Leader in LED Phosphor Solutions

- Complete Choice of phosphor materials and solutions
  - Materials, colors, spectral shapes, particle sizes
  - Remote phosphor optical components
- High volume manufacture capacity in US and China
- Supply to world’s top LED component manufactures
- More than 50% share in non-capture market
- Over 450 issued and pending patents

Fremont, California
Extensive Global Operations

Legend
- ★ Global Headquarters
- ○ Research & Development
- ○ Sales and Services Offices
- ➡ Manufacturing
## History of Phosphor Developments at Intematix

<table>
<thead>
<tr>
<th>Years</th>
<th>Phosphor Materials</th>
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<tbody>
<tr>
<td>2004</td>
<td>Yellow Silicates (Y4254, Y4453)</td>
</tr>
<tr>
<td>2005</td>
<td>Green Silicates</td>
</tr>
<tr>
<td>2007</td>
<td>Orange Silicates</td>
</tr>
<tr>
<td>2008</td>
<td>Enhanced Silicates (EY and EG)</td>
</tr>
<tr>
<td>2009</td>
<td>Large particle size YAG (NYAG) Halogen Doped CASN Red Nitride (Ruby)</td>
</tr>
<tr>
<td>2010</td>
<td>Green Aluminates (GAL)</td>
</tr>
<tr>
<td>2011</td>
<td>Yellow Aluminates (Yellow GAL) Green Nitride</td>
</tr>
<tr>
<td>2012</td>
<td>Orange Nitride Stabilized Red Nitride (XR)</td>
</tr>
<tr>
<td>2013</td>
<td>Narrow Band Green Phosphor Narrow Band Red Phosphor</td>
</tr>
</tbody>
</table>
Spectrum Comparison of Four Popular Phosphors

![Spectrum Comparison Graph]

- NYAG Family
- Red Nitride Family
- GAL Family
- Silicate Family

Relative Intensity (a.u.) vs. Wavelength (nm)
Thermal Quenching of Different Phosphor

*Thermal Quenching:* $\text{GAL < YAG, Red Nitride < Silicate}$
Phosphor Manufacturing Updates

- The high volume manufacturing of Garnets Aluminates and Silicates for LED applications are about mature
- Some of the important phosphors have high cost Rare Earth content like Eu, Lu, …
- Red Nitrides manufacturing is high cost batch manufacture process which require high temperature and high pressure
- New type of narrow red emission band Fluorides requires the development of encapsulation process for LED applications
Remote Phosphor Manufacture

- Intematix pioneered the remote phosphor manufacturing including PC/Silicone coating on glass substrates, PC injection molding, Silicone molding, and PC extrusion processes.
- The early adoption in small volume is a hurdle for the cost down in all of these remote phosphor manufacturing processes.
- The success of the silicone dome in lamp applications and the linear extrusion in cove lights and troffers will be the first high volume remote phosphor applications.
Conversion Efficacy Roadmap
3500K and 4000K 80 CRI

- Lighting system efficacy is conversion efficacy $\times$ LED WPE
- LED WPE expected to trend up to 76%-81% $\rightarrow$ 264-282lm/W
system efficacy