3D embedded freeform electrical circuitry in metal componentry

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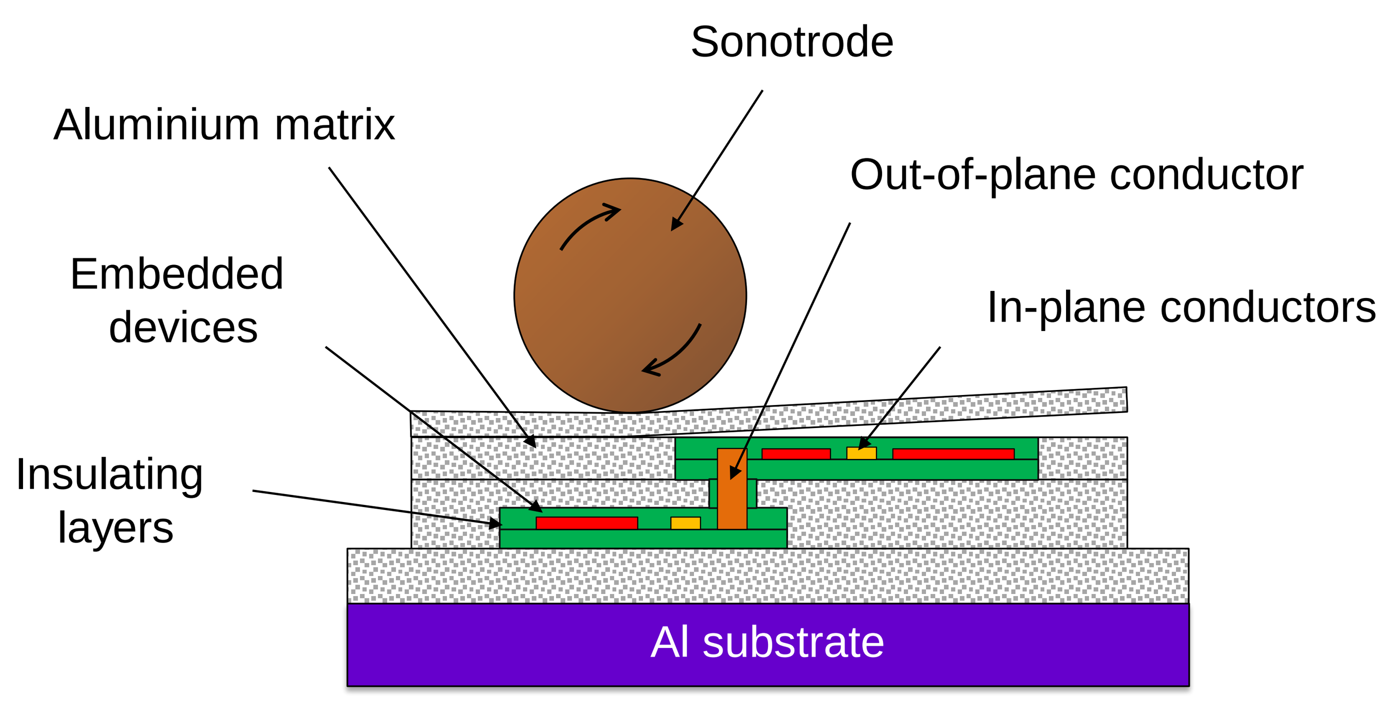
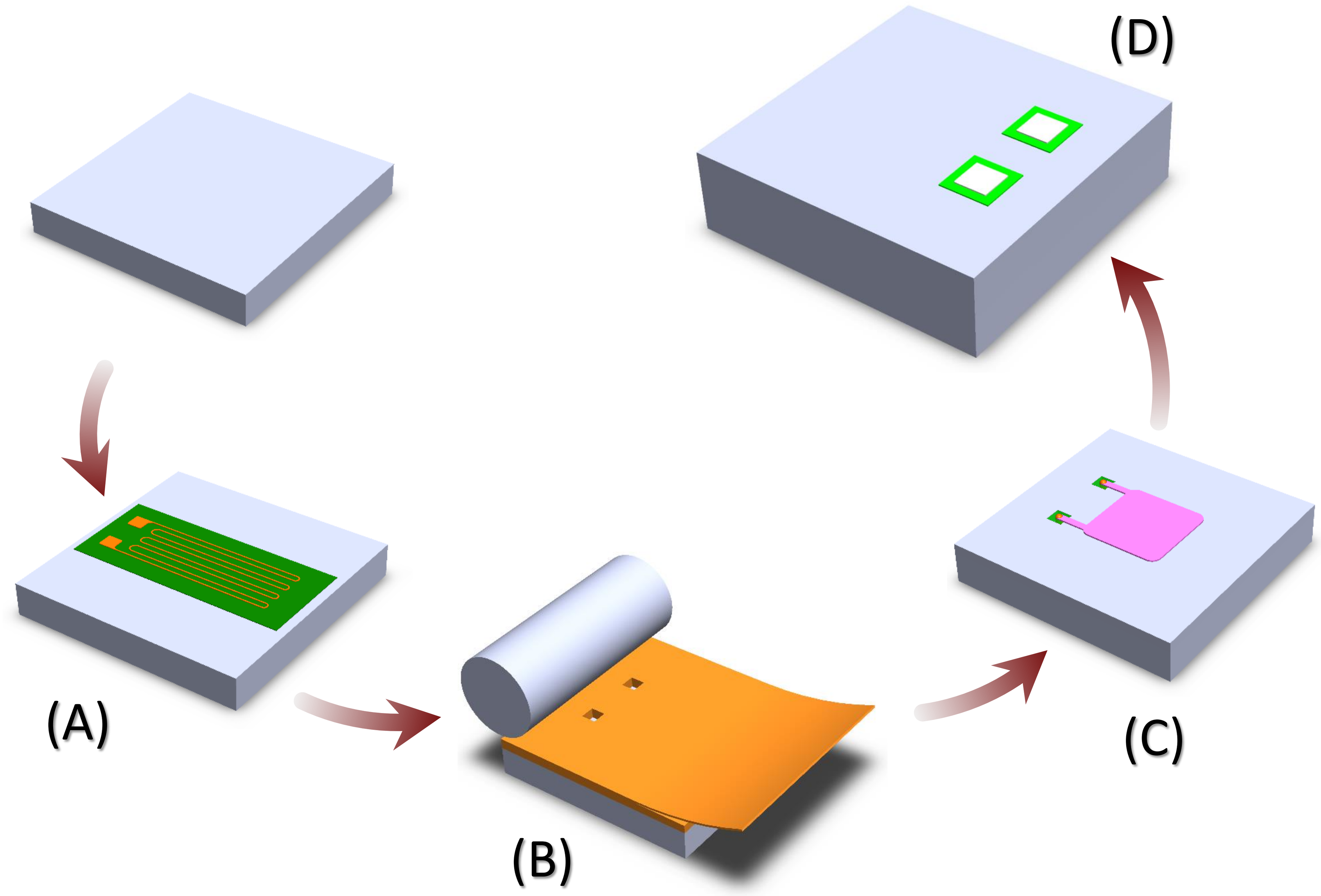
Introduction

