Investigation on Smart Parts with Embedded Piezoelectric Sensors via Additive Manufacturing

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Introduction

Objective:

- To design, fabricate, and test "smart parts" with embedded sensor.

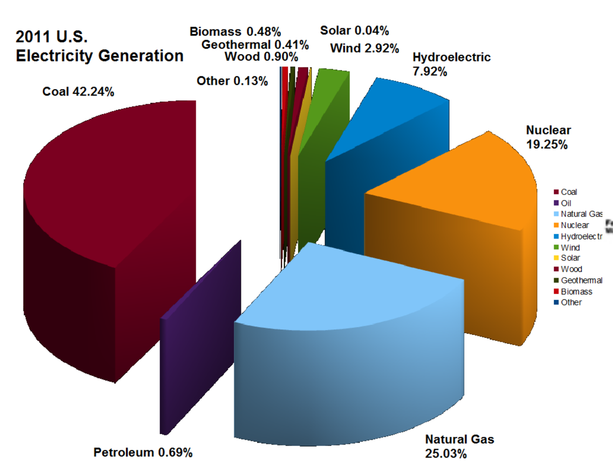


Figure 1: Motivation behind this project

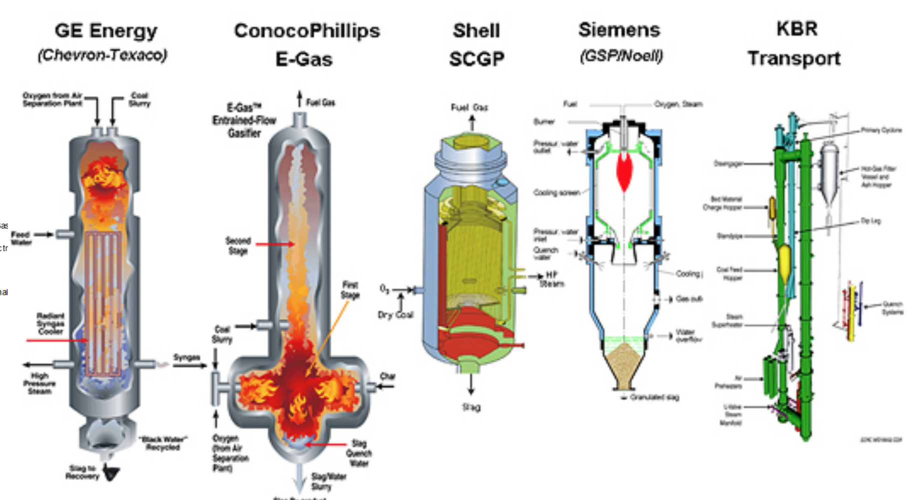


Figure 2: Potential uses for the "smart parts"

Methodology & Materials

EBM Manufacturing Process:

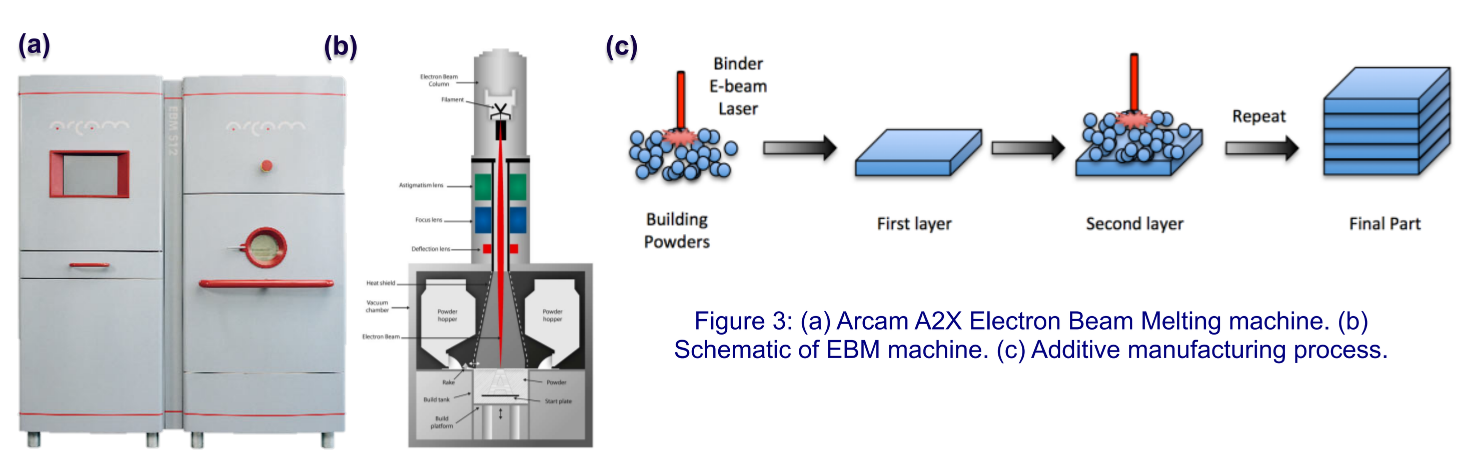


Figure 3: (a) Arcam A2X Electron Beam Melting machine. (b) Schematic of EBM machine. (c) Additive manufacturing process.

Piezo Sensing Mechanism:

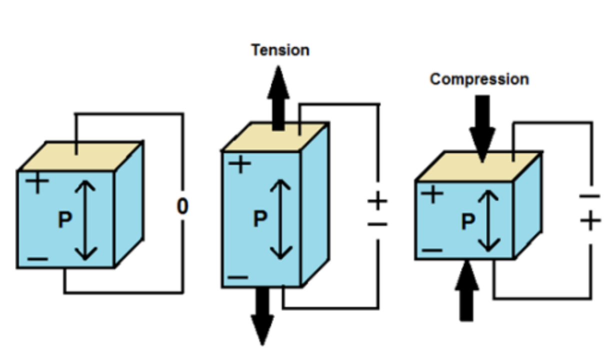


Figure 4: Piezoelectric effect, used to sense strain, vibration, and pressure. (a) no voltage, thus no induced strain or vice-versa. (b) Voltage/Tensile strain relation. (c) Voltage/Compressive strain relation.

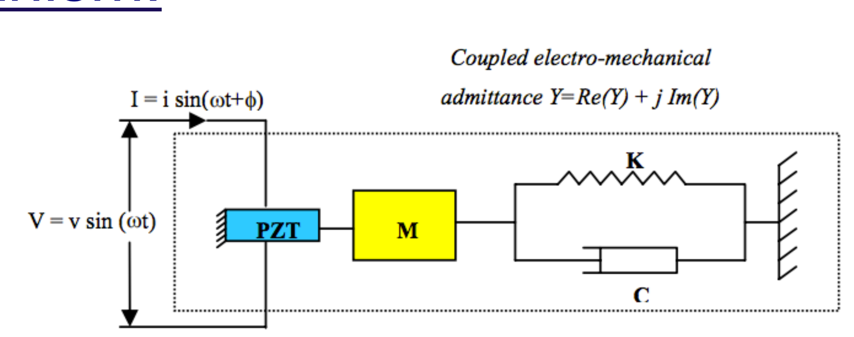


Figure 5: Model of a PZT driven dynamic structural system.

Smart Part fabrication:

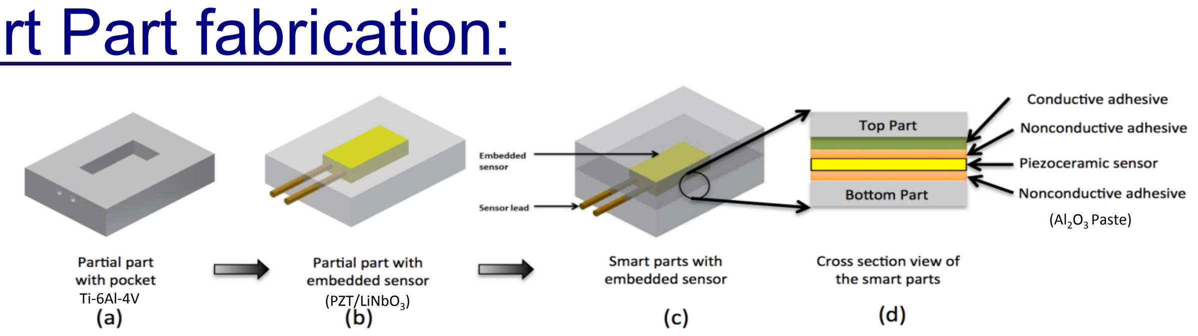


Figure 6: "Stop and go" process for smart part fabrication. (a) Partial part with pocket for the sensor. (b) Sensor has been embedded into the pocket, and nonconductive adhesive has been applied. (c) Complete fabrication of the smart part with all the internal components completely enhoused and protected. (d) Cross-section schematic view of the smart part.

