Modelling magnetron sputtering for high value manufacturing

Teer Coatings is a leading company in the production of state-of the-art thin film coating deposition systems, and hence in the development of custom-based coating solutions for any given component. They are currently involved in a collaborative modelling research project, for the efficient and accurate prediction of industrial magnetron deposition systems.

Together with its parent company (Miba Coating Group), Teer Coatings is a pioneer in manufacturing Physical Vapour Deposition (PVD) coatings and developing fully computer controlled coating systems. Not only that, but the company are currently focusing on modelling magnetron sputtering – they have helped develop a virtual machine that simulates the coating process, which will eventually speed up the development of the manufacturing process, and cut down the cost dramatically.

Introducing commercial software that can accurately perform self-consistent particle modelling, simulations of various designs and targets for thin film deposition, including magnetic field simulations, is currently at the core of the company's objectives.

WHAT IS 'SPUTTERING'?

In principle, sputtering – a term whose etymology defines it as the process of emitting saliva with noise – involves highly energetic particles that hit a given target material in order to generate, or eject, atoms which are subsequently used in thin film deposition on a given substrate. The substrate is placed in a vacuum chamber with an inert gas, and, following sputtering, the atoms emitted from the target will be deposited onto the substrate. Owing to their high energy, these particles (ions) initiate collision cascades which, ultimately, reach the intended surface with energies greater than the respective binding ones, thus triggering the ejection of the surface atoms. This implies that these highly energetic particles have kinetic energies that are much higher than the respective thermal ones, although it should be mentioned that the number of the ejected atoms will depend on their respective mass, the energies of the triggering ions, and also their respective angle of incidence.

This is an extremely significant and exciting technique that can be employed in a plethora of applications from decorative coatings on glass, to coatings that are engineered specifically on products. As such, it is at the core of today's semiconductor industry. Currently, there are many techniques for sputtering – namely electronic, heat spike, potential, chemical sputtering, etc. – each with their own advantages and disadvantages. For instance, heat spike sputtering occurs in very dense solids where the distances between the triggering ions and the target are very small. Such dense collisions will produce a so-called heat spike that induces local melting to the crystal, thus allowing many atoms to undergo sputtering because of the subsequent flow of liquid from the melting crystal.

BENEFITS OF MAGNETRON SPUTTERING

Magnetic fields can be used to control the velocity, direction and behaviour of ions. Therefore, it comes as no surprise that, even though it has been a while since sputtering has practically revolutionised thin film coatings from large R&D systems to large production systems, research has shifted its attention to magnetron sputtering, owing to its profound advantages compared to conventional sputtering.

Magnetron sputtering is based on plasma sputtering processes in which plasma is created and confined within a magnetic field.

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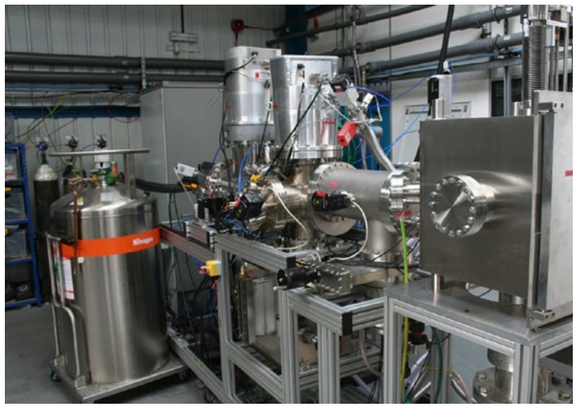

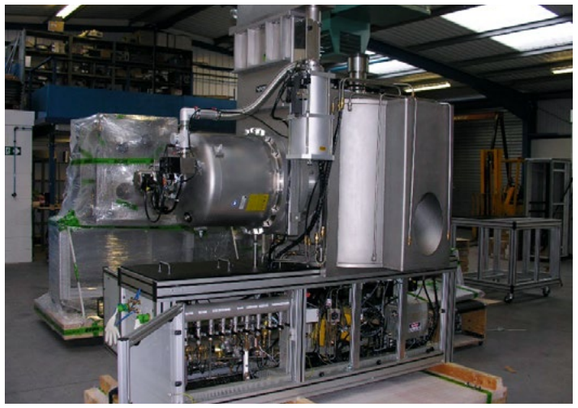

Positively charged ions from this plasma are then accelerated towards a negatively charged electrode (target) – similar to a conventional electric field. Provided that the respective potential can amount to several hundred eV (electron Volts), these positively charged particles will then strike the electrode, thus forcing atoms to be ejected from the target.

The closed magnetic field is used to trap electrons more efficiently, thus allowing the formation of plasma under lower pressure. This not only decreases the electrons lost as a result of collisions with chamber wall, but it also has the capacity to limit the (unavoidable) deposition of gas on the thin films.
Magnetron sputtering allows for greater sputter efficiency and increased sputter rates at significantly lower gas pressures. However, the characteristics of the deposited thin film can vary, in a controlled manner, by altering the properties of the plasma. This is why the process has become more controlled, offering a greater number of applications in comparison to conventional sputtering. This is the field where Teer Coatings demonstrates its critical role.

