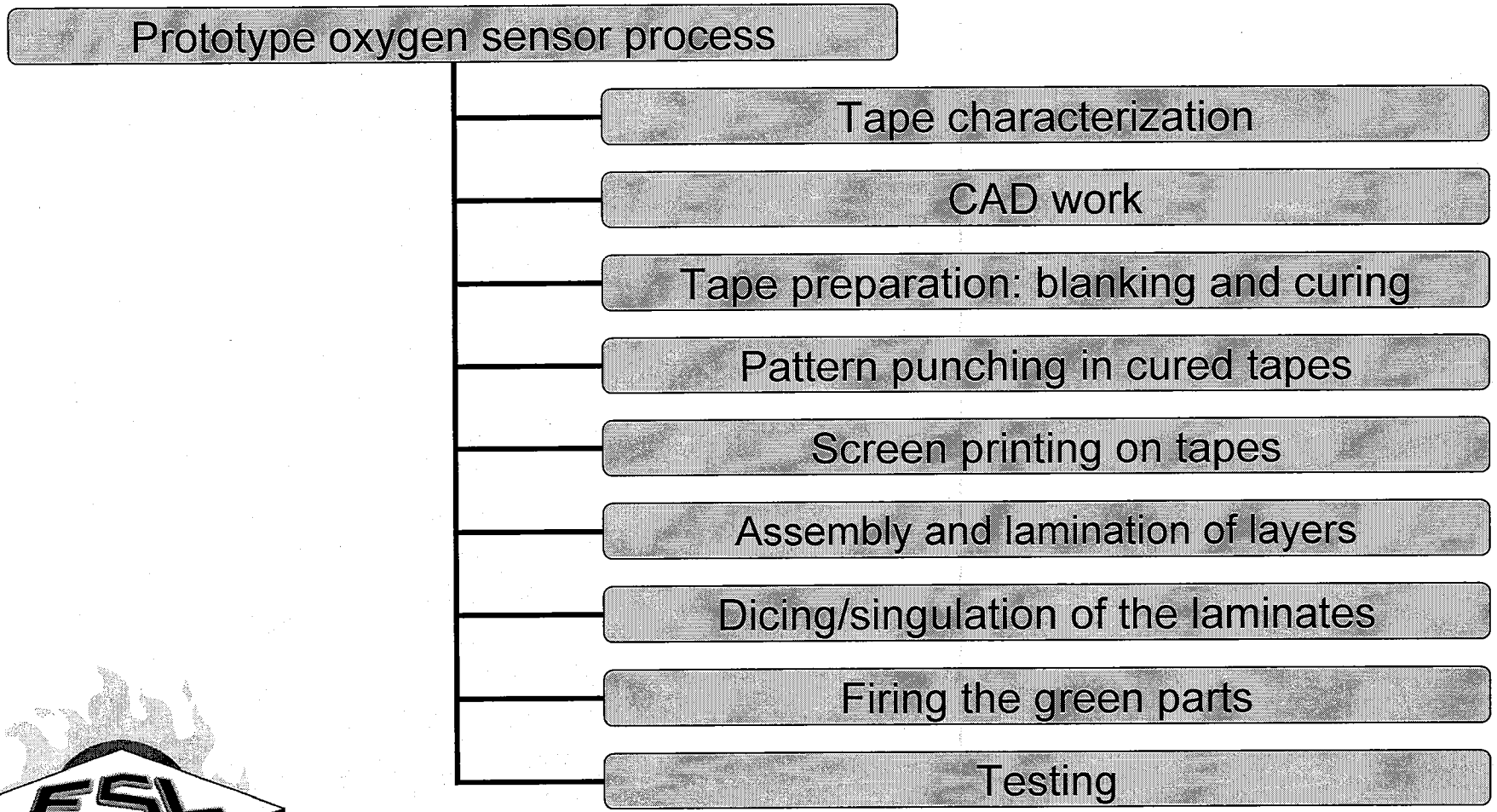
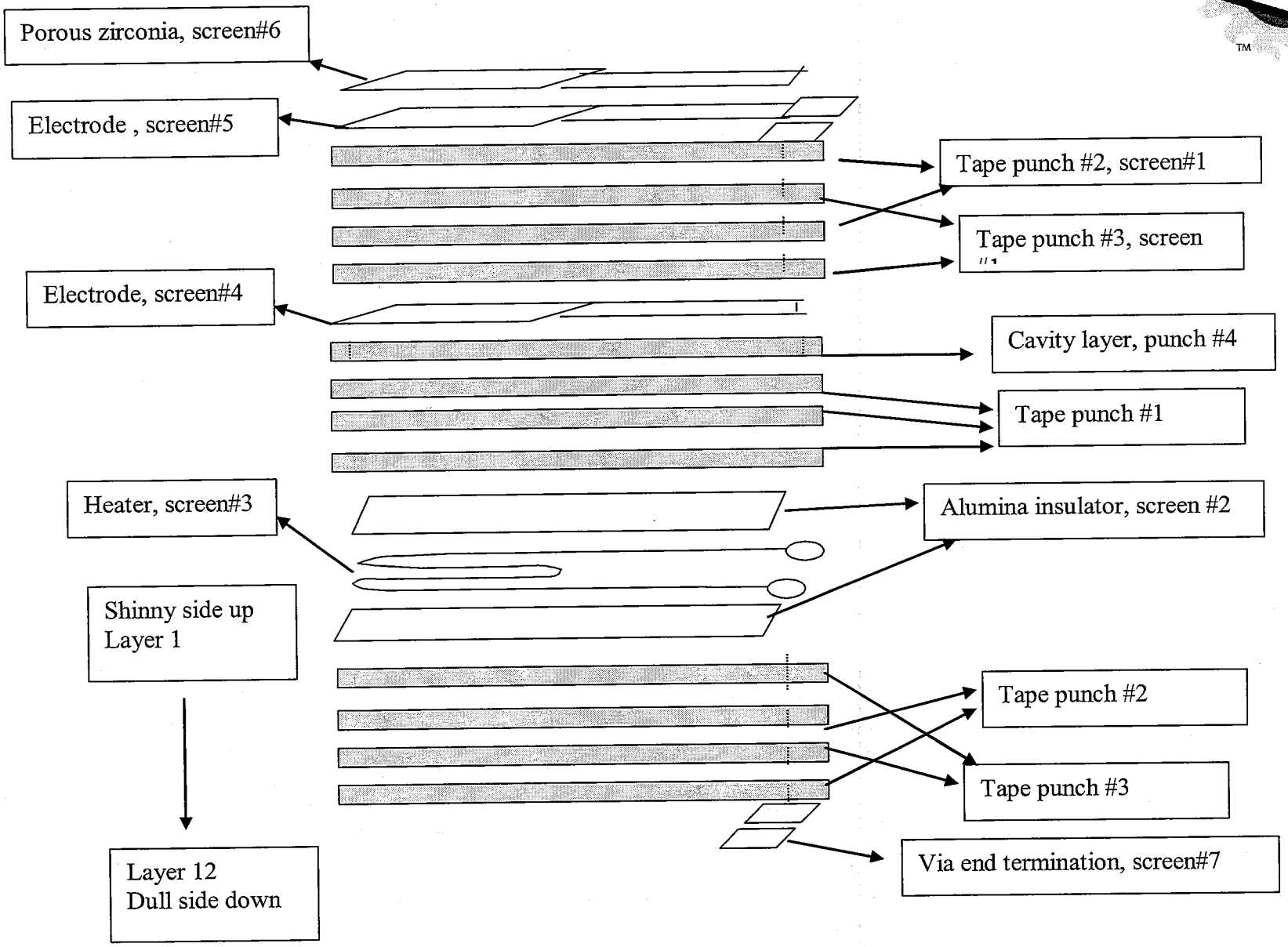
Prototype oxygen sensor process



