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SPECIFICATIONS DOCUMENT

IITM_FMM_01

AMOLED DISPLAY PROTOTYPING SYSTEM

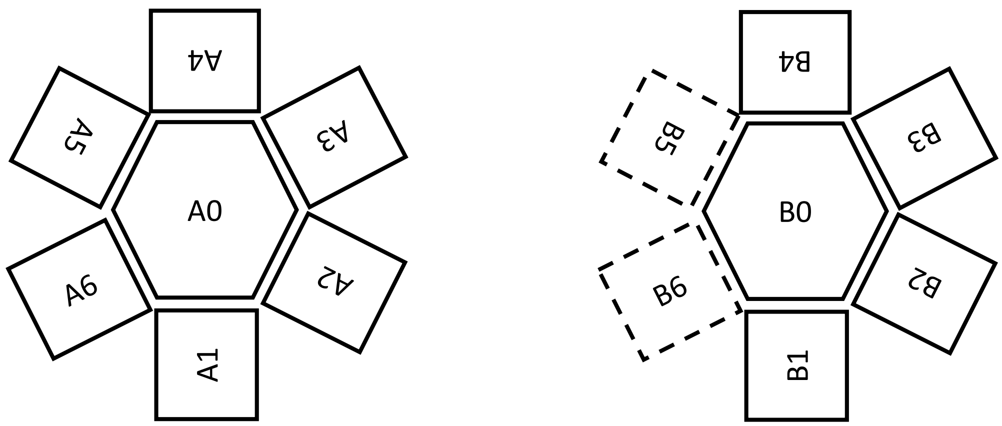
CLUSTER TYPE – FMM TECHNOLOGY

Department of Electrical Engineering, IIT MADRAS

Contents

1. Cluster-Style System Design Concept for AMOLED Display Prototyping

The Indian Institute of Technology Madras ("**IITM**") desires to purchase a state-of-the-art Active Matrix Organic LED ("**AMOLED**") display prototyping system ("**SYSTEM**")for the research and development of next-generation AMOLED manufacturing technologies. The SYSTEM will be installed inside a cleanroom facility at the IITM campus in Chennai/India and must be built to be compatible with cleanroom operations. To ensure maximum flexibility in technology development, the IITM project team has conceptualized the system design in a cluster-style layout, as shown below in Figure 1. The focus of the IITM AMOLED project is to develop and demonstrate current and next-generation building-block technologies suitable for use in the mass-production of state-of-the-art smartphone displays.



CLUSTER A	
Chamber	Function
A0	Transfer Robot
A1	L/UL w/Xfer Case
A2	Organic Chamber 1
A3	Organic Chamber 2
A4	Cathode Chamber
A5	L/UL w/Cassette
A6	Mask Stocker

CLUSTER B	
Chamber	Function
B0	Transfer Robot
B1	L/UL w/Xfer Case
B2	Dispensing
B3	Sintering
B4	Laser Curing
B5	Not Needed Now
B6	Not Needed Now

Figure 1: IITM's Cluster-Style AMOLED Prototyping System

The AMOLED display device structure for smartphone displays consists of several functional layers of organic materials (*hole-injection layer, hole-transport layer, emission layer with dopant materials, electron or hole-blocking layers, electron transport layer and electron injection layer*) situated between a patterned anode layer on the display substrate below and a cathode layer above. Several of these layers will need to be patterned area-wise to create a high-resolution AMOLED display with red, green and blue subpixels. The AMOLED display prototype is completed by the "hermetic", perimeter sealing (or encapsulation) of the entire AMOLED device structure using a transparent glass substrate. The SYSTEM is envisioned to integrate several layers of the AMOLED device structure through the controlled, hands-free transport of display substrates through each of the process chambers attached to each of the two sub-clusters ("**Cluster A**" and "**Cluster B**"). This document provides a brief overview of the general requirements for the cluster, the sub-clusters and each of the process chambers attached to the sub-clusters.

2. General Requirements

The IITM project is exclusively focused on vacuum-deposited, small-molecule AMOLED devices and the SYSTEM must be capable of depositing the organic materials and the cathode layer in a vacuum ambient and completing the encapsulation in an inert ambient. The SYSTEM should be capable of semi-automatic operation as described below.