MODELLING MAGNETRON SPUTTERING

Teer Coatings has dedicated more than 30 years to manufacturing and designing magnetrons that can be rectangular, cylindrical, circular, and of various sizes. They have developed a plethora of targets that can be directly cooled or bonded, and can be manufactured in such a way that can fit most magnetron sizes. However, and most importantly, Teer Coatings is following the trend of magnetic sputtering, and hence has been seeking the best solutions to model the overall process.

The development and commercialisation of software that can enable the distinct modelling of magnetron sputtering is bound to enhance its productivity, applicability, and reproducibility

Magnetic fields can essentially define the behaviour and the properties of the ion charged particles that are used for sputtering. So, with collaborators at Cobham and the Open University, the team together developed and validated the modelling software Opera, which can model the interaction of plasmas in electromagnetic fields, and accurately evaluate the efficiency and eventually the properties of the coatings themselves. This method can also be extended to model specific target utilisation – including multi-target coaters – which are, consequently, validated against production devices.

The development and commercialisation of software that can enable the distinct modelling of magnetron sputtering is bound to enhance its productivity, applicability, and reproducibility. This, in turn, will provide a level of high performance and unprecedented accuracy to the semiconductor industry in general.

Q&A

What was the company's incentive to place magnetron sputtering modelling as its primary aim?
For the magnetron sputtering industry, our current problem is that we have to go through extensive trials, or build multiple prototypes, in order to respond to new customers' requirements. This process can be very time-consuming, and it uses lots of resources. The incentive for the company is to use a software to model the whole process, which will greatly cut down the development time, even eliminating the need for building prototypes. Obviously, this will reduce the cost, and significantly improve efficiency.

Why is magnetron sputtering more important or efficient than other types of sputtering, including chemical and heat spike?
Magnetron sputtering technology has many advantages over other types of coating technologies, such as (1) high deposition rates, (2) ease of sputtering any metal, alloy or compound, (3) high-purity films, (4) extremely high adhesion of films, (5) ease of automation, and (6) excellent uniformity on large-area substrates. Another advantage is that it's environment friendly. For example, the electro-plating industry produces large amounts of Cr (IV), which is toxic and causes serious contamination to the environment; the magnetron sputtering technology can do the chromium coating efficiently without any by-product of Cr (IV).

What will be your primary means for commercialising this product?
The commercialisation and promotion of the software is up to the company Cobham. Teer Coatings have access to the software, and will fully utilise the software to model the magnetron sputtering process. This will provide our customers with better coating services, like faster turn-around time, better coating uniformity, and more competitive pricing.

Is the developed software user-friendly, and if so, what can the designer predict and optimise?
Yes, the software developed by Cobham is user-friendly, with an intuitive graphic user interface to set up the 3D model, and carry out the simulation process. The magnetic field of the magnetron can be precisely predicted, which will help the engineer to optimise the layout of magnets to achieve the desired sputtering conditions. The dense plasma in front of the magnetron can also be modelled, which is important to determine the racetrack on the target and the utilisation rate of the target. Furthermore, the trajectories of the particles can be simulated, and hence the coating uniformity can be predicted.

Can the developed software be used to model all electromagnetic devices?
The software Opera has been developed over many years by Cobham, and it was indeed designed to be used as a general modelling software for all electromagnetic applications. Magnetron sputtering is a special case, which hasn't been covered by any major electromagnetic modelling tools. During the period of the collaborative research project, a plasma physics module was developed and added into the software package Opera. It won't answer all the questions we have in practice, but certainly it's very useful to reduce time spent on the sputtering process development.

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Detail

RESEARCH OBJECTIVES

Teer Coatings focus on developing individual coating solutions for components. Their recent research has centred around validation of magnetron sputtering modelling for more efficient coating process development.

FUNDING

Innovate UK

COLLABORATORS

- Derek Monahan, John Simkin, Chris Riley (Opera Software, Cobham Technical Services)
- Dr Alexandre Nominé, Prof Nicholas St John Braithwaite (Plasma Lab, Department of Physical Sciences, The Open University)

Cobham is responsible for the development of the software, called Opera; Open University is responsible for the investigation of plasma physics, which is the key process in the magnetron sputtering; Teer Coatings is responsible for the running of the actual magnetron sputtering experiments, collecting data, and verifying whether the predication made by the modelling is correct.

BIO

Teer Coatings Ltd develop individual coating solutions for components and are leaders in building coating machines. They specialise in Physical Vapour Deposition coatings and have one of the world's most comprehensive coatings portfolios. They are also firmly committed to research and development and are heavily geared to progress and innovation.

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