Reduced Metal Consumption in Electroplating Saves Big Money

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Given the scarcity and price developments of today's metals, virtually all of them can be counted as being 'precious'. As a result, electroplating firms such as PEM always look for ways to reduce the amount of metals that are consumed as part of a process. Thanks to studies conducted using COMSOL Multiphysics, we have made significant advances, often including savings between 10% and 30% of the metal we deposit during electrolysis.

Components on reels

With sales of roughly 20 million euros in 2007, PEM is heavily involved in treating and finishing surfaces, and our specialty is reel-to-reel electroplating. The customer supplies a reel, which can be from several hundred to several thousand meters, and whose tape holds a continuous series of metal parts such as connectors for electronics systems. At our facilities, we unwind the tape or carrier strip from these reels, and send it through a sophisticated process consisting of cleaning, plating and rinsing stages. This happens at speeds from 1 to 20 m/min (Figure 1).

During the metal-plating stage, the tape passes through a reacting cell that is continuously replenished with electrolyte. The tape is made cathodic through contact to a voltage source, and the electrolyte completes the electrical circuit to anodes in the plating cell.

Getting a uniform plating layer is not simple. Consider that more metal tends to migrate towards the edges because if the tape (the cathode) is standing on end and the anodes are to its sides, the shape of the electric potential field follows the tape — up one side, around the top, and down the other side. Spikes in the current-density distribution occur where the tangential gradients for potential contribute, along with the normal gradients, to the overall ionic transport of species to and from the electrode surface (see blue trace in Figure 2). These are more commonly known as edge effects.

PEM's answer is to design a shield, a type of insulating screen or tray through which the tape travels as it passes through the plating reactor. Made with insulating materials that are chemically compatible with the bath, the shield is shaped so the lines of electric potential essentially run parallel along the entire width of the tape, and the gradient to the tape surface is even. The red trace in Figure 2 shows the benefits of adding such a shield.

Figure 1: Factory floor with a series of reel-to-reel electroplating units. Reels of solid or stamped metal plates are passed through the electroplating units, and metal is deposited over the whole or sections of the tape according to the application of electric current and the placement of shields.

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Shield design without prototypes

The shield's shape varies with the components on the reel, the plating material and its thickness, electrolyte concentration, and tape traveling speed. Developing shields experimentally can require multiple time-consuming prototypes, so PEM started to use COMSOL Multiphysics to help us better understand the underlying phenomena and thereby come up with an appropriate shield for each process. These days, we are generally successful on the first try.

The multiphysics model accounts for several effects: conductive media for the electrical current, Navier-Stokes for the electrolyte flow, and electrokinetic flow to simulate the transport of species. For this, we use the Chemical Engineering Module along with the COMSOL Multiphysics modeling environment.

Save even more material

We have successfully designed shields that handle most of the types of products we run through our process. Our next goal with COMSOL is to examine the effects of limiting currents so as to design our reactor cell with high fluid velocities near the cathode surface and thus increase process throughput. If you can replenish the metal ions better, you can raise the current density and thus production (Figure 3).

