9. 학사논문 지도교수: 여 재 익

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9-1. [수치해석|sim.] Numerical analysis of the swirling flame in the gas turbine combustor (남재현, Jaehyun Nam)

- Swirling flame in the gas turbine combustor
  - Highly turbulent and complex flow structure
  - Used for the stabilization of flame
  - Possibly trigger combustion instabilities

- Simulation of the swirling flame in the gas turbine combustor requires
  - Large-eddy simulation (LES) turbulence eddy-viscosity model
  - Finite rate chemistry or flamelet reaction model
  - Three-dimensional modeling based on unstructured mesh
  - Parallel computing

- Investigation of the thermochemical process from simulation
  - Identify the qualitative and quantitative details of swirling flame
  - Parameterize the mixing and reacting process
  - Clarify the cause of the combustion instability
  - Investigate the effects of the numerical method

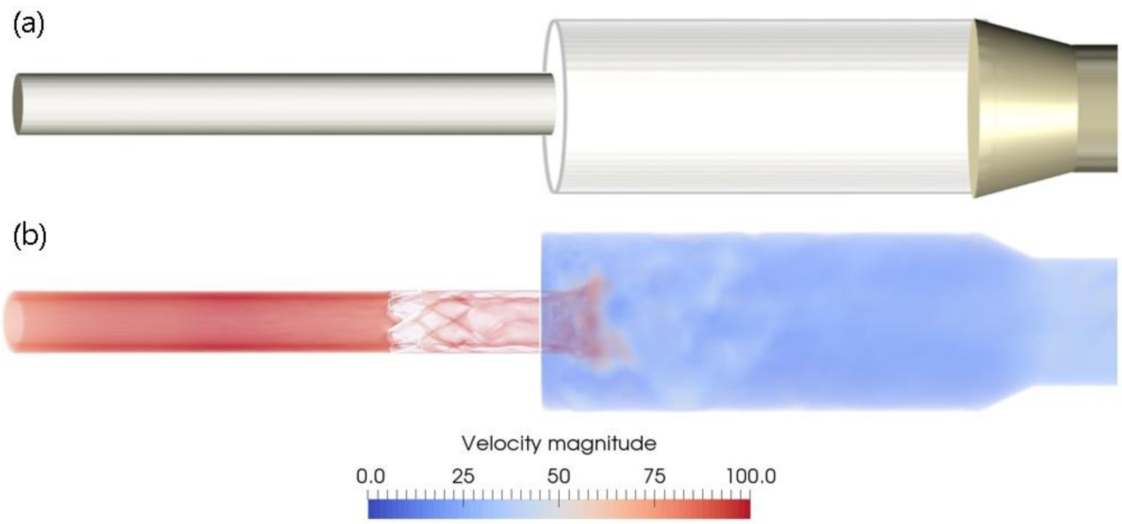

Fig. (a) Schematic of the gas turbine combustor and feedline and (b) LES result of the flow field in the combustor

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9-2. [수치해석|sim.] Multi-phase simulation based on DSC experiment (남재현, Jaehyun Nam)

- representation of the chemical reaction velocity equation
  - For accurate computational simulation of high-energy materials composed of solid or liquid state
  - using the reaction kinetics which can be obtained by experimental data from differential scanning calorimetry (DSC)
  - chemical species variable calculated in the calculation code

- Identifying the characteristics of heat storage material systems based on DSC experiments
  - high computational efficiency of one step chemical reaction
  - very specific velocity expression variable that varies from mass fraction to fraction