A novel embedding process combining the use an **ultrasonic solid-state welding** technique coupled with a **material direct writing** technique to embed electronic devices and to print conductive features inside a three-dimensional metallic housing container is proposed. This process has the advantages of (i) <u>inexpensive fabrication</u>, (ii) <u>flexibility in sizes of embedded devices</u>, and (iii) <u>allowing for arrangement of embedded components in 3-D</u>. A fully functional demonstrator of a complete 3D LED circuitry has been successfully fabricated as the results of our fundamental researches gathered.

Research objectives and Manufacturing process



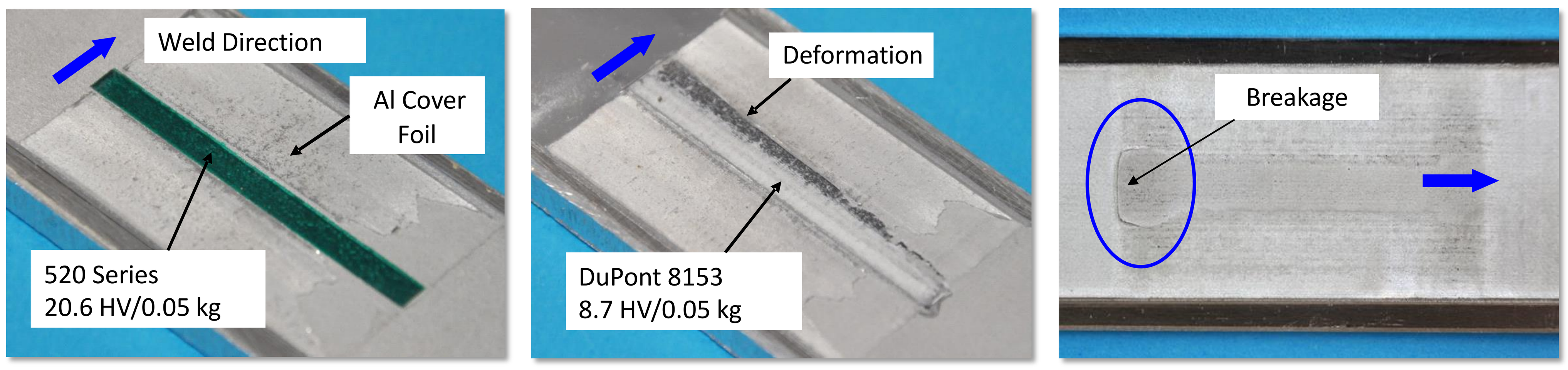
- To produce a functional metal matrix component with embedded printed circuitry which allows for 3d arrangement of features and connectors.
- To confirm quality of interlaminar bonding after embedment and electrical functionality.