ESL

TM

Layer by layer structure



Tape characterization

- Cut the tape into 3.5x3.5 inch squares and cure them at 70C, for 2hrs
- Laminate 12 layers of the cured tape at 70ºC, 3000 psi for 10 min.
- Cut the laminate into 81.3x3.6x1.5 mm bars.
- Measure the dimensions (LxWxT) of the bars
- Fire the bars using a firing profile for sensor sintering
- Measure dimensions and density of the fired bars

CAD work

Based on the tape characterization and sensor pattern requirements:

- Design sensor arrays in each layer of the tape
- Design assembly registration
- Design via punching pattern
- Design printing registration
- Design heater pattern
- Design cutting keys for dicing
- Make all the patterns into CAD files

Tape preparation

- Blank the tape when it is on Mylar into 3.5"X5.5" pcs. using steel rule die
- Peal the tape off Mylar and lay the blanked tapes into an aluminum tray
- Load the trays into an oven and cure the tape at 70°C for 2 hrs

Pattern punching

- Punch the cured tapes according to the designed pattern for via holes, printing registration, assembly registration and air channels
- Design and get all the printing screens fabricated according to the sensor design

Screen printing

- Set proper vacuum force to hold tape on a porous stone printing nest
- Set off-contact to be ~30 mil
- Set proper squeegee pressure
- Attach a piece of Mylar to the printer as the alignment aid
- For via printing, use double pass and use a paper underneath the tape to protect the porous stone
- For heater printing, check thickness and fire a test part before committing the remaining tape
- Dry the printings at 80C for 5-10mins. Some heater/alumina printings may need to dry for 40min to 1.5hrs

- Some tips
  - Paste viscosity should be maintained to achieve consistent print thickness
  - To get >1 mil thick prints, print-dry-print-dry has to be adopted to avoid cracking and solvent penetration into the tape substrates

Assembly and lamination

- Cut fugitive tape into approximately 1.5x66 mm strip inserts using a drop knife
- Stack the layers and install the inserts according to the sensor design using a 3-pin alignment fixture. Apply as little pressure as possible to prevent air from getting trapped between layers
- Put one piece of silicone-coated Mylar underneath the stack. Mylar on top of the stack is not recommended
- A rubber roller may be used during vacuuming the bag to get air/bubbles out as much as possible
- Laminate the stack at 80°C, 3000 psi, 20 min
- Tip
  - Put the layer with cutting keys on top of the assembly during lamination

Dicing/singulation

- Set the hot knife cutter to the proper temperature (70-80°C)
- Place the laminate on the stage and allow sufficient time to heat up
- Align the knife to the cutting keys on the outer layer of the laminates
- Make sure all four sides of the diced part have clean cut edges before firing

Firing

- Load the parts into the furnace with the printed electrode at the bottom. Leave some space between each part
- An alumina cover plate may be used on top of a group of parts
- Start the furnace using the appropriate firing profile
- Unload the furnace when the firing cycle is complete.

Testing

- Parts were visually examined for any defects like delamination, scratches in the printing, cracking, etc.
- Dimensions were measured on each part
- Camber was tested on selected parts from each firing batch
- Heater resistance was measured on each part
- Capacitance between the two electrodes was measured on each part
- Isolation resistance between the heater and the electrodes was measured on each part