(i) The substrate size will be either a 6-in x 6-in glass substrate or a 6-in Φ silicon wafer. Adapters are required for a change over from one type of substrate to another.

(ii) The transport of substrates between the each of the process, load/unload or stocking chambers within each of the sub-cluster must be programmable from a centrally located control console to enable automatic substrate transfer from one process chamber to another. The operator must be able to build recipes on the control console to string together a sequence of substrate transfers.

(iii) The transport of in-process substrates between the sub-clusters must use manual transfer vessels ("MTV" or "Transfer Case")). The MTV, which can maintain either a vacuum or an inert environment, should be designed for docking to one of the dedicated process chamber ports located on each of the sub-clusters. The MTV eliminates the need for glove boxes for substrate transfers between the deposition sub-clusters and the encapsulation sub-cluster. The MTV should be cleanroom compatible and result in hands-free substrate handling during AMOLED prototyping, from start to finish.

(iv) MTVs should be capable of transferring two substrates at a time. Each MTV must be compact, lightweight and portable.

(v) Most of the significant processes such as deposition, precision alignment of masks and substrates, etc. are expected to be performed by the operator in a manual mode. The SYSTEM supplier and the IITM project team will agree upon the automatic-mode requirements of each of the processes prior to design sign-off.

3. Cluster A Requirements

The process chambers attached to Cluster A was described in Figure 1. The centrally located transfer robot chamber ("A0"), which is a vacuum chamber, is capable of transferring substrates to and from six other functional process chambers ("A1" to "A6"), also vacuum chambers, attached to it. The transfer robot chamber is connected to all the process chambers through a normally closed gate valve. The functions of the various vacuum chambers in Cluster A are reproduced in Table 1 below for convenience.

Table 1: Functional Description of Cluster A

Chamber	Function
A0	Transfer Robot
A1	Load/Unload with Transfer Case
A2	Organic Layer Deposition Chamber 1

A3	Organic Layer Deposition Chamber 2 with FMM Patterning Capability
A4	Cathode Deposition Chamber
A5	Load/Unload with Cassette
A6	Mask Stocker

The requirements for each of the chambers in Cluster A is briefly described below:

3.1. A0: Transfer Robot Chamber

(i) The final vacuum pressure of the transfer robot chamber must be compatible with the vacuum pressure levels established in the organic deposition chambers A2 and A3.An appropriate vacuum pumping package must be installed in this chamber. The pump down or venting of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The maximum weight capacity of the transfer robot will be 2kg or less (including pick-up arm and substrate load)

(iii) The SYSTEM supplier must procure the transfer robot from an original manufacturer with a track record of successful installations in the display or semiconductor industry.

(iv) The top plate of the central robot chamber must be designed for removal when necessary for robot repairs, replacement or maintenance. Auxiliary equipment for field service personnel to remove and replace the top plate must be specified.

3.2. A1: Load/Unload (L/UL) Chamber with Transfer Case

(i) The final vacuum pressure in the A1 chamber must be less than 1×10^{-4} Pa. An appropriate vacuum pumping package must be installed in this chamber. The pump down or venting of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The purpose of the A1 chamber is to load an MTV containing in-process substrates that are being maintained under controlled ambient conditions during transfers from one sub-cluster to another.

(iii) The MTV must be co-designed along with the A1 chamber load/unload mechanisms for the automatic extraction from or loading of in-process substrates into the MTV under controlled ambient conditions.

(iv) The MTV must be capable of handling two substrates at a time. Each MTV must be compact, lightweight and portable.

3.3. A2: Organic Layer Deposition Chamber 1

(i) The final vacuum pressure in A2 must be less than 5×10^{-5} Pa. An appropriate vacuum pumping package must be installed in this chamber. The pump down or venting of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The purpose of A2 chamber is to deposit common (unpatterned) organic layers of the AMOLED device structure. Such layers may include hole injection layer, hole transport layers, blocking layers, electron transport layers and electron injection layers.

