Manufacturing Innovation of Advanced Materials with 10X Advantage

This presentation

Invention, Innovation, Productivity, Activity
Materials and 10X Advantage
What is Radical Innovation for manufacturing?
When can it happen?
How can we sustain it?
How do advanced materials play a role?

J. A. Sekhar
Understanding the difference between Invention and Innovation. Not all inventions lead to Innovation.

10X Invention – (Technology and Intelligence- IP issues predominate)
- High notion of value. Small teams or individuals.
  - 1μm to 100nm to 10nm (Nano technologies)
  - Increased Properties
    - Fracture Toughness
    - Tensile strength
- Some Inventions can be highly novel and potentially disruptive

10X Innovation – (Market Place Effectiveness-Cost and Profit issues predominate).
- Notion of value tempered by notion of cost.
  - Most often large number production (larger teams)
  - Plus Reduced Defects
  - Plus Improved Properties. Continuous Improvement.
  - Plus better ROI against competing ventures

We will get to radical innovation after a few slides
Invention is necessary, but not sufficient for innovation to occur.

Innovation is multi-dimensional.
- Vision with the invention
- Market need, timing, technologies require convergence
- Marketing and finance issues are very important

Innovation requires an implementation strategy to succeed

Next few slides - we now attempt an understanding of innovation and radical innovation from an activity analysis......

Henry Ford, Mr. Parmenter, Thomas Edison and President Calvin Coolidge.

Innovation requires complimentary technologies and teams
I believe that innovation is part of the life cycle or journey of a discovery and so may be modeled and manipulated. This is the major hypothesis of this presentation. (J.A. Sekhar)

In the next few slides we will study the life cycle of basic materials, long and short cycle products …look at constraints and how to influence them and also develop a generalized understanding of innovation. Our issues:

- Understanding life cycles
- Understanding innovation and radical innovation
- How does materials innovation assist radical innovation. 10X? Focus on Manufacturing.
Life cycle notion for a commercial product

Life cycles for materials are quite different

Color TV 12 Years
Playstation 10 Months
A typical activity life cycle for a material...

Chinmaya and Sekhar 2005 in press

Invention Driven Activity

Growth/

Level Off/ Maturation

TIME

ACTIVITY
Units
Million metric tons per year

Aluminum

Similar trends for Pb, Cu, W, Mo

Dow Jones Oil.....

(Al not in stage IV)
Information: Modeling of Trends.

\[ y = x^n \cdot \left[ \alpha \cdot x^2 + \beta \cdot x \cdot \sin(\omega \cdot x) \right] \]

Where \( \alpha \), \( \beta \), \( n \), \( \omega \) are parameters.
Innovation and Rapid/Radical Innovation

\[ y = x^n \left[ \alpha x^2 + \beta x \sin (\omega x) \right] \]

Where \( \alpha , \beta , n, \omega \) are parameters

<table>
<thead>
<tr>
<th>Material</th>
<th>( \alpha )</th>
<th>( \beta )</th>
<th>( \omega )</th>
<th>( \delta )</th>
<th>( n )</th>
<th>( \mu )</th>
<th>( \nu )</th>
<th>( X_0 )</th>
<th>( R^2 )</th>
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<td>30</td>
<td>0.5</td>
<td>2.32e6</td>
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<td>0.5</td>
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<td>5</td>
<td>0.5</td>
<td>2e6</td>
<td>0.45</td>
<td>90</td>
<td>0.4</td>
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<td>1.0</td>
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<td>15</td>
<td>1.0</td>
<td>1902</td>
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<tr>
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<td>0.9</td>
<td>0.4</td>
<td>1.5e5</td>
<td>1.2</td>
<td>13</td>
<td>1.5</td>
<td>1905</td>
<td>0.5225</td>
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</tbody>
</table>

Ref: Chinmaya and Sekhar, in press 2005

Radical Innovation is \( [ \alpha x^{(2+n)} ] \) dominated

J. A. Sekhar
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As long as $\alpha > 0$ and $n > 0$ we get Innovation and Rapid Innovation. The rate of growth of activity is noted to be extremely sensitive to $\alpha$ and $n$.

Radical Innovation is $[\alpha \times x^{2+n}]$ dominated

We are interested in the rate of growth

$(2+n)\alpha x^{1+n}$ must be positive

and

$d\log (y=\text{activity})$ proportional to

$2.3d((2+n)\log (x)+\log \alpha) \sim 10$

Very Difficult

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<td>43</td>
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α can go negative after some time. Stage IV. See below real example for Pb.

