Fluid Velocity Sensors Made By Thermal Spray

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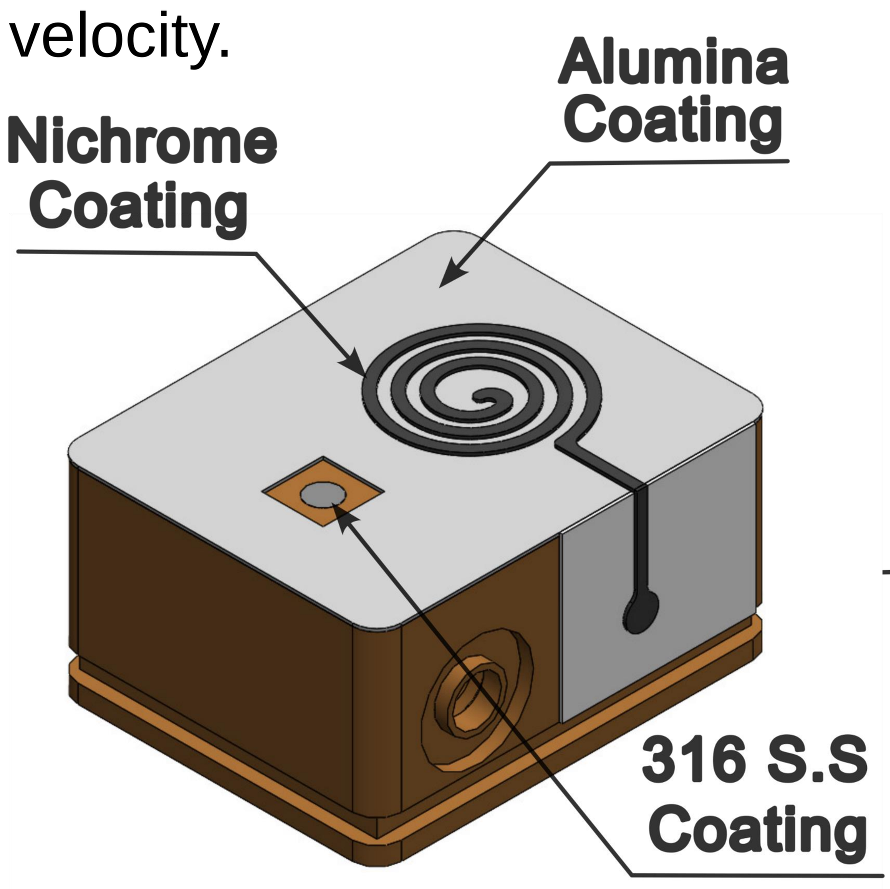
Motivation

- Fluid velocity sensors, used in many industry applications, must be:
  - Easy to install on metal surfaces
  - Robust and cost-effective
  - Non-obstructive

Objective: Fabricate fluid velocity sensors that can operate in harsh environments.