(A) Insulating layer printed; Functional devices printed; In-plane conductors printed. (B) Device-1 encapsulated; Windows reserved for vertical connectors prepared. (C) Vertical connectors printed; Void space filled; Device-2 printed/embedded. (D) Final product encapsulated.

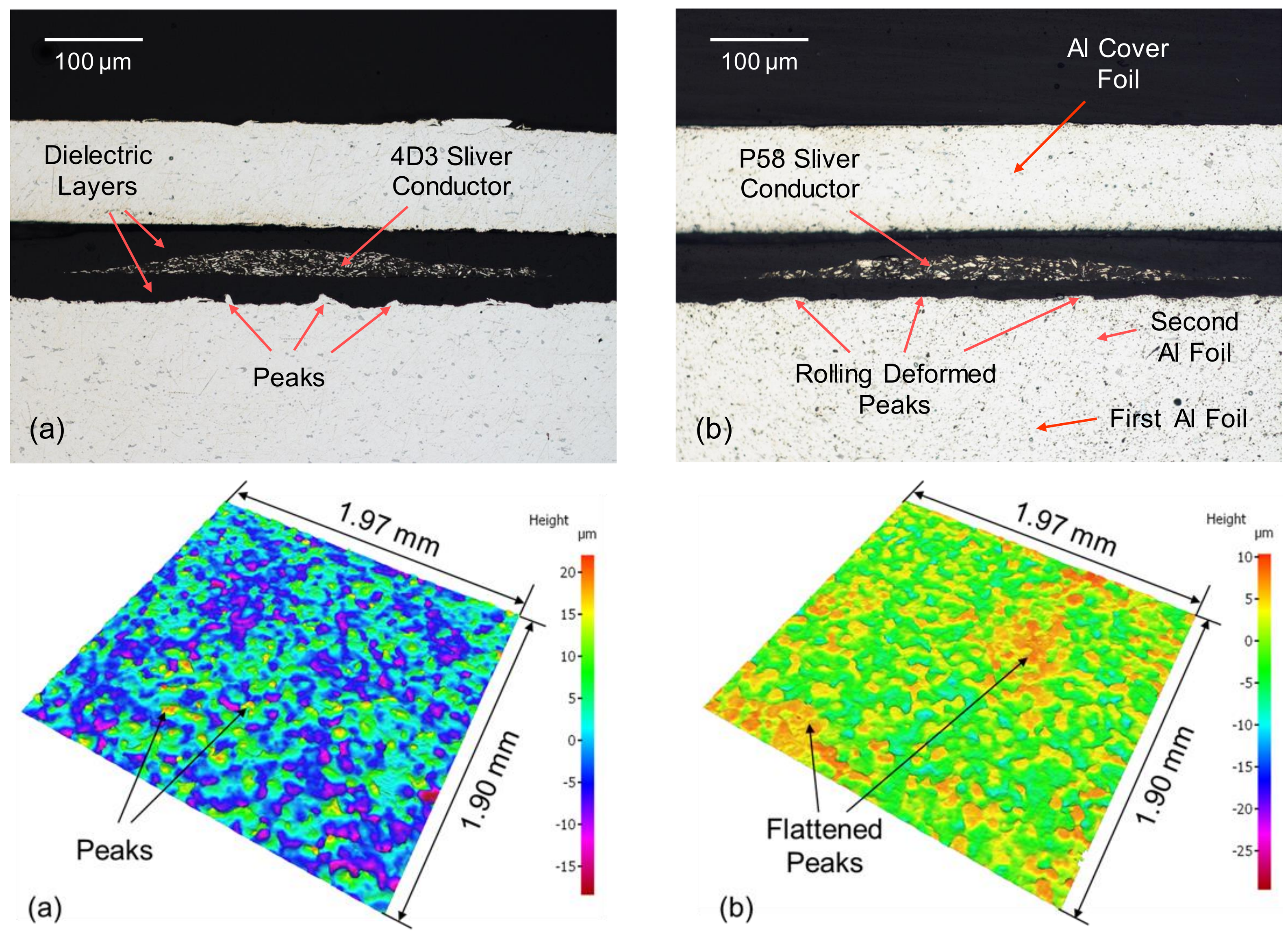
Key challenges and Associated researches