Radical innovation is influenced by time so try hard for α to remain positive.
Take away so far:

- Once into stage III you can aim for profitable radical innovation (defined as 2x-10X)
- 10X Radical innovation is very difficult - based on pattern analysis. Need high $\alpha$, $n$ and years in operation
- The two main questions
  - How do you keep $\alpha$ positive and large
    - How do you ensure stage ii goes to stage iii
  - How do minimize $\beta$ (keep the ride smooth) (very critical investor variable)
Energizing the utility function and expanding market size can keep $\alpha$, $n$ positive and large.

- Utility - expanding the use requirements and has the potential pitfall of making the material redundant when new performance materials are found. Utility function improvement may possibly also be called the “constant new product introduction strategy”.

- Market Size/Reach Expansion
  - Implies improved productivity and manufacturing cost reduction have to be addressed.
Constant price reduction is very important. Of course best if this can be controlled internally and not by factors like China Inc. type price busters which are very disruptive and severe.

Astounding finding:
No drop in price*- No manufacturing radical innovation for product!

Driving market size by supply function has consequences

Selling Price ($) vs. Life (years)

Life (years)

* Elastic supply
This implies - keep the cost function sloping downwards which implies that the production function is not static. To maintain profits one now has to pay attention to ………
This is the only Business Process Slide in this Talk. Companies must learn to compete and constantly develop New Products i.e. become Entrepreneurial. Company business processes must keep up. However this is a very different talk… we will focus only on manufacturing technology instead in the next few slides.

- Intense Competition, Changing Customer Expectations, Sophisticated Customer, Demanding Customer, Negotiating Customer

Fast, Responsive, High Productivity, Distinct Products, Reliable Products

Very Short Development Cycles, Leverage Constantly from Strained Resources, Integrate Engineers and Customers from the Early Stages of “Requirement”
Founded Mid Nineties.

- Manufacturer of High Temperature Innovative Heat Products.
  High Degree of Vertical Integration
- Main Office, Cincinnati Ohio.
- World Leader in Thermal Products and New Materials.
- Number of patents ~ Very Large.
- Global Sales: USA, UK, Germany, Switzerland, India, China, Hungary, Australia, Taiwan, Hong Kong, South Africa, Brazil, Argentina……..many more

Leading Radical Innovation Provider. How and Why?
Company is focused on creating products (hardware) that allows 10X production gains for their customers……MHI enables radical innovation. We examine how….

For 10X
dP has to be proportional to 10P
Or \([d\ln(P)=10]\)
Or \(2.3d\log(P)=10\)

To convert a natural logarithm to base-10 logarithm, divide by the conversion factor 2.303.
Fascinating result for thermal systems.

\[ \log(P) = a + b \cdot L + c \cdot L^2 + m \cdot T \]

T is temperature (C), L is part size and a, b, c, m are constants. Focus on m.

Ref: Singh, Basu.....Sekhar et al..JOM 2003

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature ($T_w$, °C)</th>
<th>a</th>
<th>b (cm$^{-1}$)</th>
<th>c (cm$^{-2}$)</th>
<th>m (°C$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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<td>0.08388</td>
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</tr>
</tbody>
</table>

\[ d\log(P) \propto (C + mdT) \]

(more accurately partial differential, however assume size of part L is unchanged)
Every year the operational temperature must go up by $\Delta T$...

- From combining the two previous slides we get $10 = 2.3(C + m \cdot \Delta T)$ For 10X gain per year and $m = \sim 0.05$
- $\Delta T = (10/2.3 - C)/m \sim 1000/10 = 100$ if $C$ is small

2x per year - 20°C per year

10x per year - 100°C per year
Every year MHI aims to improve the temperature capability of its products.
Constant product invention and innovation at MHI leads to innovation at customer sites. Look and feel of MHI Advanced Materials & Thermal Products in this slide. (used with permission)
Take aways (slide 1 of 2)....summary

- Invention and innovation are very distinct.
- There is a predictable pattern to innovation. Four stages in the activity pattern.
- Pattern features have been modeled. Important parameters $\alpha$ and $n$ have been identified. Now also modeled for many new materials, Dow Jones, Oil Production, etc. Pattern study is crucial. Recent results in this area by C&S 2005.
Innovation can lead to radical innovation even 10X for appropriate $\alpha$ and n’s (10X is very difficult simply from business practice improvements- needs hardware improvements). Beware of radical jumps in the early stages (I and II) leading to false hope. Case of W.

Selling price very often will have a downward slope with time for radical innovation to occur. Several implications.

Time is a key factor in radical innovation.

New high temperature materials can create the right technology required for radical innovation. A US company MHI has developed the lead for such radical innovation products. Case study of MHI and its products www.mhi-inc.com.

For further discussions please contact JAS through MHI.