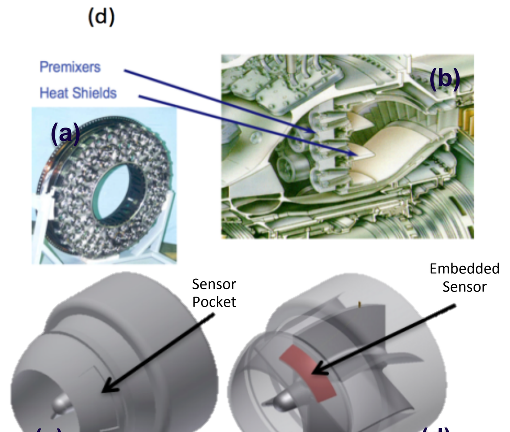


Figure 7: Schematic for "Smart Premixer" with embedded sensor. (a) heat shields. (b) Schematic of Premixer's location in Turbine. (c) Additive manufactured Premixer with pocket. (d) Smart Premixer with embedded sensor.

Results

Characterization

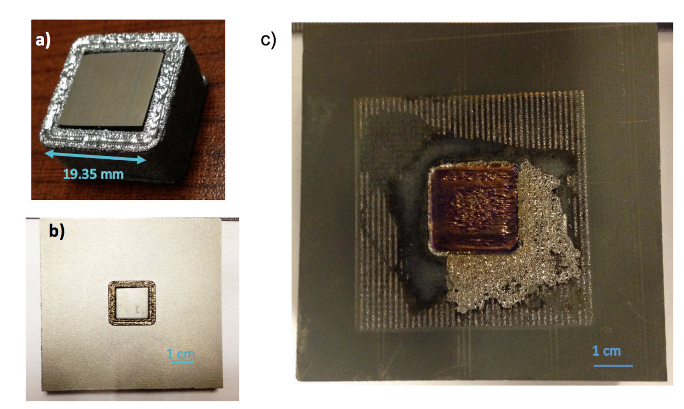


Figure 8: Fabricated "Smart Parts", (a) piezoceramic sensor and insert part, (b) bottom part press fitted in the mast plate, and (c) fabricated "smart part".

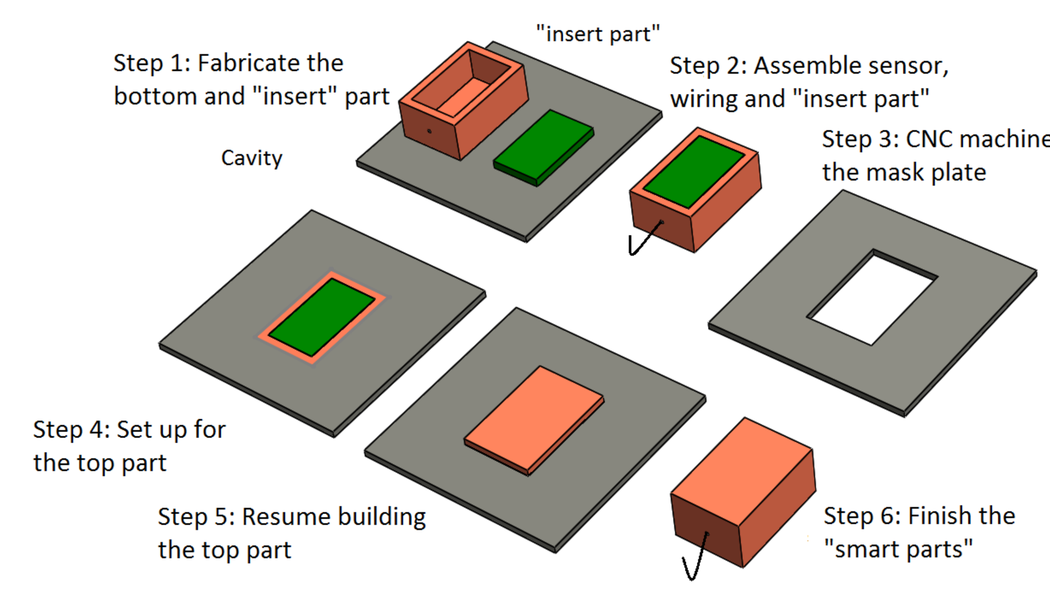


Figure 9: Schematic of "stop and go" process during additive manufacturing.

