OrcaProbe

Reconfigurable Electrical Probing System for Thin Film Devices

Requirements Document

ELEC 491 Capstone Project
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Glossary

Device	The physical device that houses the necessary hardware and probes. It has the embedded firmware running, which receives the commands, executes measurements and reports the results.
Dummy data	A form of pre-defined data that mimics the expected data and is used for testing purposes.
Host computer	Any computer system that has the software controller GUI program running and is connected to the device via USB.
Material under test	Any material that is to be measured for its characteristics.
Operator	A qualified individual from the client's company who executes the measurements and collects data.
OrcaProbe	The project name for the whole complete system including the device and host GUI.
Probe	The physical pin/terminal that contacts the material under test. It achieves the electrical connection between the material and the device.
Measurement recipe	The required actions a probe needs to take to be able to execute a measurement. It involves the type of input that should be provided to the material and the type of output that should be measured.
Test emulator hardware	A platform with a microcontroller-based evaluation board and breadboard combination that can be quickly set up to assist in the testing of individual subsystems. It is intended to reduce development dependencies between subsystems.

1. Background

1.1 Client and Industry

Thin film devices are an emerging area of technology that involves building electronic structures ranging from a few nanometers to micrometers thick. These devices have a broad range of potential use cases as they can be utilized in any application requiring thinness or portability (ex., wearables, flexible solar cells). Our client, Orca Advanced Materials Inc., is a startup based in Vancouver, BC, specializing in this area by researching and developing these thin film devices and their possible commercial applications.

1.2 The Problem

As part of Orca's development process, the client needs to be able to test and characterize the electrical properties of thin film devices. However, the current process is slow, labour-intensive, and requires multiple procedures for different tests. The large number of procedures and repetitive tasks also increases the risk of human error and raises concerns about the reliability of results. Additionally, the probes of the device currently being used by the client are prone to damaging samples, which limits testing capacity.

1.3 The Solution

Our project, named OrcaProbe, aims to develop a consolidated testing platform tailored to the needs of Orca Advanced Materials Inc., providing efficient and reliable testing for thin film devices. This device is designed to streamline the testing process by integrating multiple measurement functions into a single device, enabling various electrical measurements without needing separate tools. Enhancing efficiency will reduce testing time, shorten development cycles, and allow for faster iteration of designs. Additionally, it minimizes the resources required for testing, reduces errors, and increases the reliability of results. This solution is also designed to accommodate future automation and expanded testing scenarios, providing a scalable solution for evolving needs.

2. Project Outcome

A successful project will significantly impact the client's operations by improving the efficiency and reliability of their testing processes. The consolidated testing platform will reduce manual interference and associated errors, resulting in more consistent and trustworthy results. This project will help the client save time and cost by accelerating development cycles and reducing resource usage while enhancing overall productivity. The benefits align with the client's goals of increasing throughput, reducing operational costs, and preparing for future technological advancements.

3. Product Specification Conventions

This section covers the conventions used for the functional and non-functional requirements, as well as the constraints of OrcaProbe. These are collectively referred to as product specifications.

In this and any other document related to OrcaProbe, product specifications are described, referred to, and categorized using the following conventions.

Description

- Specifications are described using an indexing structure.
- A sub-specification is indexed under its parent specification and builds onto the parent specification by providing more information about it.
- For a parent specification to be considered as satisfied, all of its sub-specifications need to be satisfied.

Referencing

- Each specification is referenced using the “PREFIX-INDEX” structure.
- The prefix is determined by the type of specification. Prefixes are FR for functional requirements, NFR for non-functional requirements and CST for constraints.
- Indexes are numbers that are assigned sequentially.
- Sub-specifications keep their parent’s index and increment subsequent indices.
- To reference a group of sub-specifications, X is used. (e.g. 1.2.X refers to all sub-specifications of parent specification 1.2)

Categorization

- Functional requirements are further broken down into 4 categories. These categories are for the system as a complete product, the device hardware, the software controller GUI and the mechanical chassis.
- Respectively, these categories are referred to as FR-1, FR-2, FR-3, and FR-4.

4. Functional Requirements (FR)

Functional requirements describe the specific tasks, features, or behaviors that a system must perform to achieve its intended purpose. These include data processing, user interactions, and system responses to inputs, forming the foundation of the system's functionality.

4.1 Complete System Requirements (FR-1)

1. The system must be able to execute measurements for electroactive thin film devices, using different methods and offer automated configurability between which method is used.

- **1.1.** The system must have 4 probes in total, which can be grouped into 2, 3, and 4 probe configurations at the user's will.
  - **1.1.1.** Each probe must be able to function as the measurement input probe by supplying AC and DC voltage/current.
  - **1.1.2.** Each probe must be able to function as the measurement output probe by measuring AC and DC voltage/current.
  - **1.1.3.** Each functionality of a probe, either configured as input or output, should not affect other functionalities of the probe.
- **1.2.** The system must offer 2-probe measuring methods that have recipes in line with FR-1.1.1 and FR-1.1.2. The methods are DC Resistance, Current-Voltage, Capacitance-Voltage and Impedance Spectroscopy measurements.
- **1.3.** The system must offer 3-probe measuring methods that have recipes in line with FR-1.1.1 and FR-1.1.2. The methods are Output Characteristics, Transfer Characteristics, Capacitance-Voltage and Electrochemical Measurements.
- **1.4.** The system must offer 4-probe measuring methods that have recipes in line with FR-1.1.1 and FR-1.1.2. The methods are Probe Resistance, Low-Resistance and Impedance Spectroscopy measurements.

4.2 Device Hardware Requirements (FR-2)

2. The device must have a hardware system to support the probes with the necessary circuitry for measurements and a control system to utilize them.

