering technique.

- Tests of the HiPIMS PS on the HIE-ISOLDE coating system. Cathode is cylindrical and much bigger surface, thus the feasibility has to be tested.

Summary

- HiPIMS will not replace the conventional DC method, due to it's lower deposition rate and expensive power supplies.
- Enhanced film properties gives an important complement to the existing systems.
- Superconducting properties of Nb films have hardly been investigated yet, but the enhanced film properties give a promising hint of improvements.
- The community is very convinced that HiPIMS is "the way to go"

Thanks for your attention

References

- J. Alami et al., J. Vac. Sci. Technol. A 23 (2005) 278
- J. Alami et al., Thin Solid Films 515 (2006) 1731
- A. Anders, AVS 56th International Symposium 2009, SE2-MoM8
- K. Burcalova et al., J. Phys. D: Appl. Phys. 41 (2008) 115306
- J. Böhlmark et al., J. Vac. Sci. Technol. A 23 (2005) 18
- V. Kouznetsov et al., Surf. Coat. Technol. 122 (1999) 290
- W.-D. Münz et al., J. of. Phys: Conf Series 100 (2008) 082001
- HIPIMS power supply requirements : parameters and breakthrough arc management solution Pawel Ozimek, April 2009

Review on Ionized Physical Vapor Deposition (IPVD):

- U. Helmersson et al., Thin Solid Films 513 (2006) 1-24