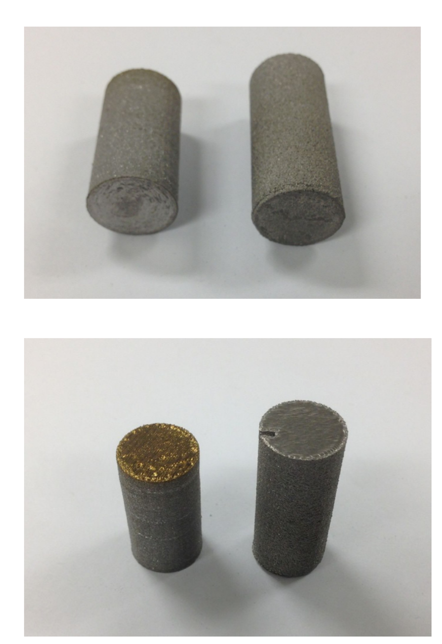


Figure 10: Cylindrical samples for material characterization.

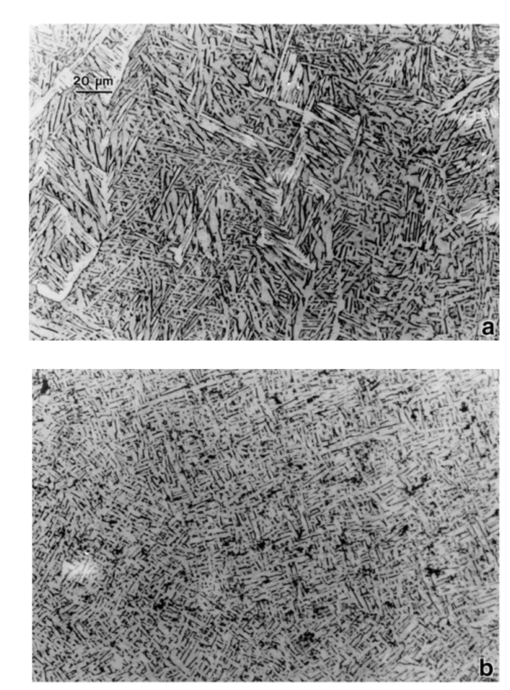


Figure 11: Metallographic images for top and bottom section of Ti-6Al-4V. [1]

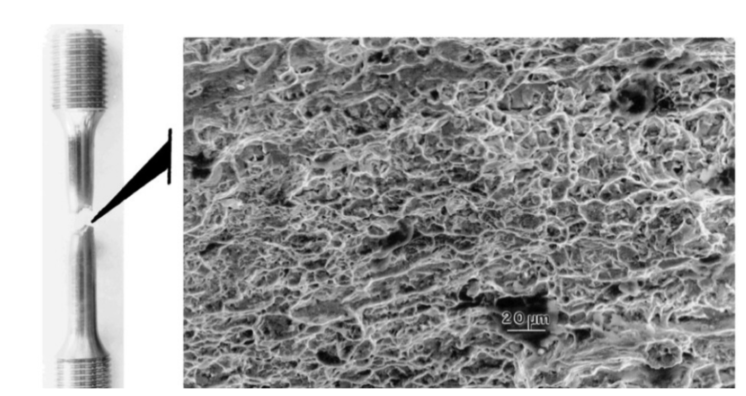


Figure 12: Cross section at fracture of tensile test sample of Ti-6Al-4V.

Simulation:

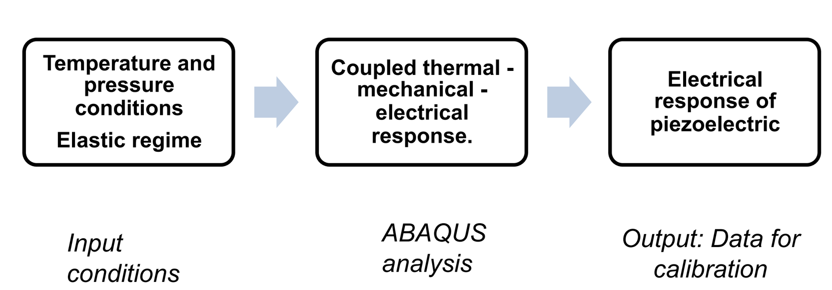


Figure 13: Conceptual design.