- **2.1.** The hardware system must have dedicated driving functionality to supply a probe with the required electrical signal.
  - **2.1.1.** The signal to supply must be able to have a voltage value in the 0 V to 5 V range.
  - **2.1.2.** The signal must have a maximum frequency of 1 MHz.
  - **2.1.3.** The current to supply must be at most 1 mA. It also must be as low as 1uA.
- **2.2.** The hardware system must have dedicated monitoring functionality to sense the required electrical signal.
- **2.3.** The hardware system must have a dedicated electrically controllable connection toggling between probes and the necessary circuitry.
- **2.4.** The hardware system must communicate with the host computer using a USB connection and USB 2.0 (or later) protocol.
  - **2.4.1.** Upon connecting to any USB port, the device needs to be “searchable”, meaning that the host must recognize the device as a unique connection.
  - **2.4.2.** A USB connection must only be opened with the pairing software GUI.
- **2.5.** The hardware system must detect any errors or defects that can hinder the device's performance. The errors are to be sent to the GUI and displayed to the operator.
  - **2.5.1.** Significant variations in the supply voltages or currents need to be detected as an error.
- **2.6.** The hardware system must have a predefined reset state.
  - **2.6.1.** The hardware system must boot in this state after an initial power-up.

- **2.6.2.** The hardware system must have ways to fall back to its reset state both via hardware and software.

4.3 Software Controller GUI Requirements (FR-3)

3. The system must have a software controller program running on a host computer with a clear and comprehensible graphical user interface (GUI) that allows the operator to control the device.

- **3.1.** GUI must allow the operator to control the selected pin configuration.
- **3.2.** GUI must allow the operator to control the selected measurement method.
- **3.3.** GUI must allow the operator to provide the device with any necessary input parameters to carry out measurements and/or calculations.
  - **3.3.1.** GUI must allow the operator to start the measurement.
  - **3.3.2.** GUI must allow the operator to define the start and end sweep points alongside increments for the measurement.
- **3.4.** GUI must display the results of the measurements.
  - **3.4.1.** For static measurements, GUI must display a measured value, including its units.
  - **3.4.2.** For dynamic measurements, GUI must display a graphical plot showing the measured output against the input sweep range.
- **3.5.** The software program must collect and store the measurement values in a local CSV and/or JSON file on the host computer.
- **3.6.** The software program must display all errors the device hardware detects with a dedicated status indicator.
- **3.7.** The software program must have a predefined reset state.
  - **3.7.1.** The software program must initially be in this state after the GUI program is run.
- **3.8.** Upon bringing up the software program, it must automatically search for the device connection on host ports and establish a USB link if it finds it.

4.4 Mechanical Chassis Requirements (FR-4)

4. The system must have a chassis housing the hardware system with openings for probes and a USB port.

- **4.1.** The chassis must have robust mechanical sliders per probe configuration that, upon sliding, selected probes extend or retract.
- **4.2.** The chassis must have visual indicators for device hardware power and USB connectivity status. These indicators are to be driven by the device hardware system.

5. Non-Functional Requirements (NFR)

Non-functional requirements define the quality attributes of a system, such as accuracy, reliability, performance, and usability. They describe how well the system performs rather than what it does, helping ensure the system meets expectations under real-world conditions.

1. The system should automate handling probe configurations and data collection/storage to minimize operator interaction and speed up the overall process by a minimum of 5 times.
2. The measurements should have less than ±5% error compared to benchmark equipment.
3. The device and its chassis must be designed to withstand frequent handling and repositioning. It should maintain operational integrity when subjected to continuous movement in various directions.
4. The system, both device hardware and software GUI, must be designed such that future modifications and new measurement types can be easily added with minimal re-design of the base system.
5. The system must be designed to be easy to navigate for an operator with basic familiarity with the materials under test. This means the physical device layout, the graphical user interface (GUI), and the accompanying workflow document should be intuitive, logically organized, and require minimal training to use effectively.
6. The probes should minimize the contact pressure on the material under test to avoid damaging or deforming the material.

6. Constraints (CST)

Constraints are limitations or restrictions that the system must operate within, such as hardware capabilities, time, budget, regulatory standards, or environmental conditions. These factors influence design decisions and can affect both functional and non-functional requirements.

1. The hardware system and the software controller GUI must communicate using USB protocol. The connection needs to adhere to the USB 2.0 (or higher) standards, both for data transmission and device hardware system power. The total power consumption should be less than 2.5 W.
2. The probes are to be oriented in a single line adjacent to each other, with a pitch distance of a minimum of 2 mm and a maximum of 10 mm.
3. The chassis size (housing the hardware system and the probes) must not exceed 20 cm x 10 cm.
4. The program for the software controller GUI must run on Microsoft Windows 10 or a later version.

Appendix A. Team Roles

Name	Initials	Tech Lead	Management Lead
Aaron Loh	AL	Monitoring System	Team Liaison
Dipak Shrestha	DS	Switching Network	Inventory Manager
Idil Bil	IB	Software / GUI	Project Manager
Kerem Oktay	KO	Firmware / MCU	Document Manager
Peggy Yuan	PY	Driving System & Mechanical Design	Treasurer

Appendix B. Contributions

Section	Major Contribution	Minor Contribution	Author	Reviewer
1.1 Client and Industry	AL	PY	AL	PY
1.2 The Problem	AL	PY	AL	PY
1.3 The Solution	PY	AL	PY	AL
2. Project Outcome	PY	AL	PY	AL
3. Requirement Conventions	KO	IB	KO	IB
4. Functional Requirements	KO	IB	KO	IB
5. Non-Functional Requirements	KO	IB	KO	IB
6. Constraints	DS	KO	DS	KO