(iii) The A2 chamber shall require the following items:

a. 9 sets of cell-type evaporation sources with an operating temperature control range of 250°C to 400°C and a maximum degassing temperature of 500°C.
b. 9 sets of power supplies
c. 3 sets of temperature control units
d. 9 sets of film thickness sensors
e. At least 1 set of deposition rate controller (with 4 channels each)
f. At least 1 set of film thickness monitor (with 4 channels each)
g. Substrate delivery mechanism
h. 1 set of frame mask
i. Substrate rotation mechanism (3 to 10 rpm)
j. Source and substrate shutters

(iv) The A2 chamber shall require a mask to substrate alignment accuracy of +/- 0.5 millimeter

(v) The A2 chamber shall require a film thickness uniformity within +/- 5%

3.4. A3: Organic Layer Deposition Chamber 2 (with FMM Patterning Capability)

(i) The final vacuum pressure in A3 must be less than 5×10^{-5} Pa. An appropriate vacuum pumping package must be installed in this chamber. The pump down or venting of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The purpose of A3 chamber is to deposit patterned organic layers of the AMOLED device structure. Such layers may include hole transport layers, blocking layers, electron transport layers, emission layers and dopants.

(iii) The A3 chamber shall require the following items:

a. 9 sets of cell-type evaporation sources with an operating temperature control range of 250°C to 400°C and a maximum degassing temperature of 500°C.
b. 9 sets of power supplies
c. 3 sets of temperature control units
d. 9 sets of film thickness sensors
e. At least 1 set of deposition rate controller (with 4 channels each)
f. At least 1 set of film thickness monitor (with 4 channels each)
g. Substrate delivery mechanism
h. 1 set of frame mask
i. Substrate rotation mechanism (3 to 10 rpm)
j. Precision alignment mechanism
k. Source and substrate shutters

(iv) The A3 chamber shall require a mask to substrate alignment accuracy within +/- 3 micrometer. The SYSTEM supplier must specify their strategy for guaranteeing this precision alignment accuracy. (Note: the precision mask will be designed and supplied by the IITM project)

(v) The A3 chamber shall require a film thickness uniformity of within +/- 5%

(vi) The A3 chamber shall require an in-situ mechanism for the pick-up and delivery of precision mask assemblies from the mask stocker chamber.

3.5. A4: Cathode Deposition Chamber

(i) The final vacuum pressure in A4 must be less than 5 x 10^{-5} Pa. An appropriate vacuum pumping package must be installed in this chamber. The pump down or venting of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The purpose of A4 chamber is to deposit inorganic materials as cathode layers.

(iii) The supplier should provide a system that is capable of depositing cathode layers for either a bottom emission (BE) or a top emission (TE) OLED device. If any of the evaporation sources have to be shared between the BE or TE configurations, then the supplier shall provide spare sources for use in order to prevent cross-contamination between cathode materials.

(iv) The A4 chamber shall require the following items:

   a. 1 set of high temperature evaporation source with a temperature control range of 500°C to 700°C and a maximum capability of 750°C (usable for either TE or BE configurations)
   b. 1 set of power supply for the high temperature source
   c. 2 sets of boat type resistive evaporation source (usable for either TE or BE configurations)
   d. 1 set of power supply for the resistive type evaporation source
   e. 1 set of temperature control unit
   f. 3sets of film thickness sensors
   g. At least 1 set of film thickness monitor
   h. Substrate rotation mechanism (3 to 10 rpm)
   i. Substrate delivery mechanism
   j. Frame mask alignment mechanism
   k. Source and substrate shutters

(v) The A4 chamber shall require a mask to substrate alignment accuracy within +/- 0.5 millimeter.

(vi) The A4 chamber shall require a film thickness uniformity of within +/- 10%. The film thickness shall be measured on a 100nm aluminium (Al) film deposited on a substrate that is being rotated at 10rpm

3.6. A5: Load/Unload (L/UL)Chamber with Cassette

(i) The final vacuum pressure in the A5 chamber must be less than 1 x 10^{-4} Pa. An appropriate vacuum pumping package must be installed in this chamber. The pump down or venting of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The purpose of the A5 chamber is to load a multi-slot cassette containing freshly cleaned and baked substrates from the cleanroom into the SYSTEM and pump down to the vacuum pressure levels required for the transfer of substrates to other process chambers in Cluster A.

(iii) Once the substrates have been delivered to the SYSTEM using the cassette, all substrate transfers between Cluster A and B will be required to be performed using MTVs until they are encapsulated.

