Methods for Integrating a Controller onto a Ceramic Reaction Board

TECHNICAL AREA:

The present disclosure relates to controlling a ceramic PCB board designed for exothermic or endothermic reactions.

BACKGROUND:

Many types of reactors have been built and tested to create exothermic reactions. These reactors range from wet cells using electrolysis to solid state reactors to plasma reactors. Each reactor type requires specific materials, activation procedures, and triggering methods. Each reactor has specific requirements for pressure, voltage, temperature, and other control conditions to create and sustain the reaction. The feedback and control can become automated and put onto a control board that lives with the reactor. The control board can also report status information back to a central office.

Due to the unique conditions of the exothermic reactors, a traditional PCB with integrated controllers cannot be used and survive with the reactor. Typically, PCBs and their ICs are limited to about 70°C, but exothermic reactors can be expected to require temperatures beyond 300°C. Therefore, the control board will need to be made of materials that can withstand higher temperatures, such as ceramic.

Other exothermic reactor specific materials can be integrated onto the ceramic control board, too. Many reactors require materials such as palladium or nickel, which are not found on normal PCB applications. The reactor materials, as well as the controlling IC logic, can be integrated onto the same ceramic backplane to create an all-in-one controlled and monitored exothermic reactor.

EXISTING TECHNOLOGIES & PROBLEMS WITH EXISTING TECHNOLOGIES:

PCB design and fabrication are very well understood processes. However, PCBs are typically built on FR4 and uses integrated controllers that have temperature limits around 70°C. Sometimes, industrial grade PCBs and ICs are used, but the temperature limit still exists well below that required by exothermic reactors.

PCBs also use materials such as silicon and copper. They do not integrate the materials specific to an exothermic reactor onto the PCB to create a complete exothermic reactor solution, including monitoring and control.

Most exothermic reactors are also monitored and controlled manually, where human intervention is required to adjust the control parameters such as pressure or voltage in order to create and sustain the reaction. Once the feedback mechanisms are well understood, these can be automated and integrated onto the control board.

SUMMARY OF THE PROPOSED SOLUTION AND THE ADVANTAGES THE PROPOSED SOLUTION PROVIDES:

The proposed solution greatly simplifies and automates exothermic reactors. It will:

- Make manufacturability of exothermic reactors easier by leveraging known PCB fabrication techniques
- Integrate the reactor materials with feedback and control for an integrated, all-in-one solution
- Automate feedback and control mechanisms to create and sustain the reaction. This will be better control than a manual human and require no human intervention
- Monitoring data can be sent back to a central office for decision making, such as safety, efficiency, and needing to manually service

DETAILED DESCRIPTIONS OF THE PROPOSED SOLUTION AND FIGURES:

An exothermic reaction can be controlled and monitored by several factors including pressure, voltage, temperature, and gas type. All of these feedback systems tend to be controlled manually in current systems. Once the feedback relationship is well understood, then the monitor and feedback control can be transitioned to an automated system and integrated onto a control board that lives with the reactor. In addition to monitoring and feedback control, the integrated controller can also report status information back to a central office. The board can also contain the materials and spatial relationship required for the reactor itself (see US Provisional Application No.: 62/347369).

1. Example Reactor + IC

This embodiment shows a fabricated circuit board where the materials required for the reaction are on one area of the board, and the materials and logic required to monitor and control the reaction are on a different area of the board.

On the reaction side of the board, unique materials for the reaction, such as Palladium, Nickel, or Platinum, may be used to create traces. The traces may require specific geometries in order to induce magnetic fields. More detail about this side of the board can be found in US Provisional Application No. 62/347,368.

The board is made of layers of ceramic, or another insulating material that can withstand very high temperatures (up to 450°C), instead of using traditional FR4 or similar materials. Both the right and left sides of the board use the same insulating material.

The logic area of the board is separated from the reaction side because the chips still have temperature limits. Extra heat sinks can be added to this side of the board to help disperse heat from the reaction. Water or gas can also be flowed across the reaction side of the board to take heat away, not only to use the heat for energy, but also to help protect the logic area of the board.

The logic area of the board can be designed much like any other control and monitoring board. Off-the-shelf integrated ICs or ASICs can be used for the design. The control and monitoring board integrates with sensors to actively monitor things like pressure, voltage, and temperature in real time. Based on the programmed feedback loop, the control logic will increase/decrease pressure, change gases, apply various voltages, and/or turn heaters on/off. These actions will create and then sustain the exothermic reaction.