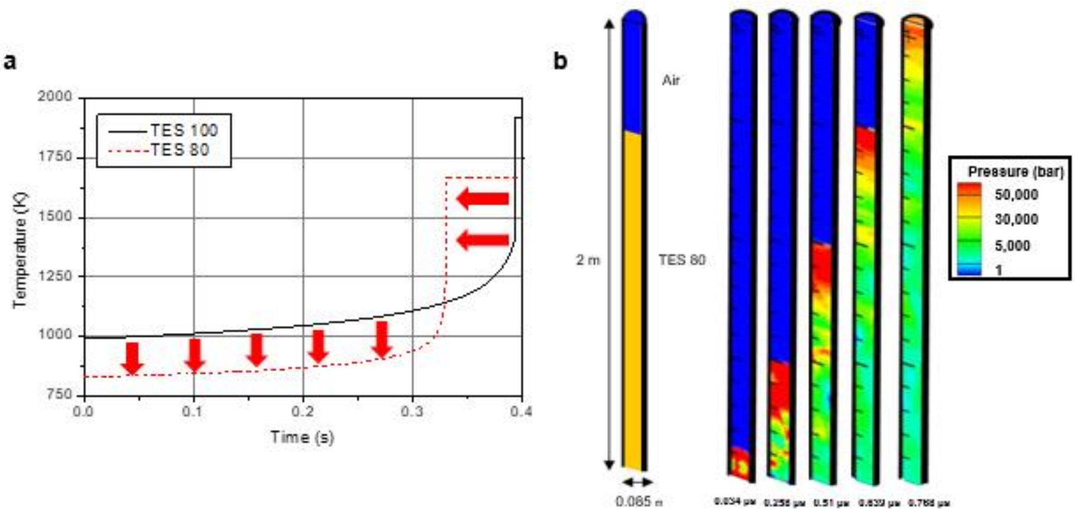

Fig. (a) 0-D simulation based on DSC data and (b) 2-D simulation based on DSC data

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9-3. [수치해석|sim.] Numerical analysis of metalized solid propellants on the meso-scale (최홍석, Hongsuk Choi)

- Metalized solid propellants
  - High energy density
  - Aluminum, boron, and zirconium …
  - heterogeneous properties because of adding plasticizers and metal particles to change mechanical properties or control the combustion rate

- Numerical analysis
  - Melt layer of Solid propellants on the meso-scale
  - In-house CFD tool called hydrocode using the level-set method and the ghost fluid method