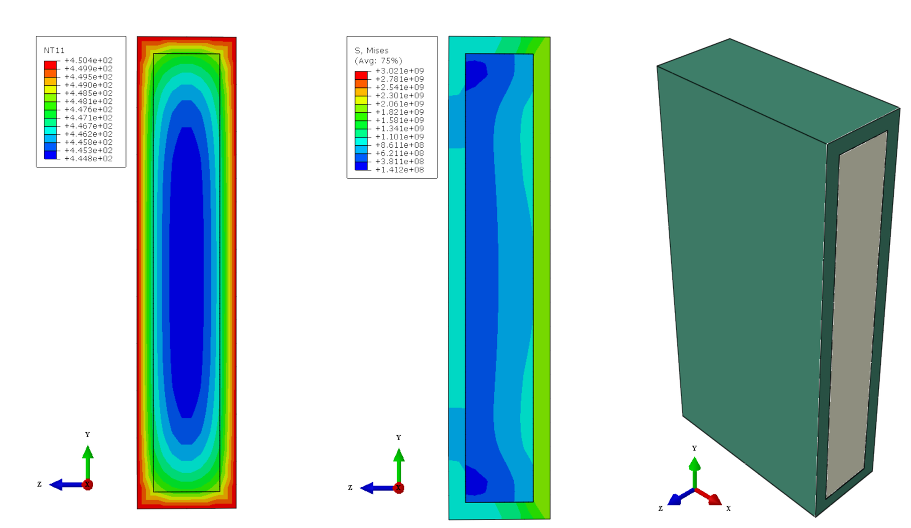


Figure 14: 3D simulation of piezoelectric ceramic and alumina coating (right). Results of temperature distribution (left) and von misses stress (middle)

High-Temperature Wiring:

Table 1: The chosen wiring elements, Platinum and Titanium properties, are compared to Copper.

Wiring Material	Melting Point	Electrical Resistivity (at 20 °C)	Elongation at Break
Platinum	1768.3 °C	105 nΩ·m	35%
Titanium	1668 °C	420 nΩ·m	54%
Copper	1084.62 °C	16.78 nΩ·m	60%