The logic/control side of the board will also be able to determine if safety requirements have been violated, so it can immediately kill the reaction. It can also be used to send PMFL (Performance Monitoring and Fault Locator) back to a central monitoring system.

2. Example Reactor + IC for Wet Cells

In this example, the reactor+logic board is used in an electrolytic cell instead of a dry reactor. There are 2 key differences to the wet cell board from the dry reactor board:

1) The logic area of the board must be coated in a water-resistant conformal coating to protect the ICs.
2) Since temperature requirements are lower in a wet cell, the reaction area of the board and the logic area of the board can be closer or more integrated.

Wet cells typically have lower temperature requirements. Therefore, it is less important to keep the reactor area and logic areas of the board separated. However, since the board will be submerged into an electrolyte solution, a water resistant conformal coating must cover any control and monitoring logic on the board.

The board should still be made out of a ceramic material on the backplane, due to FR4's lower temperature requirements. The logic side of the board has the same control and monitoring requirements as the logic side of a dry board.

3. Example Full Block System Design + Central monitoring and control

The reactor + control & monitoring board will need to interact with sensors, though many known technologies can be integrated on the board, and the control logic will be integrated on the board.

Communication protocols such as Ethernet, WiFi, or Bluetooth can be integrated on the board for communication back to a central monitoring station or to interface with monitor and control devices. Other well-known protocols, such as I2C, SPI, or other known technology/devices can be integrated for control and monitoring. The logic side of the board can be treated like other PCBs, except with the different backplane material to withstand higher temperatures.

Other devices, such as temperature sensors, pressure sensors, and valves will need to be used to monitor the reaction, though the control board will receive all sensor information and make decisions on how to control valves, MFCs, or other equipment. When appropriate, some elements to be monitored, like voltage and current, can be integrated on board instead of needing a third party sensor.

4. Example Feedback System

This is one embodiment of how the control and monitoring side of the board will monitor and make decisions to create and sustain the exothermic reaction.

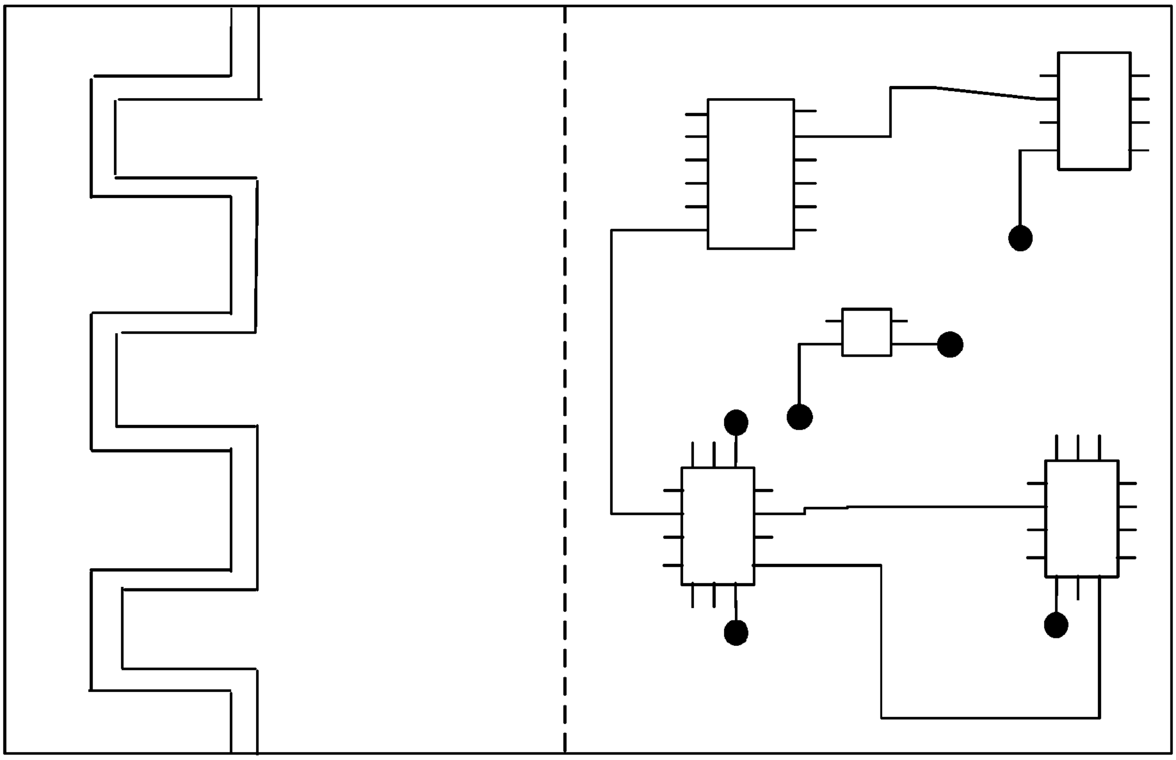
To begin the reaction, the monitoring board will see if the reactor is at room temperature so that it can flow the appropriate amount of gas into the reactor. Since Deuterium can be absorbed, the board will monitor the pressure after flowing in Deuterium to determine if additional gas needs to be added. Once the pressure is stable, then the board will turn voltage on to the heaters to increase temperature.

