Finishing Trends & Technologies

Dr. E. Jennings Taylor • Faraday Technology, Inc.
315 Huls Drive • Clayton, OH 45315-8983 • E-mail: Jennings@erinet.com

Managing Innovation ... The Science of Creativity?

Previous columns have dealt extensively with innovation as related to the metal finishing industry. Specifically, past columns have addressed:

1. the "innovator's dilemma"[1]
2. "billion dollar innovation industry"[2]
3. case studies related to innovation in the metal finishing industry[3,4]
4. the role of intellectual property as the foundation of the innovation process[5]
5. the importance of industry structure and industry clockspeed on technological innovation.[6]

Creativity

The process of innovation or commercialization of a disruptive technology may be broadly defined as "development to a level of technical maturity, verification in a production setting, and broad insertion into the target market." But, what about the starting point, that is, the invention or conceptualization of the disruptive technology? How does this creative process occur?

For myself, it seems the creative process is somewhat illusive or *ad hoc*. For example, while working intently on a particular problem in terms of background research and detailed analysis of data, the creative idea almost never materializes during this phase. For me, the creative idea usually emerges during my morning shower or while I'm mowing the lawn or rollerblading, etc. It seems that the problem is just below the level of consciousness during these physically engaging activities, but the mind is free to wander. So, the lightbulb goes off and the *eureka* moment occurs. I encourage such moments with a combination of intense study/data analysis, and activities such as those described above.

Worsening Feature → / Improving Feature ↓		Weight of moving object	Weight of stationary object	Volume of moving object	Volume of stationary object	Speed	Force (Intensity)	Stress or pressure	Shape
		1	2	7	8	9	10	11	12
1	Weight of moving object	+	-	29, 2, 40, 28	-	2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40	10, 14, 35, 40
2	Weight of stationary object	-	+	-	5, 35, 14, 2	-	8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14
10	Force (Intensity)	8, 1, 37, 18	18, 13, 1, 28	15, 9, 12, 37	2, 36, 18, 37	13, 28, 15, 12	+	18, 21, 11	10, 35, 40, 34
11	Stress or pressure	10, 36, 37, 40	13, 29, 10, 18	6, 35, 10	35, 24	6, 35, 36	36, 35, 21	+	35, 4, 15, 10
12	Shape	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+
13	Stability of the object's composition	21, 35, 2, 39	26, 39, 1, 40	28, 10, 19, 39	34, 28, 35, 40	33, 15, 28, 18	10, 35, 21, 16	2, 35, 40	22, 1, 18, 4
14	Strength	1, 8, 40, 15	40, 26, 27, 1	10, 15, 14, 7	9, 14, 17, 15	8, 13, 26, 14	10, 18, 3, 14	10, 3, 18, 40	10, 30, 35, 40

From discussions I've had with a number of other inventors and technologists, it seems my experience with the creative process is quite typical. So, the notion of managing the invention process is absurd, or at least I thought so until recently.

The Science of Creativity

I recently attended a talk by Ellen Domb on "Managing Creativity for Project Success."[7] The talk was based on some amazing work by Genrich S. Altschuller, a brilliant Russian inventor. Altschuller received his first patent at the age of 15. By the time he was 30, Altschuller had published more than 350 technical papers and 20 books. In 1946, Alschuller had conceptualized the Theory of Inventive Problem Solving[8], known by the Russian acronym TRIZ.

Genrich Altschuller's hypothesis was that there are universal principals of invention that are the basis for creative innovations that advance technology. By analyzing more than 2.8 million patents, Altschuller and his colleagues "discovered" three characteristics:

1. Problems/solutions are repeated across industries and scientific disciplines,
2. Patterns of technological evolution are repeated across industries and scientific disciplines, and
3. Innovations used scientific principles outside the field where they were developed.