(iv) The Load/Unload cassette must be designed for seven (7) substrates

3.7. A6: Mask Stocker Chamber

(i) The final vacuum pressure of the A6 chamber must be compatible with the vacuum pressure levels established in the organic deposition chamber A3 and the transfer robot chamber. An appropriate vacuum pumping package must be installed in this A6 chamber. The pump down or venting of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The purpose of the A6 chamber is to store tensioned **FMM** (Fine Metal Mask) assemblies. The A6 chamber shall contain seven (7) sets of FMM assemblies in their respective slots on a cassette. A Z-axis lifting mechanism shall be designed for the mask stocker system so that any mask slot can be raised to the transfer robot plane.

4. Cluster B Requirements

Cluster B provides the processes for the encapsulation of the display substrate after all the OLED device structure layers have been formed in Cluster A. The selected encapsulation method will use the dispensing, sintering and laser annealing of a frit material between the display substrate and the encapsulation substrate to provide a "hermetic" seal. A simple schematic of the laser frit encapsulation method is shown in Figure 2 below.

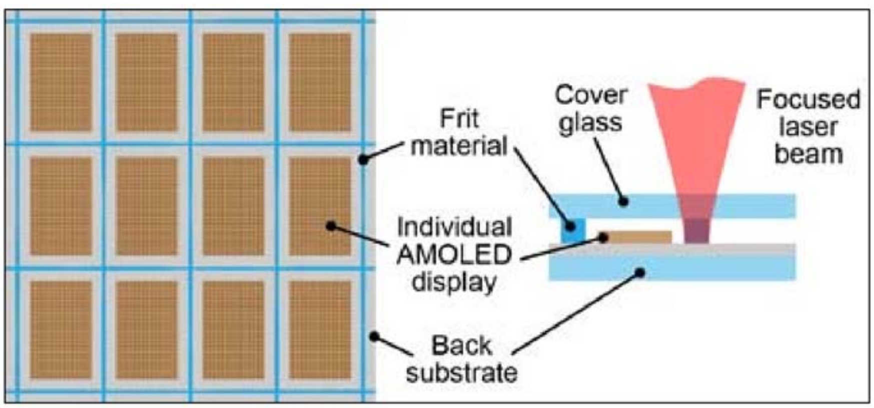


Figure 2: Concept of Laser Frit Encapsulation Method

The process flow sequence for encapsulating an OLED device is described below:

(i) An MTV containing at least two substrates, namely, the display substrate and the encapsulation glass substrate, is loaded into the load/unload chamber while the MTV is maintained under vacuum or dry nitrogen conditions.

(ii) After pumping down the load/unload chamber, its environment is replaced with dry nitrogen before the MTV is opened to remove the substrates.

(iii) The encapsulation substrate is moved to a dispensing chamber where the laser frit material is applied around the perimeter of the OLED device.

(iv) The encapsulation substrate is then moved to a sintering chamber where its temperature is raised to 450^{o}C to eliminate solvents from the laser frit material.

(v) The encapsulation substrate is then moved back to the dispensing chamber where a UV resin is applied at selected spots.

(vi) Next, the encapsulation substrate and the display substrate are brought in close proximity together in the laser curing chamber and aligned together.

(vii) While the substrates are under alignment, the UV resin spots are cured.

(viii) Next, using a high-power laser irradiation, the frit material is cured to provide a "hermetic" seal.

(ix) The encapsulated OLED device is placed back into the load/unload chamber

The process chambers attached to Cluster B was described earlier in Figure 1. The centrally located transfer robot chamber ("B0") is capable of transferring substrates to and from all functional process chambers ("B1" to "B4") attached to it. The transfer robot chamber is connected to all the process chambers through a normally closed gate valve. The functions of the various vacuum chambers in Cluster B are reproduced in Table 2 below for convenience. In normal operation, all the process chambers will operate under dry nitrogen ambient pressure of 5Pa. The customer (IITM) will provide the nitrogen purification and recirculation system to deliver dry nitrogen with H_2O and O_2 levels below 1ppm to all the encapsulation process chambers. However, all the chambers, except the dispensing chamber, shall require vacuum pumping capability so that dry nitrogen ambient can be substituted under controlled conditions.