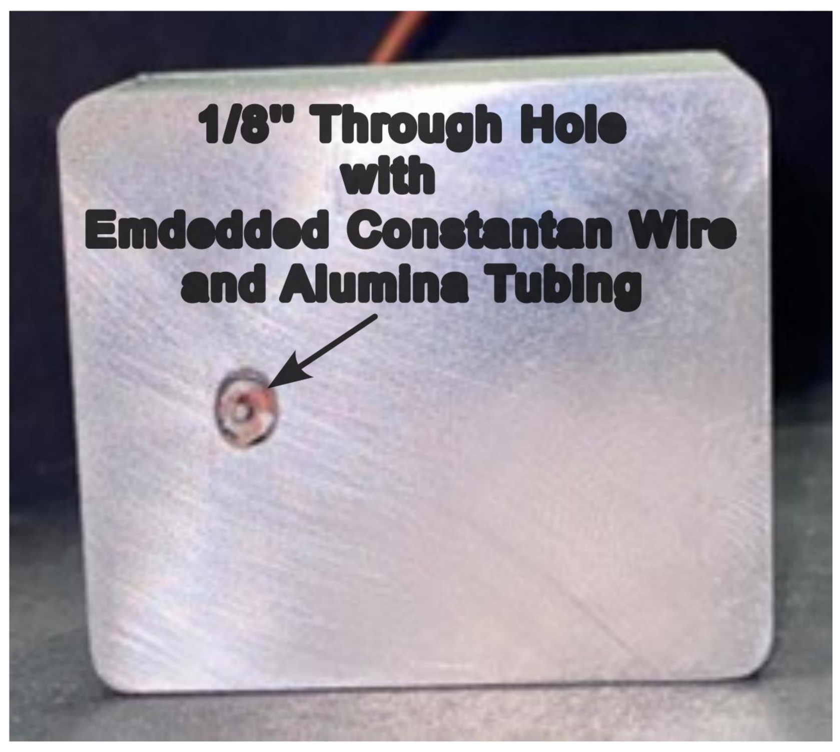
Sensor Principle

- Spray Nichrome (using a wire arc system) through a polymer mask to make a spiral heater coil on an insulating alumina layer (plasma sprayed),
- Insert an insulated Constantan wire vertically through the stainless-steel substrate and spray a steel coating to short the tip of the wire to the substrate. This forms a Constantan-steel thermocouple junction.
- Apply voltage pulses to the heater and measure the cooling rate of the substrate using the thermocouple. Calibrate the time constant for cooling as a function of fluid velocity.