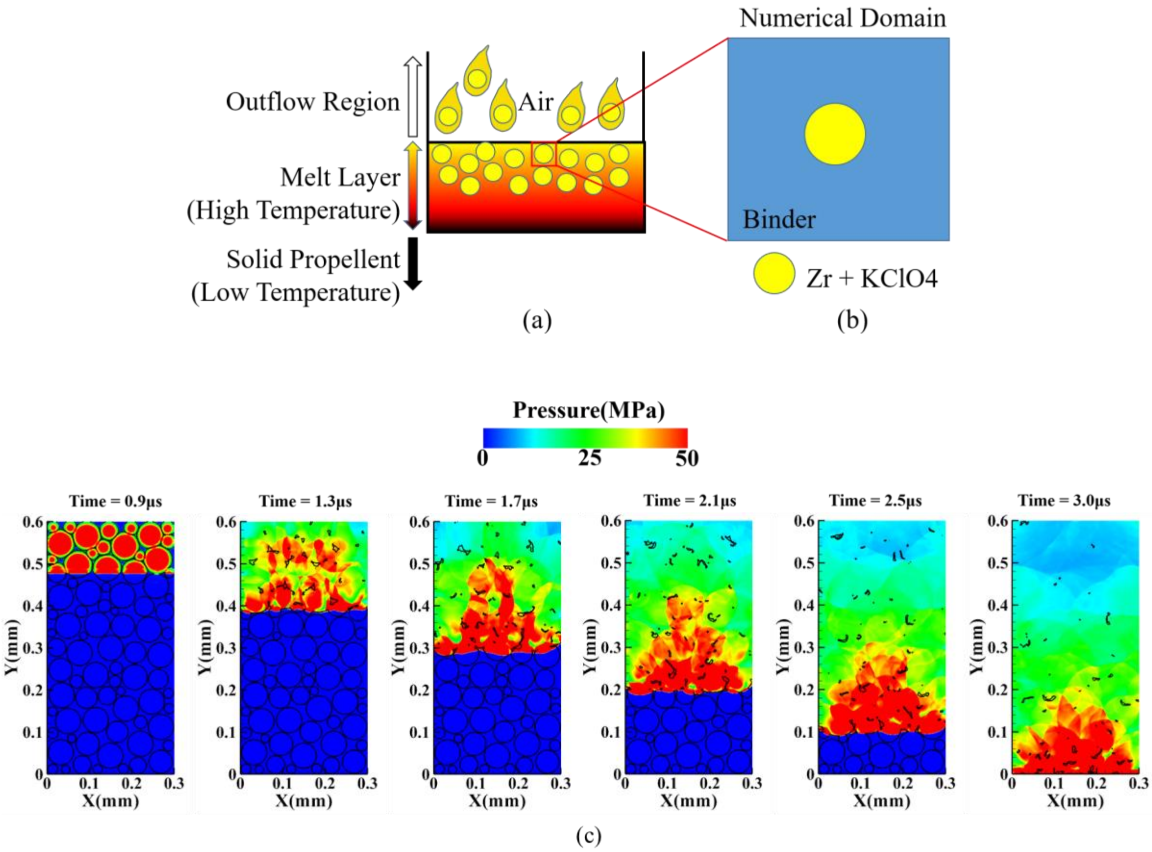

Fig. (a) Schematic of Zr + KClO4 surface burning, (b) Numerical domain, and (c) Zr + KClO4 particle reaction (pressure contour)

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9-4. [수치해석|sim.] Numerical analysis of heat transfer effect in metal and detonation of high explosive via high power laser irradiation (박기성, Gisung Park)

- Heat transfer effect in metal
  - When laser beam is irradiated to metal, heat transfer occurs due to optical energy.
  - Analyze heat transfer using the heat diffusion governing equation.
  - Analyze heat transfer according to the laser irradiation with and without atmospheric disturbances.

- Detonation of high explosive
  - When temperature of the surface in contact with the metal increases by heat transfer, the high explosive detonates.
  - Analyze detonation using Euler equation.
  - Analyze the presence or absence of high explosive by changing the amount of laser beam power and irradiation time.

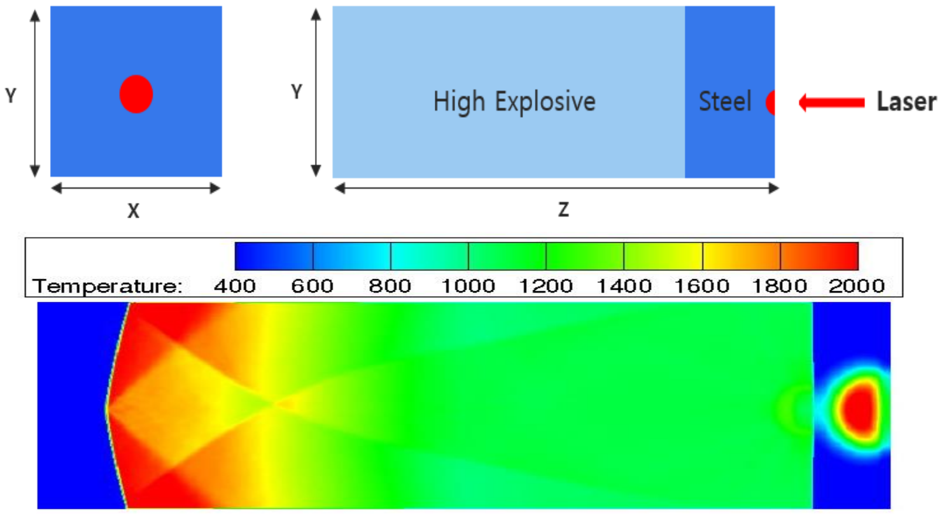

Fig. (a) Schematic of the steel-high explosive model (b) Simulation result of heat transfer effect in metal and detonation of high explosive via high power laser irradiation

담당조교 : 박기성 (pac9422@snu.ac.kr)

9-5. [실험|expt.] Spark induced plasma spectroscopy (SIPS) for real-time analysis about fine dust and virus air propagation with deep learning (양준호, Jun-Ho Yang)

- Spark-induced plasma spectroscopy and new sensing device
  - SIPS utilizes an electrical discharge from a high voltage at a low current to produce plasma when the applied voltage is higher than the ambient voltage
  - This compact sensing device was used in combination with a new quantitative analytical method using Bandpass filter and photodiode

- Real-time monitoring of toxic components from fine dust and virus
  - In current study, the development of an innovative and effective technique for real-time, quantitative monitoring of toxic fin dust and virus using plasma emission spectroscopy is presented

- Spark-induced plasma spectroscopy combined with deep learning
  - Recently, plasma spectroscopy coupled with supervised machine learning, partial least squares, and artificial neural networks has demonstrated great utilities for efficient classification of samples with similar chemical composition
  - This work presents a new attempt on the use of deep learning in identifying the source of fine dust samples