Table 2: Functional Description of Cluster B

Chamber	Function
B0	Transfer Robot
B1	Load/Unload with Transfer Case
B2	Dispensing Chamber
B3	Sintering Chamber
B4	Alignment, UV & Laser Curing Chamber
B5	Not Required: *port intended for future upgrade*
B6	Not Required*: port intended for future upgrade*

The requirements for each of the chambers in Cluster B is briefly described below:

4.1. B0: Transfer Robot Chamber

(i) An appropriate vacuum pumping package must be installed in this chamber. The pump down or dry nitrogen refill of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The maximum weight capacity of the transfer robot will be 2kg or less (including pick-up arm and substrate load).

(iii) The SYSTEM supplier must procure the transfer robot from an original manufacturer with a track record of successful installations in the display or semiconductor industry.

(iv) The top plate of the central robot chamber must be designed for removal when necessary for robot repairs, replacement or maintenance. Auxiliary equipment for field service personnel to remove and replace the top plate must be specified

4.2. B1: Load/Unload (L/UL) Chamber with Transfer Case

(i) An appropriate vacuum pumping package must be installed in this chamber for achieving base vacuum pressures before substitution with dry nitrogen. The pump down or dry nitrogen venting of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The purpose of the B1 chamber is to load an MTV containing in-process substrates that are being maintained under controlled ambient conditions prior to encapsulation.

(iii) The MTV must be co-designed along with the B1 chamber load/unload mechanisms for the automatic extraction from or loading of in-process substrates into the MTV under controlled ambient conditions

(iv) The MTV must be capable of handling two substrates at a time. Each MTV must be compact, lightweight and portable.

4.3. B2: Dispensing Chamber

(i) The dry nitrogen filling of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The purpose of this B2 chamber is to dispense laser frit material and UV resin spots on the encapsulation substrate

(iii) The supplier shall provide the following items:

a. 1 unit of a suitably designed dispensing chamber that operates at a 5Pa dry nitrogen ambient pressure
b. 1 dispensing robot unit that can handle laser frit material and UV resin material
c. Substrate delivery and pick-up mechanisms to and from the dispensing robot

4.4. B3: Sintering Chamber

(i) An appropriate vacuum pumping package must be installed in this chamber for achieving base vacuum pressures before substitution with dry nitrogen. The pump down or dry nitrogen venting of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The purpose of this B3 chamber is to sinter the dispensed frit material at 400^{o}C

(iii) The supplier shall provide the following items:

a. 1 set of sintering heater control unit
b. Substrate delivery and pick-up mechanisms to and from the sintering chamber

4.5. B4: Alignment, UV & Laser Curing Chamber

(i) An appropriate vacuum pumping package must be installed in this chamber for achieving base vacuum pressures before substitution with dry nitrogen. The pump down or dry nitrogen venting of the chamber must be automated and capable of being controlled from the central console unit.

(ii) The purpose of the B4 chamber is to bring together the display substrate and the encapsulation substrate (with sintered frit material and uncured UV-resin material) in close proximity, align the substrates, curing the UV-resin spots, and complete the encapsulation by laser curing the frit material along the perimeter.

(iii) The supplier shall provide the following items:

a. Substrate alignment mechanism with an accuracy within +/-0.5 millimeters. The alignment mechanism shall include mechanisms for ensuring planarity between the substrates as they are brought together for encapsulation
b. 1 set of focused laser source (wavelength: 940nm; power:1000W)

c. 1 set of laser scanning mechanism
d. 1 set of UV-LED source (wavelength to matched to the selected UV-resin)
c. Substrate delivery and pick-up mechanisms to and from the laser curing chamber

4.6. B5: Not Required: *Port Intended for Future Upgrade*

4.7. B6: Not Required: *Port Intended for Future Upgrade*

5. Central Control Unit

The SYSTEM supplier shall provide a central control unit with the following capabilities:

(i) Remote manual operation capability with interlock functions for preventing damage to the equipment
(ii) The control unit contains the PLC sequencer
(iii) Operation is performed using a remote display panel with graphical user interface
(iv) Data logging to a connected PC

6. Delivery Milestones

The IIT_FMM_01 project will have the following milestones:

(i) Purchase order (follows supplier selection after technical bids are reviewed and financial bids are opened by IIT Madras)
(ii) Approval of design drawings by IIT Madras
(iii) Successful completion of Factory Acceptance Tests (FAT) at the supplier location
(iv) Successful completion of Site Acceptance Tests (SAT) at IIT Madras

Note: At the FAT and SAT events, various criteria listed in this requirement document will have to be demonstrated by the supplier. Additionally, the supplier must demonstrate the transfer of one-hundred (100) substrates to and from the Load/Unload Chambers to any of the chambers within each cluster and twenty-five (25) transfers of FMM assemblies between Chambers A6 and A3.