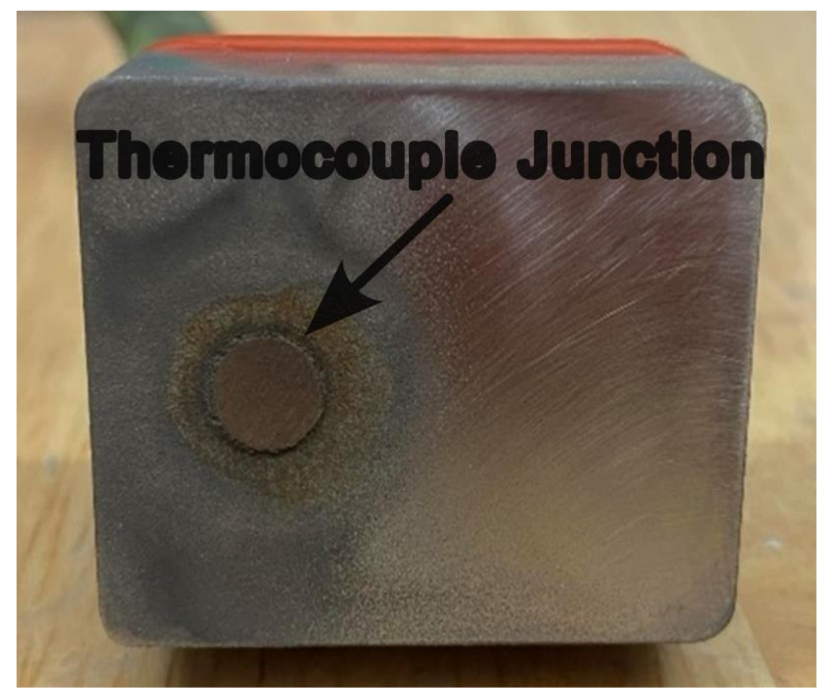


Fabrication

Step 1: Insert Constantan wire in alumina tubing through substrate

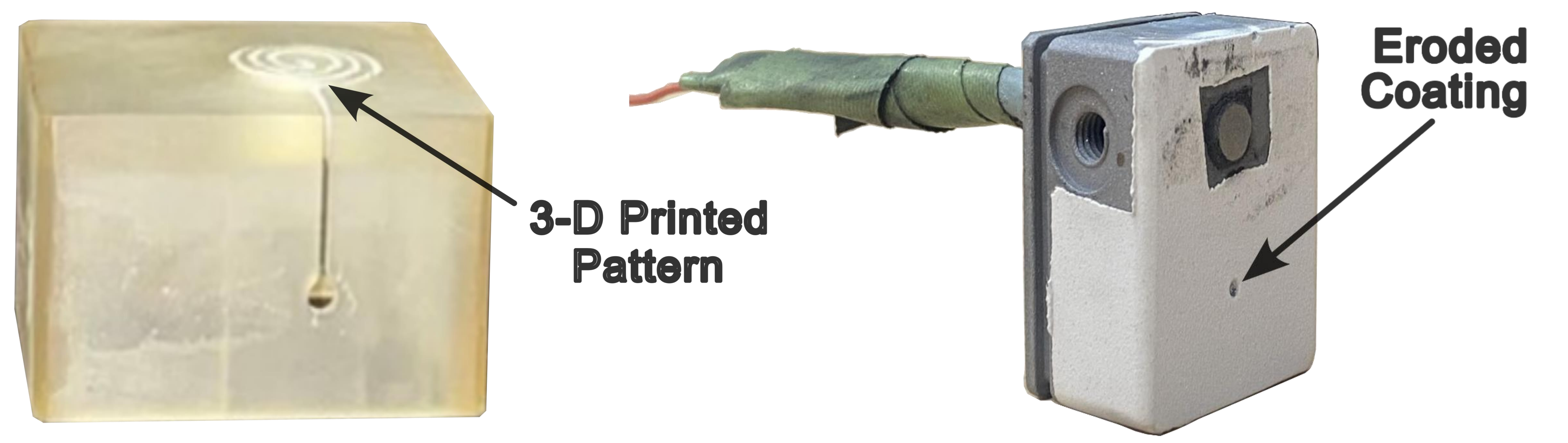


Step 2: Grit blast substrate, spray 316 stainless steel to form thermocouple junction and polish.