The key to applying the TRIZ principles is in the initial definition of the problem in terms of "standard" features or attributes. The invention is required because the improvement of one attribute leads to a decrease in performance of another attribute. These attribute contradictions are generally solved by the traditional engineering trade-off. The patent research identified 39 standard features and categorized 40 inventive principles representing the solution of the attribute contradictions. The standard features are tabulated in a "contradiction matrix" as "improving feature" on the vertical axis and "worsening feature" on the horizontal axis. When the contradiction is identified—for example, as standard feature xx is improved standard feature yy becomes worse—the intersection of the horizontal rows and vertical columns lists the inventive principles for solving the contradiction.

I was not convinced of the potential of this emerging "science of creativity" until I took a cursory look at an invention in which I was intimately involved.

TRIZ This!

My colleagues and I have been engaged in a number of inventions related to electric field mediation of electrochemical processes, as opposed to control by chemical additives. For a skeptical look at TRIZ, I chose our recent work in electrodeposition of electronic interconnects for integrated circuit (IC), chip scale packages (CSP) and high density interconnect (HDI) circuit board applications. Some of the initial work is summarized in a *Plating & Surface Finishing* paper selected by the AESF Paper Awards Committee for the Abner Brenner Award (Silver Medal) for 2000.[9]

The problem is that in support of the increasing miniaturization and performance demands of electronic products, interconnects of smaller diameter and increasing aspect ratio are required. Plating of these features using conventional electrodeposition approaches results in features with a tapered metal deposit and/or voids. In terms of TRIZ attribute or standard feature, the "no. 12 shape" of the deposit must be improved. Using the conventional electrodeposition approach, the "shape" is improved by reducing the plating rate. Of course, reduced plating rate means lower product throughput and, therefore, increased capital and/or operating cost. So, the worsening TRIZ attribute or standard feature is "no. 9 speed."

As shown in the partially reproduced contradiction matrix, the suggested inventive solutions are No. 35 Parameter Change, No. 15 Dynamics, No. 34 Discarding and Recovering, and No. 18 Mechanical Vibration.

In the description of these inventive solution principles are some very relevant comments. Of particular note, No. 35 suggests that the concentration be changed. Regarding the electronic interconnect problem, the difficulty in plating small asperity and/or high-aspect-ratio features is due to depletion of the metal ions within these hydrodynamically inaccessible features. The *P&SF* paper cited above uses charge-modulated electric fields to affect the "electrodynamic diffusion layer," and to increase the effective concentration of the depleted metal ions.

Inventive Principle No. 34 Discarding and Recovering, suggests that consumable parts be replaced directly in operation. This seems to address another part of the solution to plating very precise electronic modules, which is to replace soluble anodes (consumable parts) with insoluble anodes. The insoluble anodes provide a uniform and unchanging plating cell design, *vis-à-vis* the soluble copper anodes. As electronic module plating is becoming more and more demanding, the importance of an unchanging primary current distribution is being recognized.

Inventive Principle No. 15 Dynamics, states that the object should be divided into parts capable of movement relative to each other. A further embodiment in the *P&SF* article is the movement of the CSP and HDI panels in a knife-edge fashion relative to the stationary anodes, and the rotation of the IC wafer relative to the stationary anodes.

Inventive Principle 18 Mechanical Action, suggests the use of electromagnetic field oscillation. The charge-modulated process described in the *P&SF* article does just that, through the use of pulsating (*i.e.*, oscillating) currents. And, related to Principle 18, Principle 19 Periodic Action, suggests frequency and magnitude of the oscillations should be altered! The influence of frequency and current or voltage amplitudes on electrochemical processes is just beginning to be understood, and is currently the subject of considerable inventive (patent) activity by a number of electrochemical technology-based companies. As stated in a previous column,[10] not all pulse plating waveforms are created equal!

I'll be very interested in any reader's thoughts and comments after exploring the TRIZ website: www.triz-journal.com *P&SF*

References

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10 E.J. Taylor, "Not All Electric Fields are Created Equal for Emerging Electronic Applications," *Plat. & Surf. Fin.*, pp. 118-20 (May 2000).