Temperature will be actively monitored at all times for a runaway reaction. If the temperature ever goes above 400°C, then the voltage to the heaters is immediately turned off. The gas is vacuumed out to attempt to stop the reaction but not hurt the reactor. The runaway condition is reported to the central monitoring system.

Under normal conditions, the temperatures are just checked for stability and then continuously monitored until a user tells the reactor to turn off, for example, with a stop button. At that time, the control board will turn voltage off to the heaters, wait for cool down, and then vacuum out the reactor so that it can be used later.

This is only one example of part of the control and monitoring. Other sensors could be monitored, PMFL reports generated and sent to central control, and various levels of the reaction can be monitored or sustained.

Figure 1.



Reaction Side

Logic/Control & Monitoring

Figure 2.

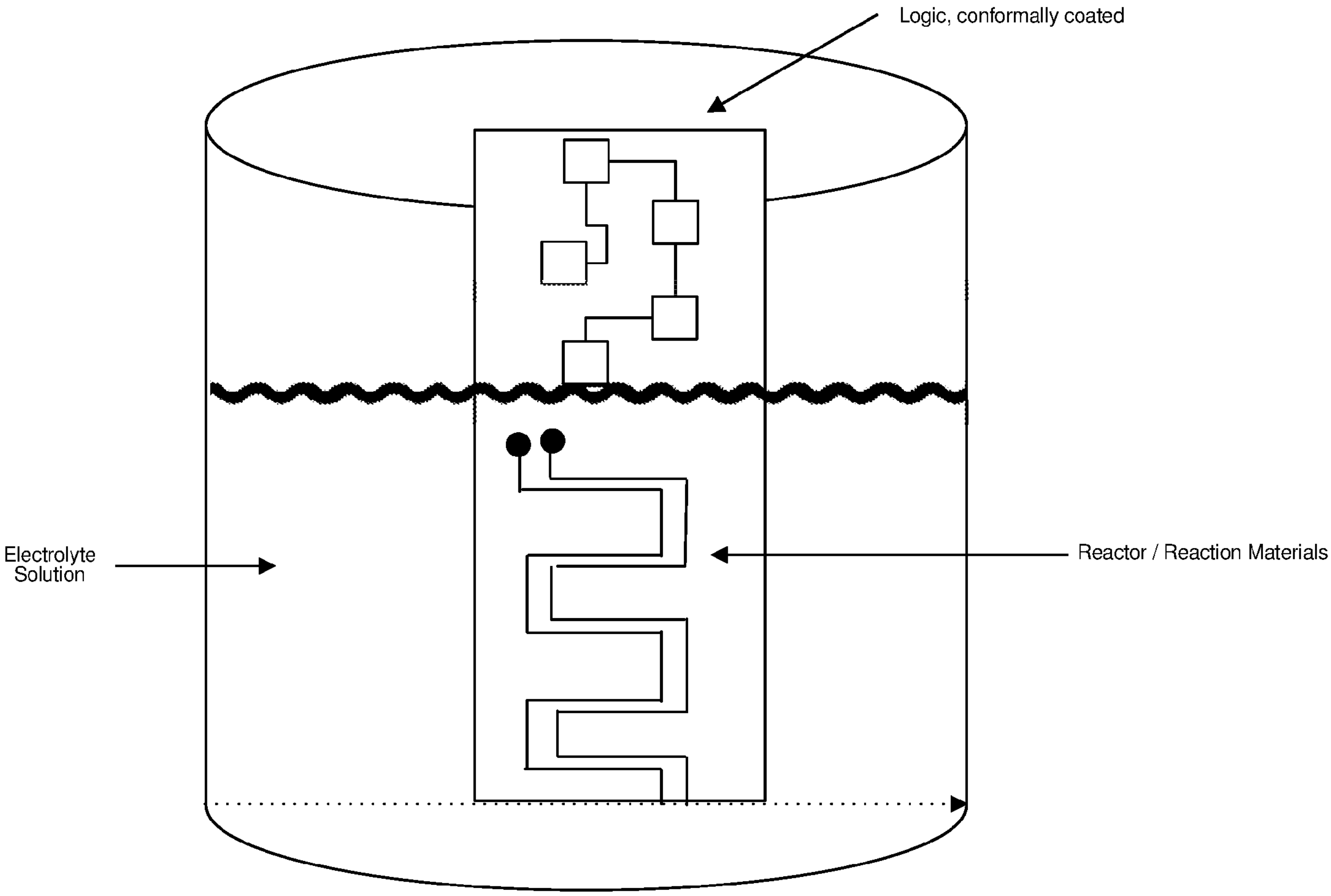

Logic, conformally coated
Electrolyte Solution
Reactor / Reaction Materials

Figure 3.

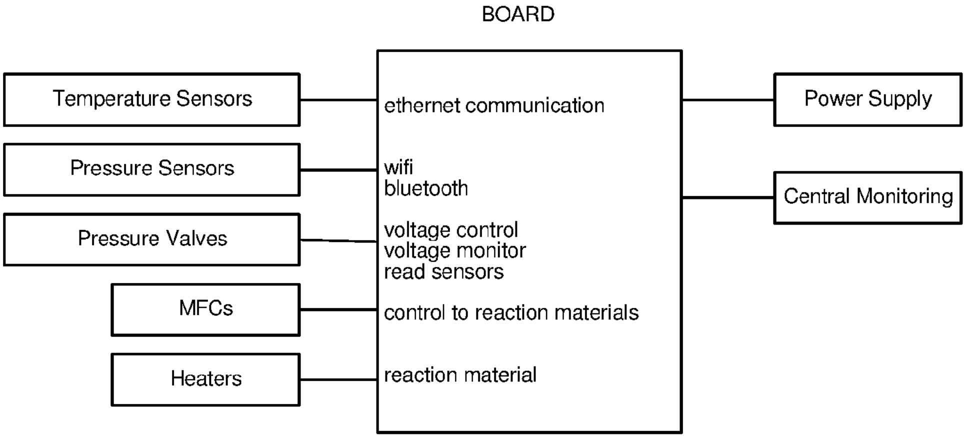
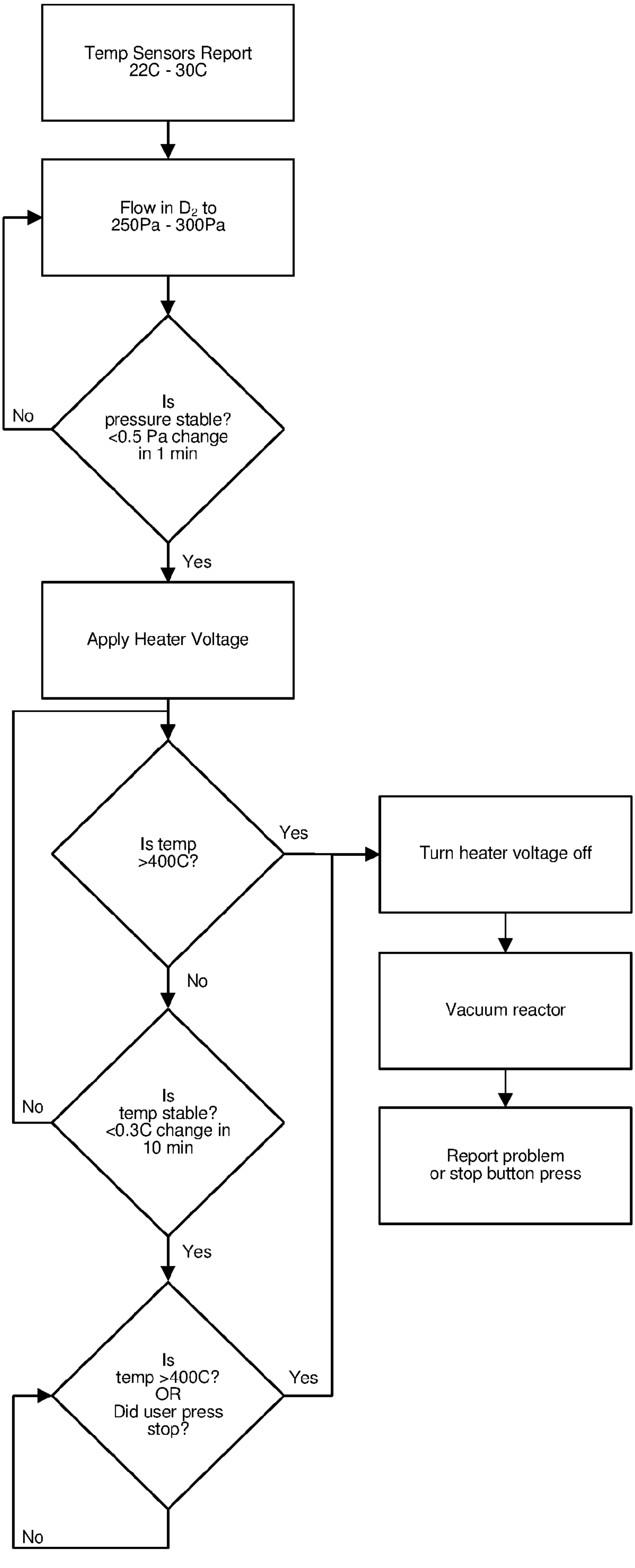
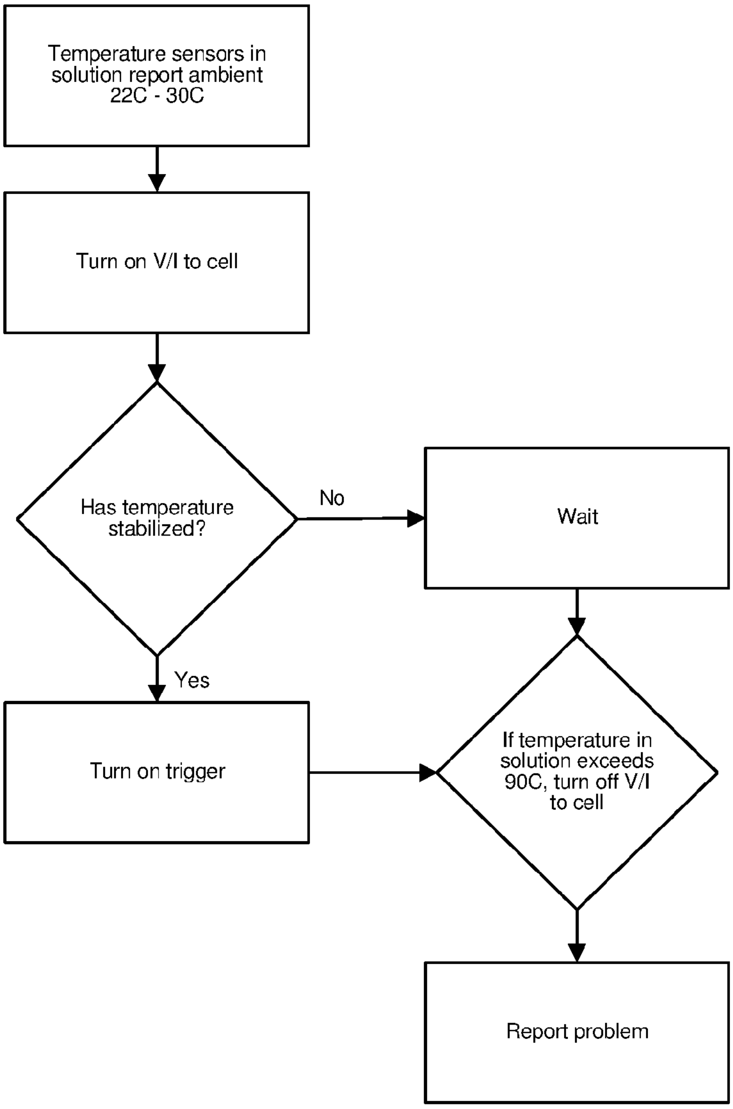

BOARD
Temperature Sensors
Pressure Sensors
Pressure Valves
MFCs
Heaters
ethernet communication
wifi
bluetooth
voltage control
voltage monitor
read sensors
control to reaction materials
reaction material
Power Supply
Central Monitoring

Figure 4.



Temp Sensors Report
22C - 30C
Flow in D_2 to
250Pa - 300Pa
Is
pressure stable?
<0.5 Pa change
in 1 min
No
Yes
Apply Heater Voltage
Is temp
>400C?
Yes
Turn heater voltage off
Vacuum reactor
Report problem
or stop button press
No
Is
temp stable?
<0.3C change in
10 min
No
Yes
Is
temp >400C?
OR
Did user press
stop?
Yes
No

Figure 5.


Temperature sensors in solution report ambient 22C - 30C
Turn on V/I to cell
Has temperature stabilized?
No
Wait
Yes
Turn on trigger
If temperature in solution exceeds 90C, turn off V/I to cell
Report problem