7. Optional Specifications

The vendor shall provide separate proposal options for the following two chambers

(i) Chamber A2 package: 6 sets of sources and associated items instead of 9 sets of sources and associated items as specified in Section 3.3
(ii) Chamber A3 package: 7 sets of sources and associated items instead of 9 sets of sources and associated items as specified in Section 3.4

8. Additional Requirements

(i) The supplier must provide a minimum of two (2) year warranty on parts, labor and maintenance. A clear warranty statement must be provided with the proposal which indicates the terms governing parts and labor.
(ii) The warranty period should commence after the installation of the equipment at the IIT Madras site and upon the successful completion of the site acceptance tests (SAT).

(iii) The supplier must provide a comprehensive annual maintenance contract (CAMC) proposal for the next three (3) years beyond the warranty period.

(iv) The supplier’s proposal must most provide solutions for the entire set of requirements described in this document IITM_FMM_01, namely, both of the clusters.

(v) The supplier’s proposal must include detailed specifications for each of the chambers in each of the clusters.

(vi) The supplier must provide a breakup of costs for each of the chambers in each of the clusters.

(vii) The supplier must provide the names of at least three (3) of their customers who have successfully installed and are currently operating OLED device fabrication equipment which contain several of the elements of the building block equipment technologies similar to those requirements being specified here by IIT Madras. The supplier must provide the place and address of their customers being provided as a reference. The supplier should arrange to provide one reference letter from one of their key customers.

(viii) The AMOLED Display Prototyping System IITM_FMM_01 is being specified for “hands-free” substrate handling to facilitate AMOLED display fabrication. Therefore, supplier proposals containing glove box solutions for encapsulation will be rejected. The supplier must propose a controlled environment (vacuum or dry nitrogen) transfer case technology for the transport of substrates between Cluster A and Cluster B. The transfer case (or MTV) design must allow it to be loaded into Clusters A or B through a dedicated load/unload chamber and must be able interact with the substrate transfer robots situated within each of the clusters. The supplier must provide the names of at least two (2) of their customers who have successfully installed and are currently operating systems containing MTVs.

(ix) The supplier must have experience in laser frit encapsulation solutions and must have provided systems incorporating this technology to one or more customers. The supplier must provide the names of such customers for reference. Any proposals that do not contain equipment solutions for laser frit encapsulation technology will be rejected.

(x) The supplier must agree to develop and demonstrate at least one tensioned, fine metal mask (FMM) assembly during the factory acceptance test (FAT). The FMM assembly must be able to successfully interface with the precision alignment mechanisms incorporated in one of the organic chambers in Cluster A and be able to demonstrate high-resolution pixel patterning technology. After the FAT milestone, the supplier must transfer the FMM supply chain details to IIT Madras.

(xi) The supplier must be willing to share the substrate cassette design with other equipment suppliers who will be supplying glass cleaning equipment. This will be helpful for designing a “hands-free” process flow in the IIT Madras AMOLED display fabrication facility.

(xii) The supplier or the supplier’s representative must establish a service center in Chennai to support the operations at IIT Madras. The engineers representing the supplier or the supplier’s representative, and assigned to the Chennai service center, must have received training at the supplier’s manufacturing location and be fully qualified to handle the AMOLED Display Prototyping System (IITM_FMM_01).

(xiii) Both clusters (Clusters A and B) must be designed, manufactured and delivered by single supplier and supported at the IIT Madras site by the same supplier or the supplier’s authorized representative

(xiv) The supplier shall provide a list of utilities to be provided by IIT Madras at the Chennai site

(xv) The supplier must provide the interface specifications for an UPS (Uninterrupted Power Supply) system to be used in India with the central console of the AMOLED Display Prototyping System (IITM_FMM_01)

(xvi) The supplier must provide separate technical and financial bids in sealed envelopes.

(xvii) The tender number must be clearly noted and visible on the top of the envelope

(xviii) Vendors who qualify the technical specifications shall be required to make a presentation of their designs before the opening of the financial bid.