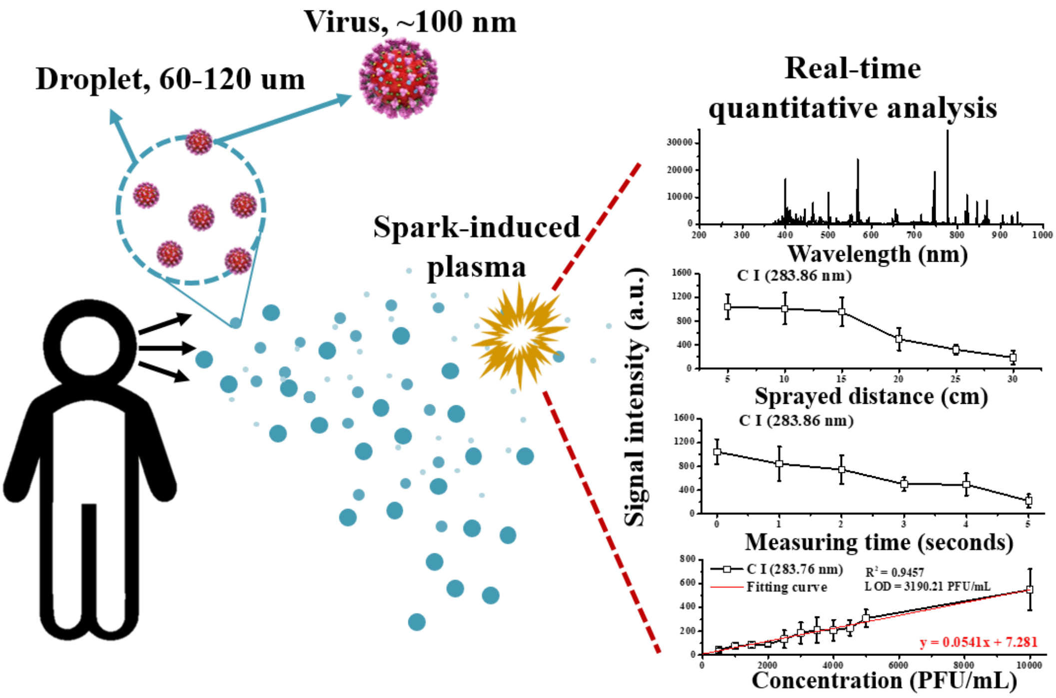

Fig. How to conduct real-time quantitative analysis

- optimized and determined to be the suitable for the classification

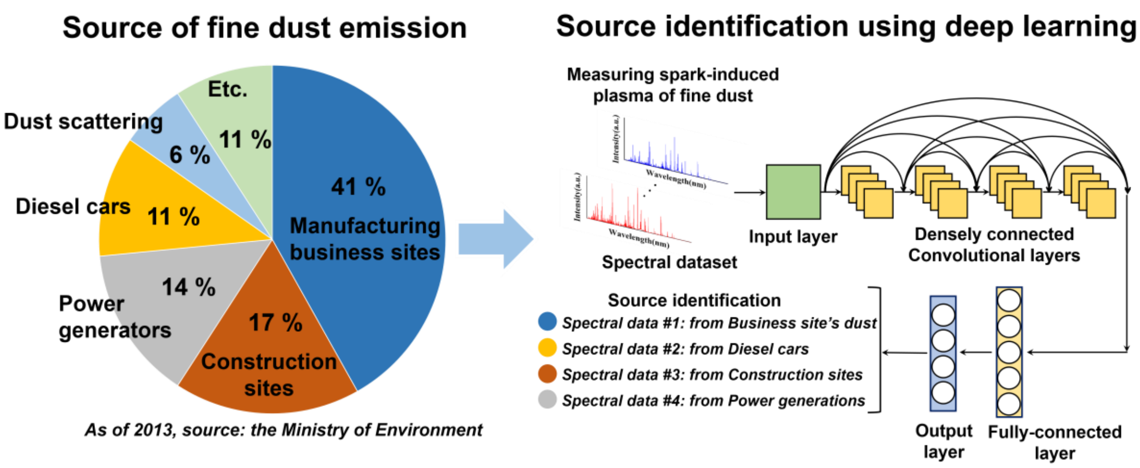

Fig. Deep learning algorithm for classification using SIPS

담당조교 : 양준호 (vkgkgk1002@snu.ac.kr)