1) Materials which can survive under UC energy



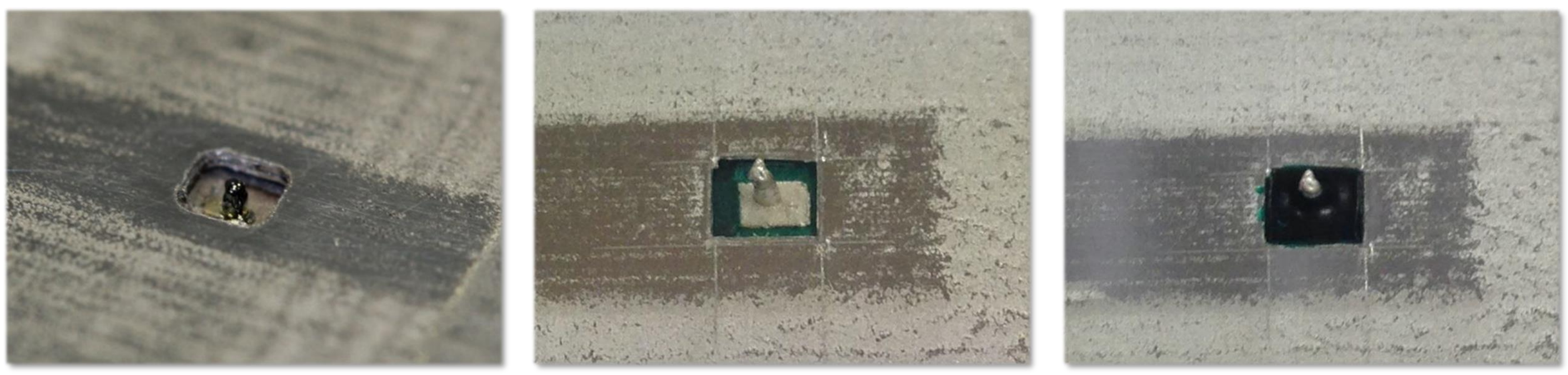
Excitement from the sonotrode can deform and even break features underneath if materials do not have sufficient stiffness. High stiffness can however prevent the aluminium foils to be welded as they are broken at the welding onset. Different insulating and conductive materials have been examined and their performance under UC have been investigated [1].

2) Rolling flattening for lower surface roughness



Our experience shows that an average UC surface roughness ~20um results in a number of peaks on the surface which penetrate insulating layer through to conductive layer and cause circuit shorting. Surface flattening is therefore crucial, which can reduce surface roughness Rz by ~30% [2,3].

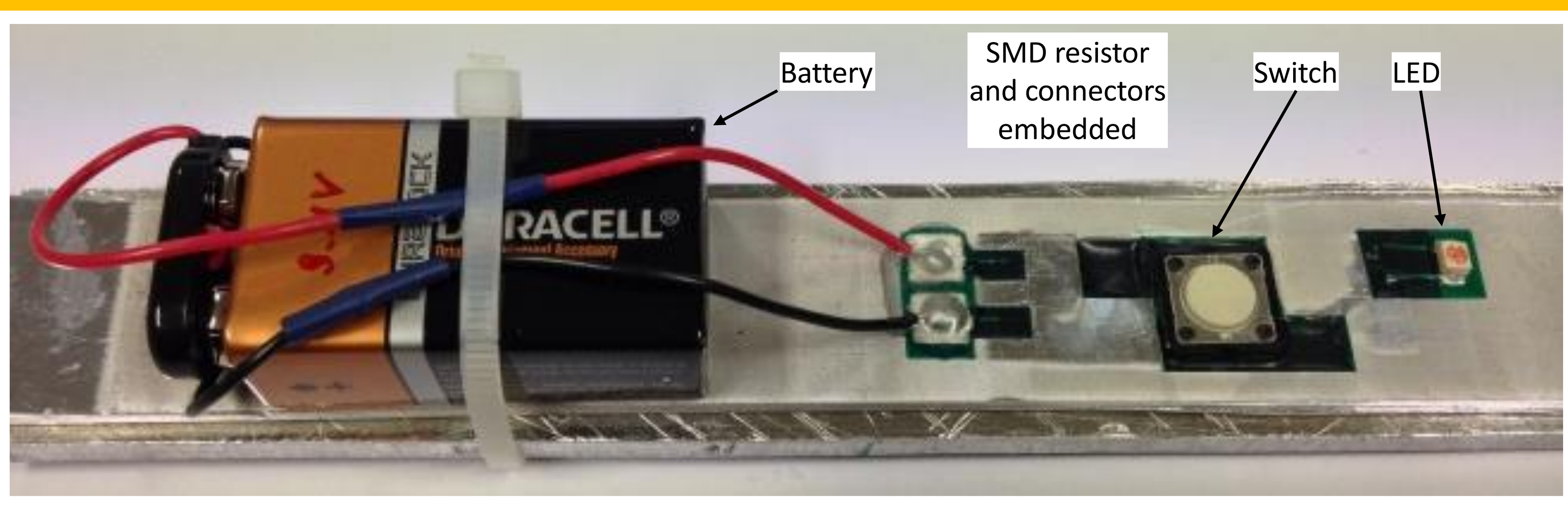
3) Printing of in-plane and out-of-plane connectors