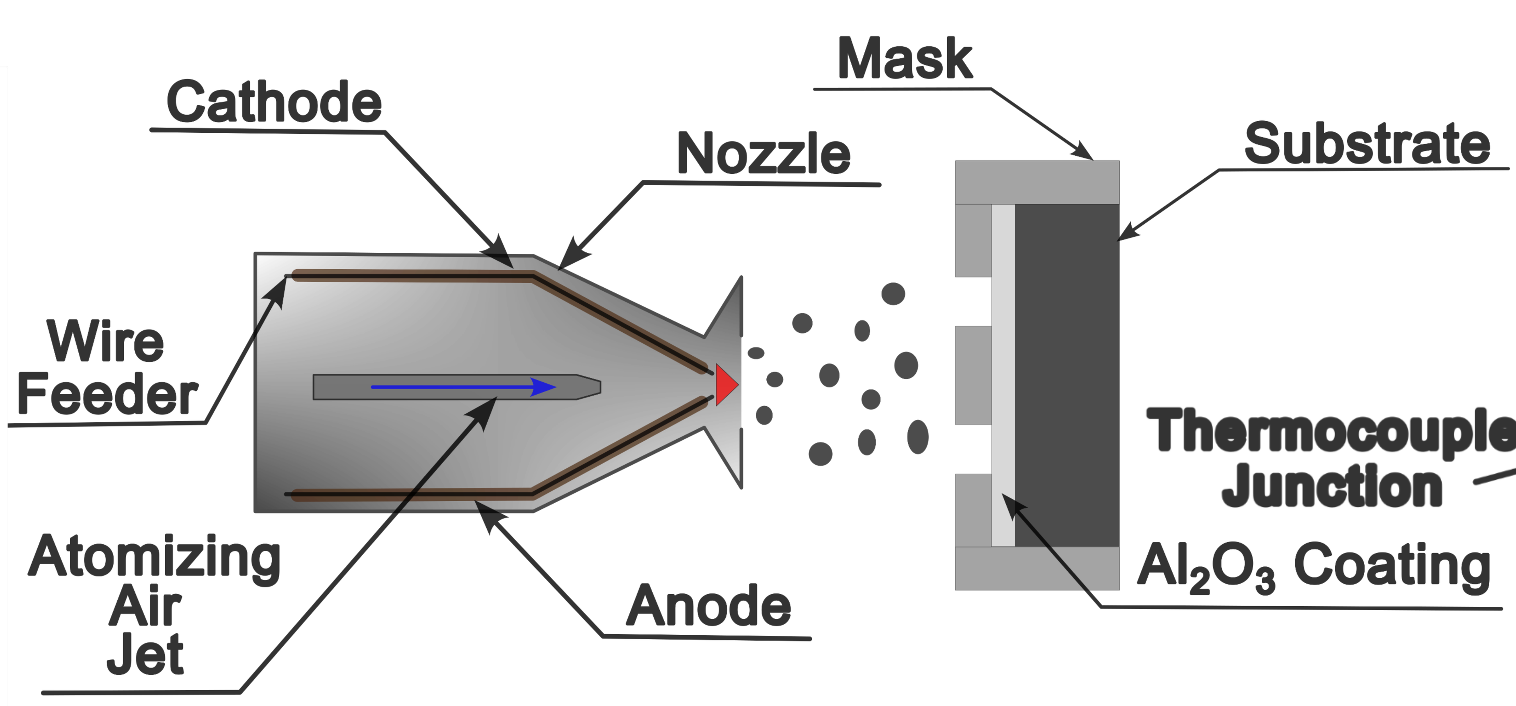


Step 3: 3-D print high temperature polymer mask.

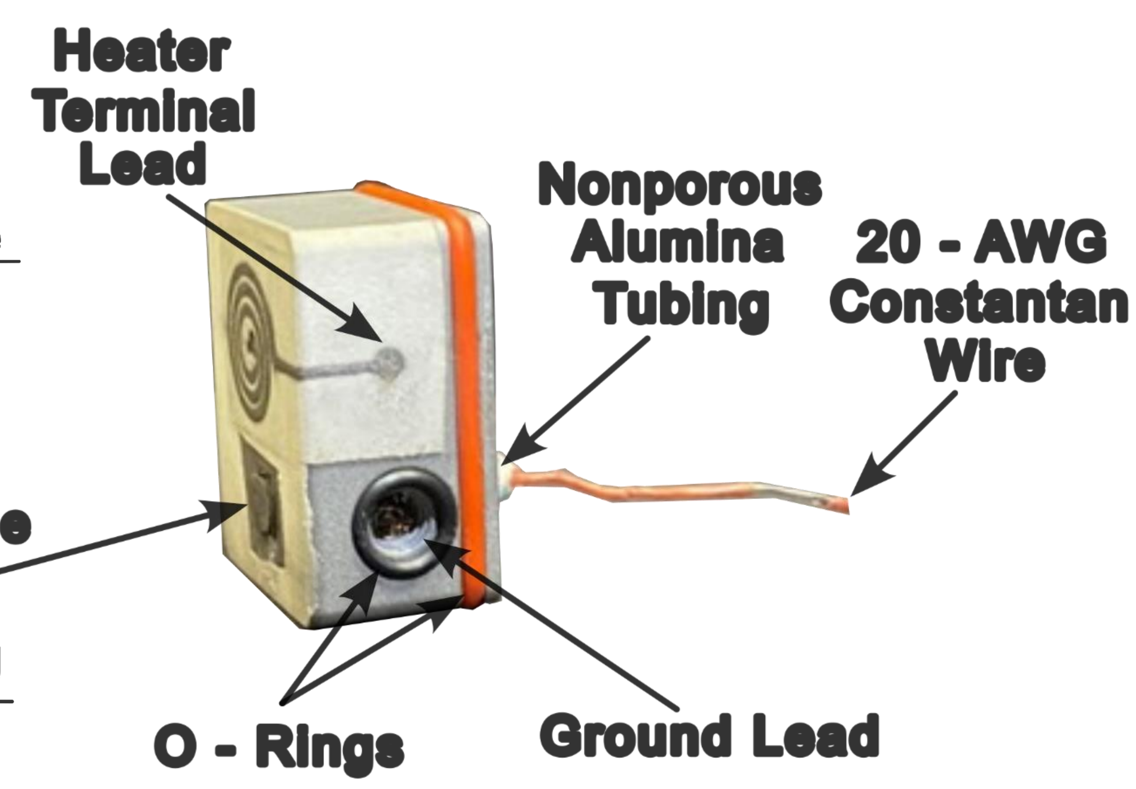
Step 4: Coat Alumina layer and erode insulation at one point to ground end of heater coil



Step 5: Coat Nichrome using Twin Wire Arc Spray with mask mounted on substrate.