9-6. [실험|expt.] Compact-size all-in-one sensing module for in-situ detecting of components in fine-dust or virus based on spark-induced plasma spectroscopy (양준호, Jun-Ho Yang)

- Spark-induced plasma spectroscopy (SIPS)
  - A spark generates via electrical discharging when a voltage is higher than the breakdown voltage of the medium around electrodes
  - SIPS utilizes the spark-induced plasma to obtain atomic information of the medium (fine dust or virus in current research) that exists between two electrodes

- Sensing module
  - When the medium becomes plasma, it emits plasma emission light with a wavelength exhibiting atomic information of the medium
  - A band-pass filter filters only the light in the wavelength band of a targeted atom, and a photodiode below the band-pass filter converts the light signal to the electrical signal

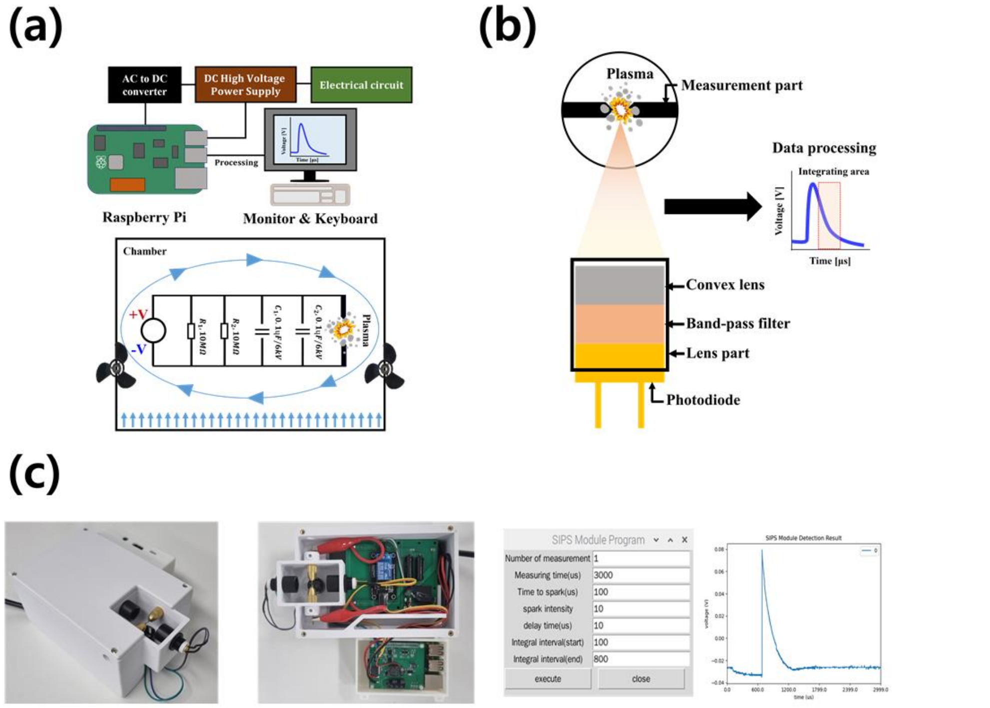

Fig. (a) The schematic of SIPS module how to operate, (b) The schematic of the measuring system, and (c) SIPS module and user interface

담당조교 : 양준호 (vkgkgk1002@snu.ac.kr)

9-7. [실험|expt.] Dielectric breakdown-induced shockwave and its biomedical application (함휘찬, Hwichan Ham)

- Mechanism
  - Dielectric breakdown by short pulsed voltage discharging
  - Effective underwater streamer propagation by electron-attractive microchannel

- Shockwave treatment & Medicine injection
  - Application to extracorporeal shock wave therapy (brain-cardiovascular stimulation)
  - Hormonal medicine injection such as insulin, vaccine and antibiotics