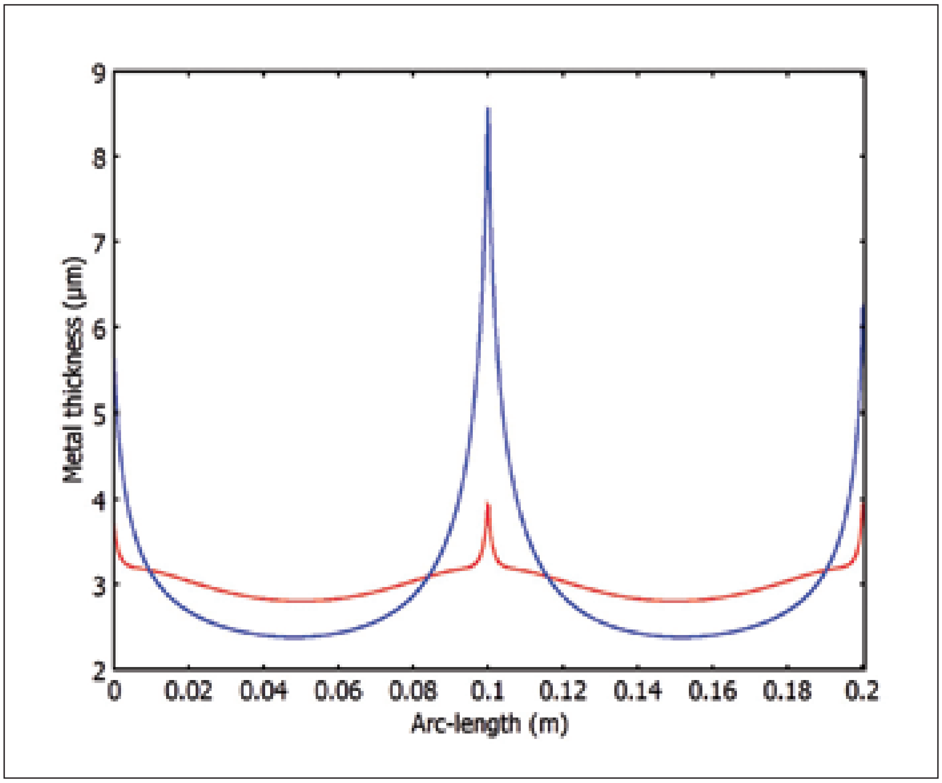

Figure 2: Comparison of plating thickness across both sides of the tape. The blue trace corresponds to metal thickness at the surface of the tape when the process does not use shields or screens. On the other hand, if edge effects are removed through the use of shields, then a far more even metal thickness distribution is achieved, as shown by the red trace.

Furthermore, the potential must be uniform throughout, so that there are no local secondary reactions such as the electrolyte electrolyzing to create hydrogen gas, leading to depleted areas of metal deposition or "tape burns." Thus, the tradeoff is to run the process as quickly as possible but where the entire surface is just below the current-limiting density. This type of modeling is particularly challenging because of the reactor size, as well as lateral and vertical oscillations due to tape movement with respect to the electrolyte injection holes. Yet, accurate predictions will have a major influence on future reactor designs.

One final aspect is that modeling is only a part of my job. Previously I had no real modeling experience, and my initial problems were not in learning COMSOL, as the software is very well designed and support is quite efficient, but rather mastering the underlying physics. Yet COMSOL allowed me to understand the physics quickly and I came to appreciate that you don't have to be a modeling expert to make good use of it. Anyone who is sufficiently curious and motivated can have great success. ■

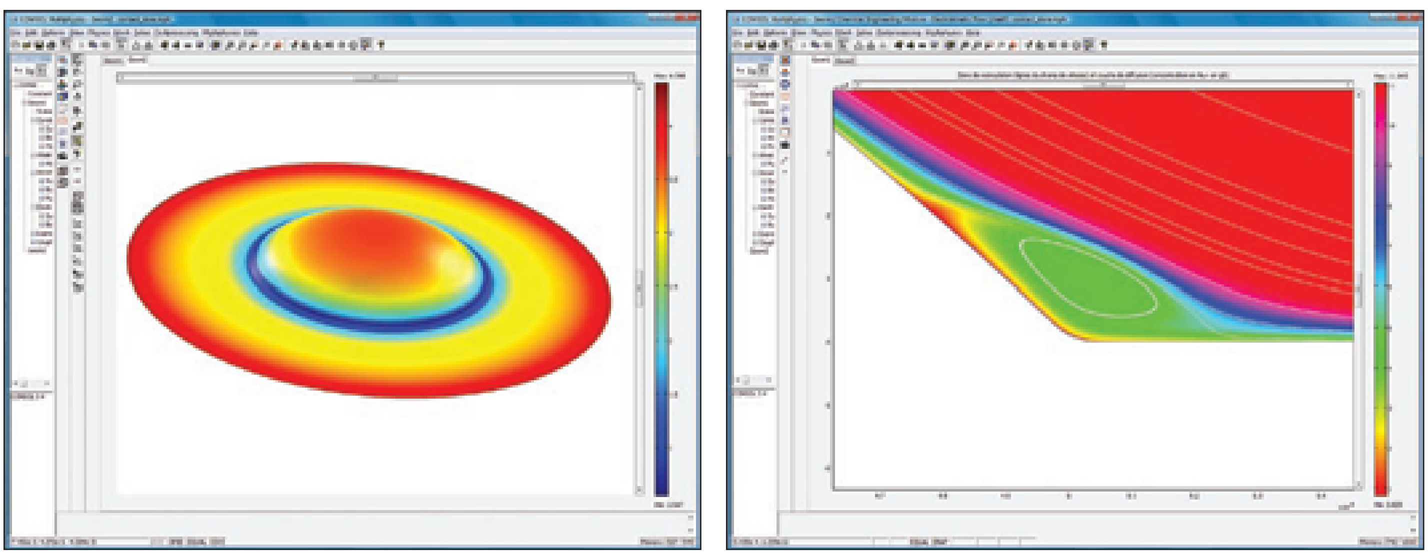

Figure 3: In order to understand the effect of geometry, fluid flow, and shield placement, a model such as this one is produced by PEM. The geometry is of a gold-plated contact for the automotive industry, which would sit on the tape moving through the electroplating unit. The first figure shows the extent of gold deposition on the contact, which is a maximum at the top of the contact, and a minimum where the contact is bent due to its rounded shape. Zooming in on the region of the bend, a 2D image indicates flow recirculation where the deposition is least, and therefore the concentration of gold ions is depleted. This is an area where secondary reactions can take place.