Mechanical Testing

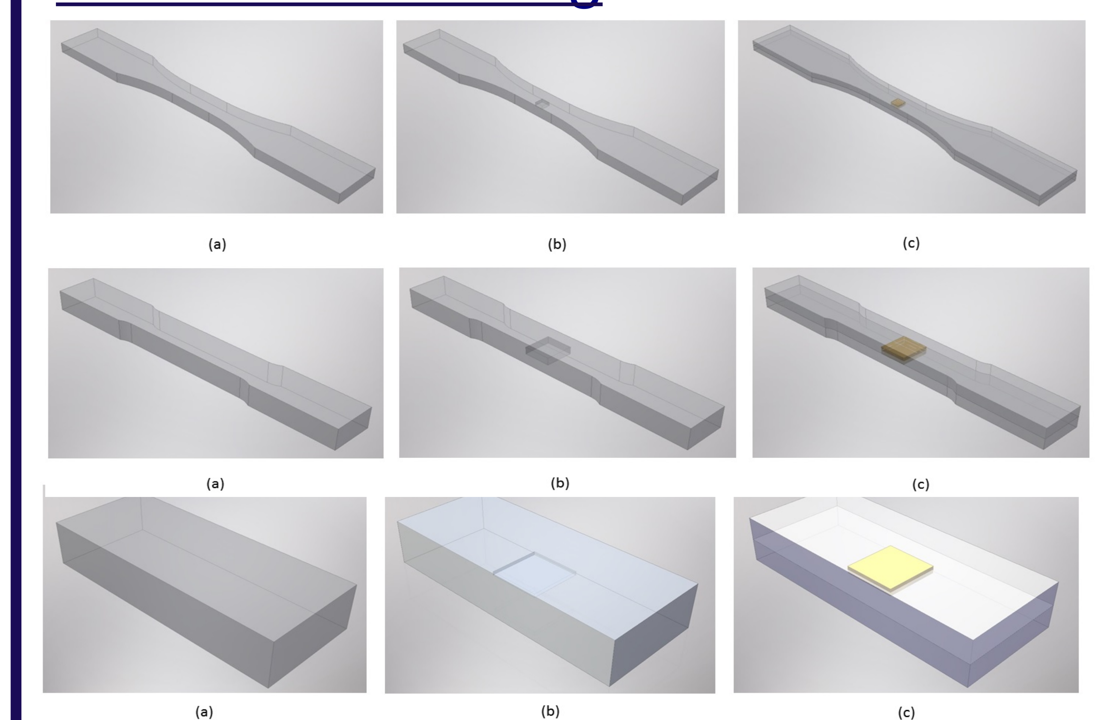
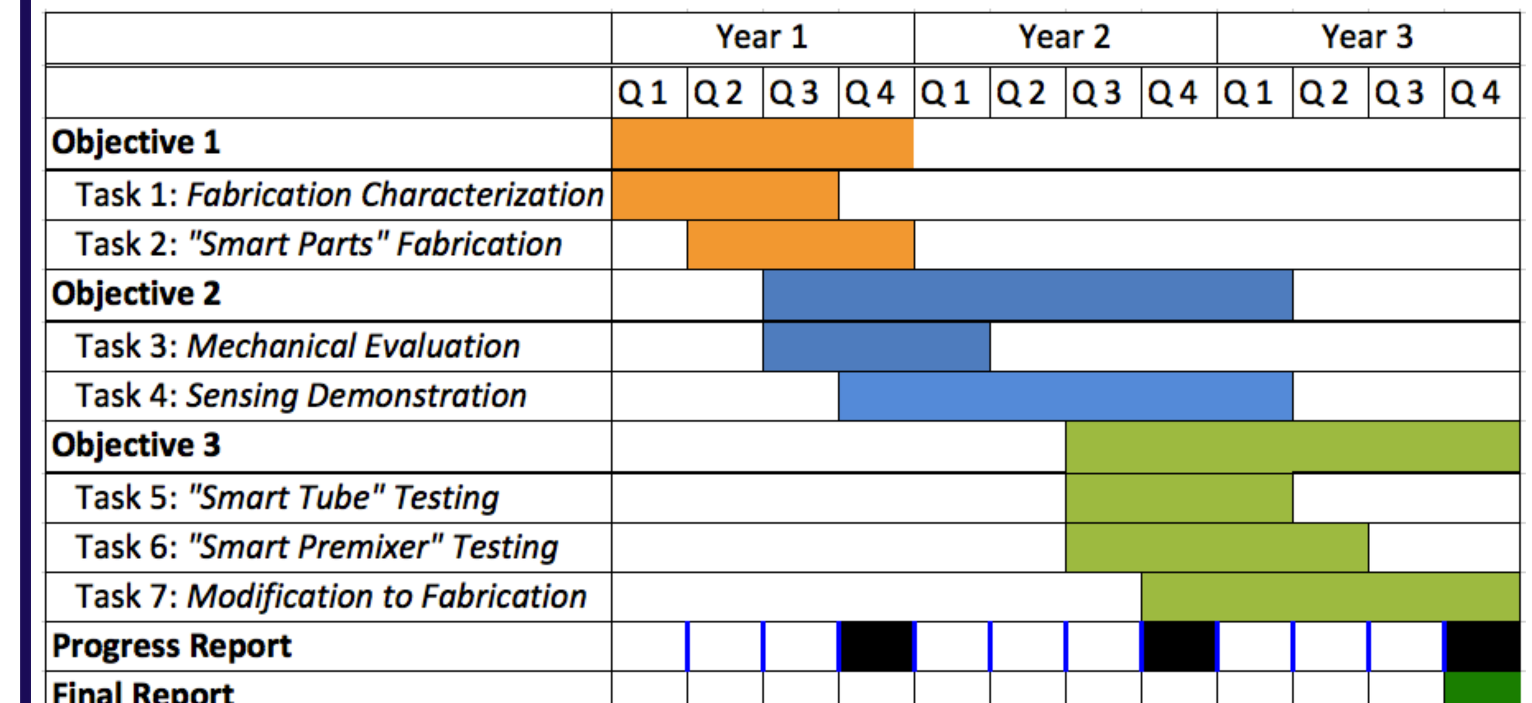


Figure 13: Samples for, tensile test (top), fatigue test (middle), three point bending test (bottom). (a) Test sample without pocket or sensor, (b) with pocket for the sensor, (c) with embedded sensor in the pocket.

Future Work

- Perform mechanical testing.
- Evaluate the bonding strength of alumina paste as bonding agent.
- Assessment of sensing parameters before and after fabrication.



Student Involvement

Acknowledgements

- The authors acknowledge the financial support for this work by the DOE - National Energy Technology Laboratory. Award Number:DE-FE0012321.

1. Gaytan, S.M., et al., Advanced metal power based manufacturing of complex components by electron beam melting. Materials Technology: Advanced Performance Materials, 2009. 24(3): p.180-190.
2. Li, X., et al., Fabrication and characterization of porous Ti6Al4V parts for biomedical applications using electron beam melting process. Materials Letters. 2009. 63(3-4): p. 403-405