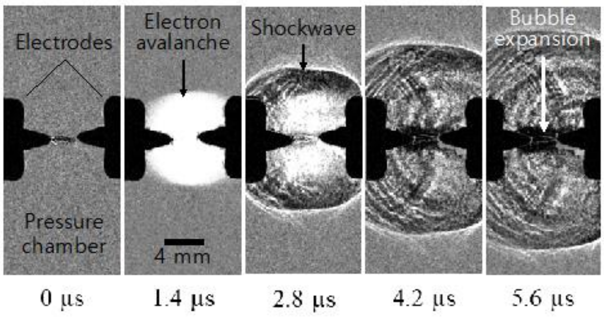

Fig. Pressure contours as per dielectric breakdown

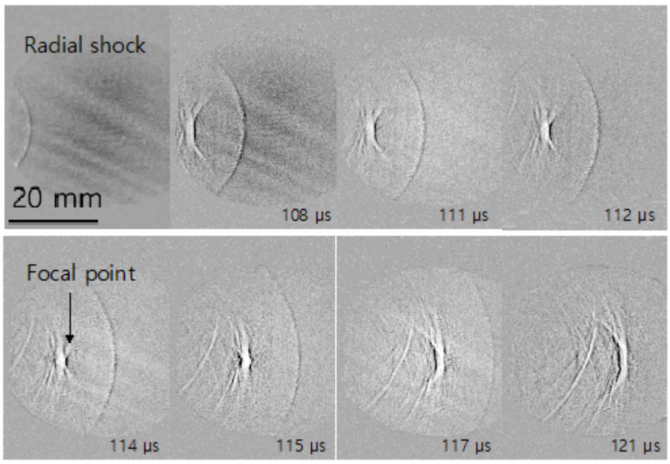

Fig. jet speed and pressure with respect to breakdown voltage

담당조교 : 함휘찬 (hamn2012@snu.ac.kr)

9-8. [실험|expt.] Combustion and thermal behaviour of electrically controlled solid propellants (임대홍, Daehong Lim)

- Electrically controlled solid propellants (ECSPs) exhibit
  - specific combustion characteristics
  - achieve ignition and combustion only with sufficient electric power
  - completely extinguish below certain threshold of power
  - establish discreet impulse bits and multiple start/stop operations
  - offer creative use in various applications such as gas generator systems, on-demand variable throttle control devices, pulsed plasma thrusters, micro-propulsion systems, long duration spacecraft applications, etc.

- Investigation of thermal behaviour & combustion mechanisms of ECSPs involve
  - Development of new propellant formulations
  - Studying the influence of oxidizer and metal content on the pyroelectric behaviour of ECSPs
  - Thermal characterization of ECSPs using DSC/TGA and extraction of their reaction kinetic parameters (activation energy, pre-exponential factor, etc.)
  - Establishing a combustion test stand for performing experiments
  - Conducting tests under pressurized conditions using a windowed strand burner
  - Obtaining their combustion characteristics (burning rates, flame temperature, combustion product analysis, etc.)