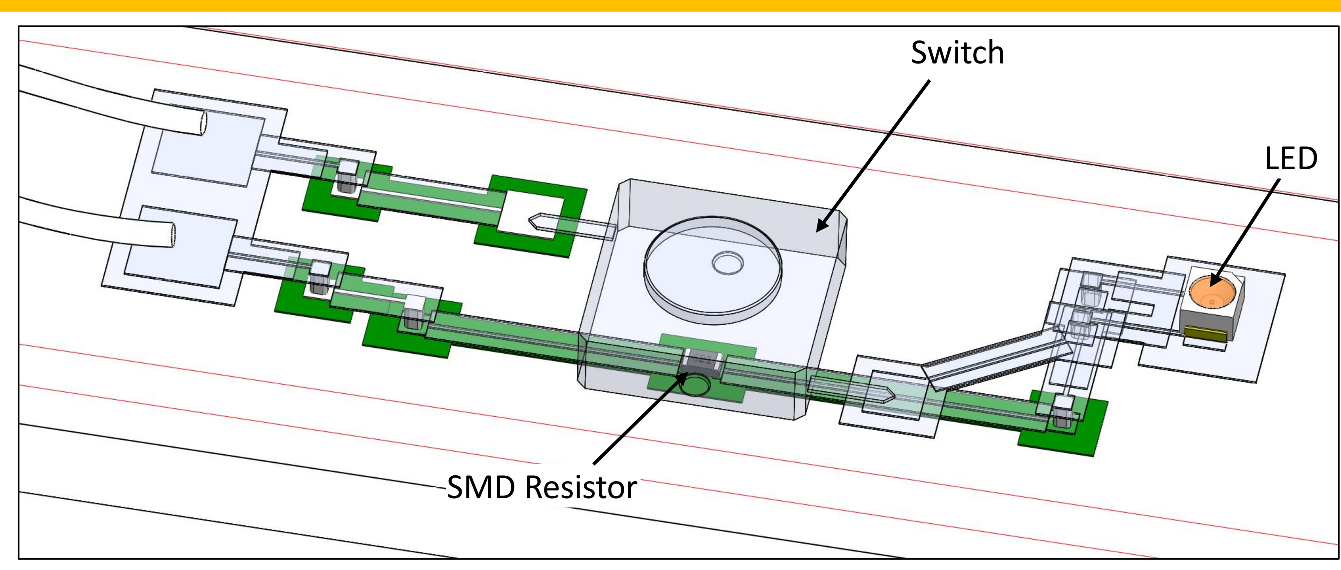


Research on this topic have been conducted to overcome difficulties in printing out-of-plane connectors, which eventually lie on the properties of the material to be printed, i.e. its viscosity to hold itself from collapsing during printing, printing patterns to maintain the top print as flat as possible, shrinkage of material before / after cured, curing conditions, etc.

[L: vertical copper wire with IR curing (collaboration with Nottingham), Mid: silver wire with thermal curing, R: silver wire after filling insulating material in]

Functional demonstrator by hybrid manufacturing





[1] J. Li et al., *Mat Sci and Eng A,* 2015 [2] J. Li et al., *Mat Sci and Eng A*, 2016 (submitted) [3] J. Li et al., Comp Part A, 2016 (submitted)