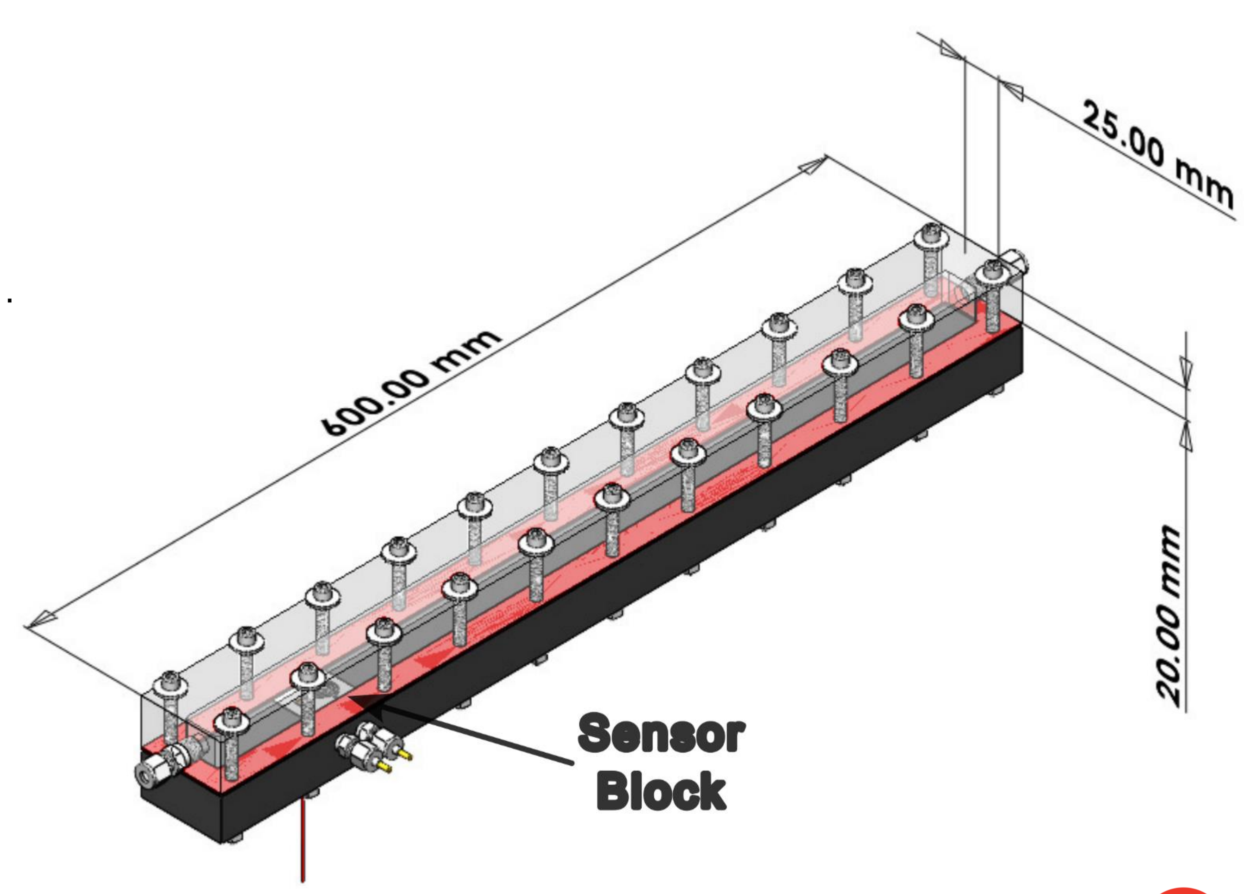


Step 6: Finished velocity sensor. Heater resistance 22 Ohms.

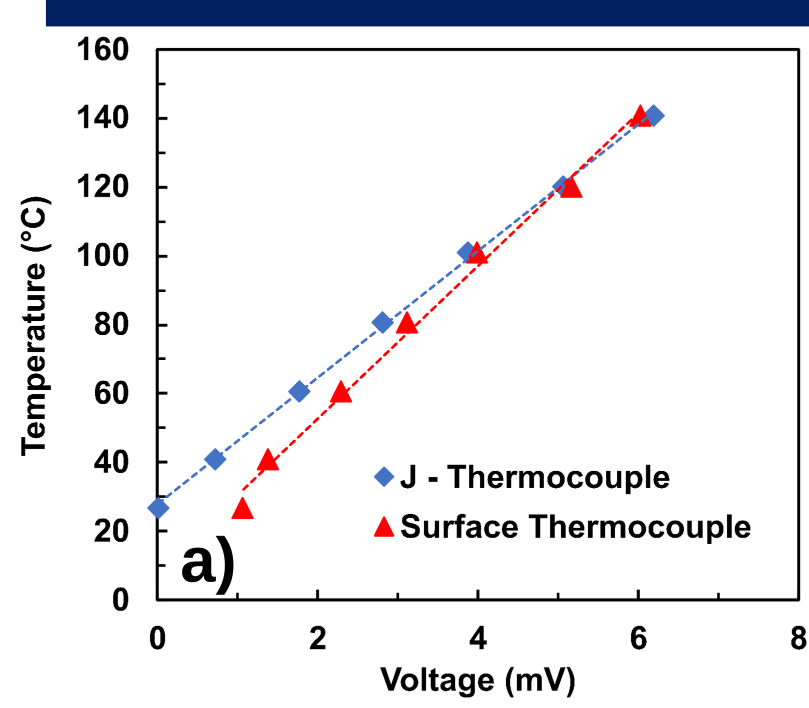


Test Channel

- The block with the sensor was placed in a recess near the end of a fluid channel, with its face flush with the channel wall. The flow was fully developed when it reached the sensor.
- Compressed air was passed through the channel with average velocities from 0.5 to 4.5 m/s by varying the inlet pressure from 7 kPa to 207 kPa.

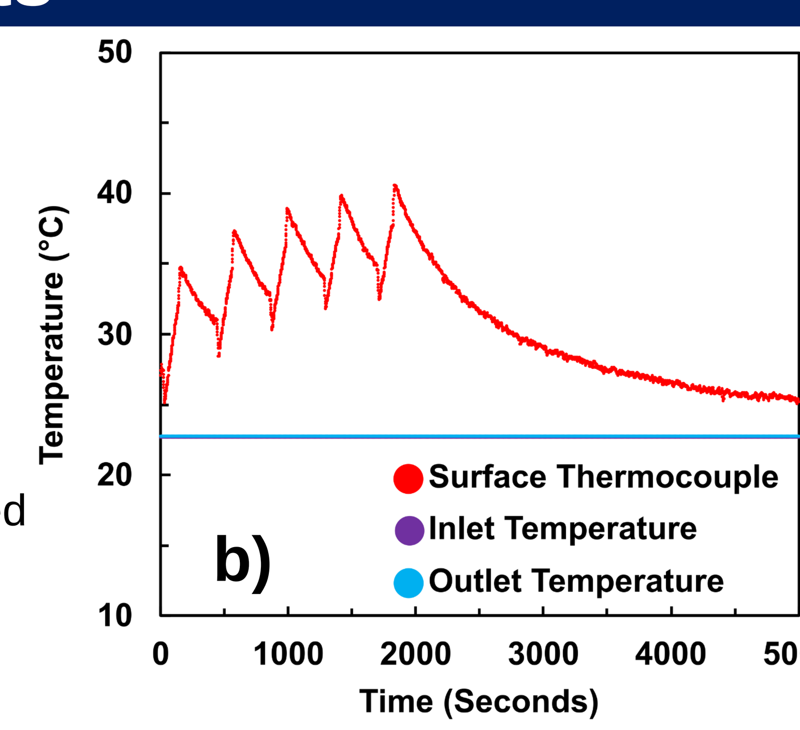


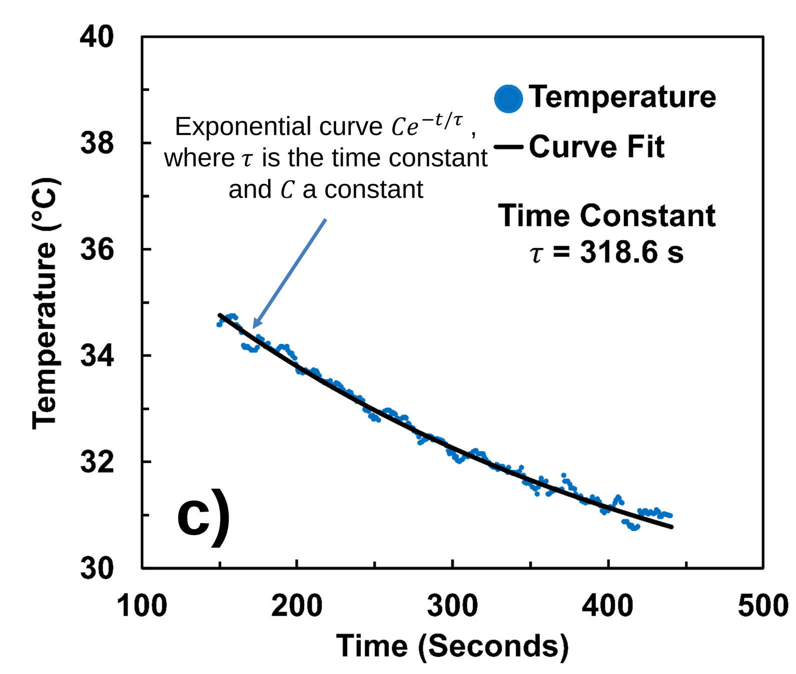
Experimental Results



a) Voltage output of sprayed Steel-Constantan thermocouple, compared with Iron-Constantan (J type) thermocouple

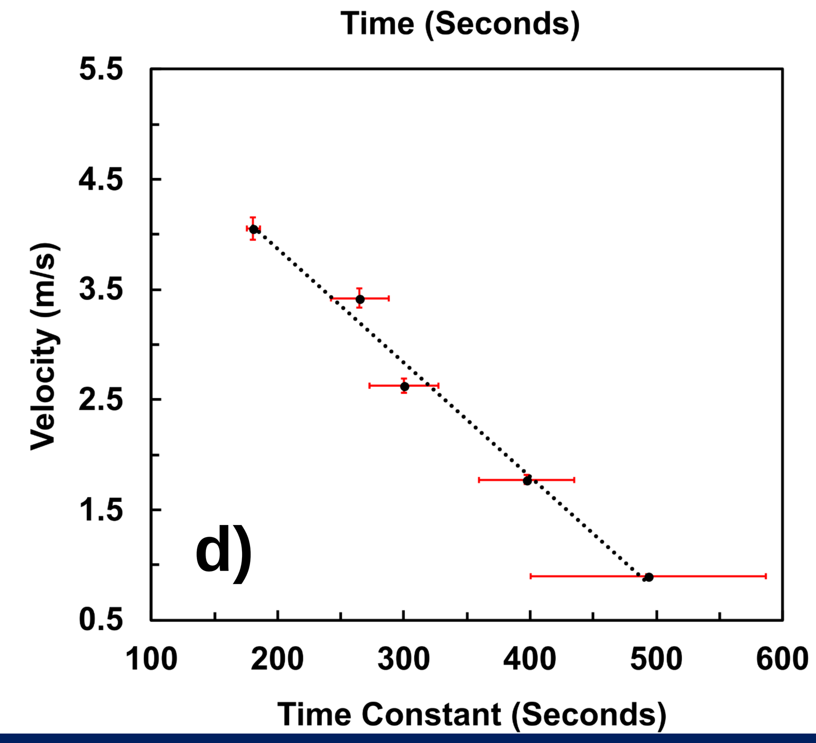
b) Surface temperature variation with 5 successive 10.9 V (5.4 W) pulses applied to the heater for 2 min, and then cooled for 5 min





c) Temperature variation during cooling with an exponential curve ($Ce^{-t/\tau}$) fitted through it

d) Air velocity as a function of time constant



Summary

- Thermal spray was used to fabricate a velocity sensor.
- Fluid velocity is calibrated as a function of the surface cooling rate.
- The sensor is unobtrusive, easy to fabricate, and can tolerate harsh environments.

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