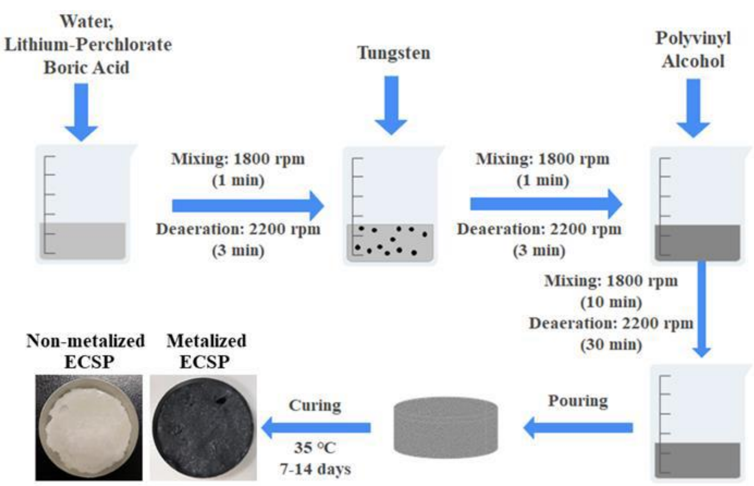

Fig. Preparation procedure of ECSPs

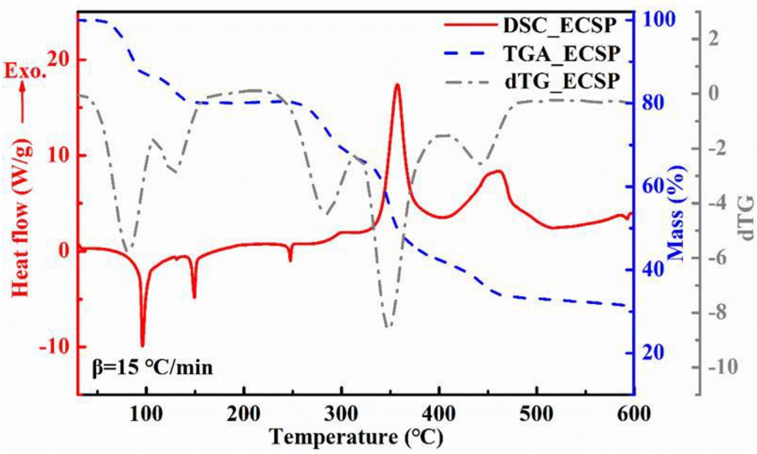

Fig. DSC, TGA and dTG curves of non-metallized ECSP

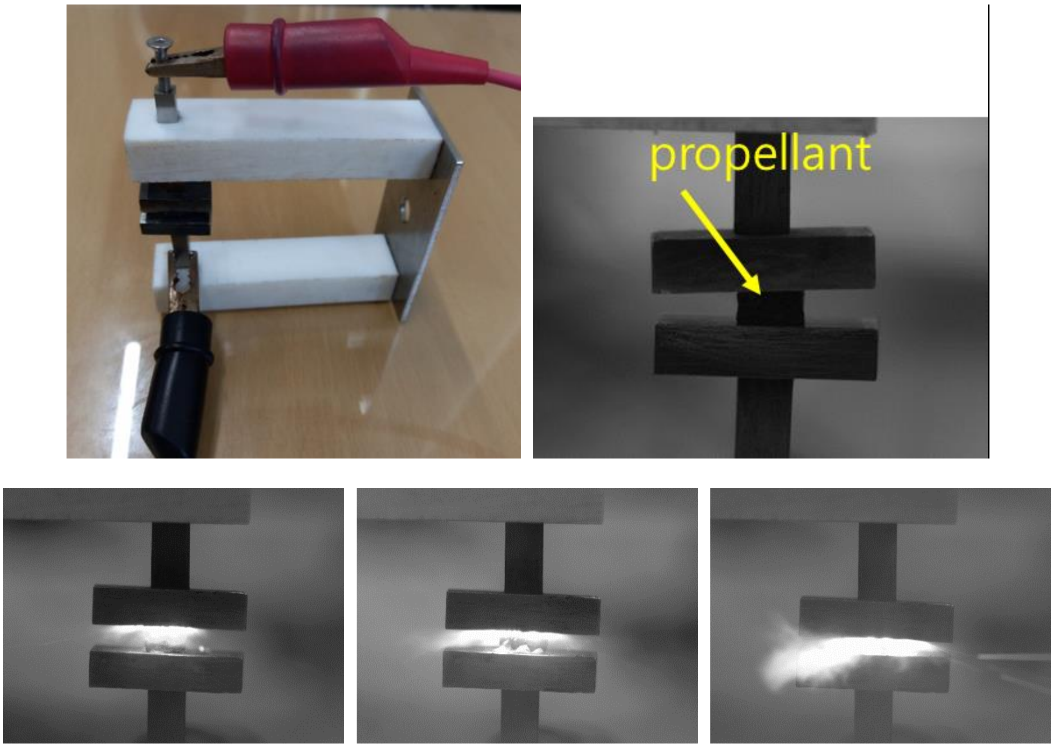

Fig. Combustion test stand, propellant configuration, and propellant burning images from ECSP combustion experiments

담당조교 : 임대홍 (limdae5199@snu.ac.kr)

9-9. [실험|expt.] Aging analysis for the energetic materials comprising of metal fuels (오주영, Juyoung Oh)

- Identification of the effects of the moisture content on the thermodynamic characteristics of the aged energetic materials. (Thermal analysis)
  - Utilized samples: thermally aged or hygrothermally aged metals
  - Instruments: differential scanning calorimetry (DSC)/thermogravimetric analysis (TGA)
  - Thermodynamic characteristics: onset temp., peak temp., endset temp., heat of reaction, peak intensity, peak shape., etc.
  - Kinetic parameters can be calculated by using differential isoconversional method

- Aging effects on the morphological and structure of the aged energetic materials. (Morphological analysis)
- Measurement of the thermal stability and reactivity in the aged energetic materials. (Combustion analysis)
- Predictions of the lifetime for energetic materials based on metals

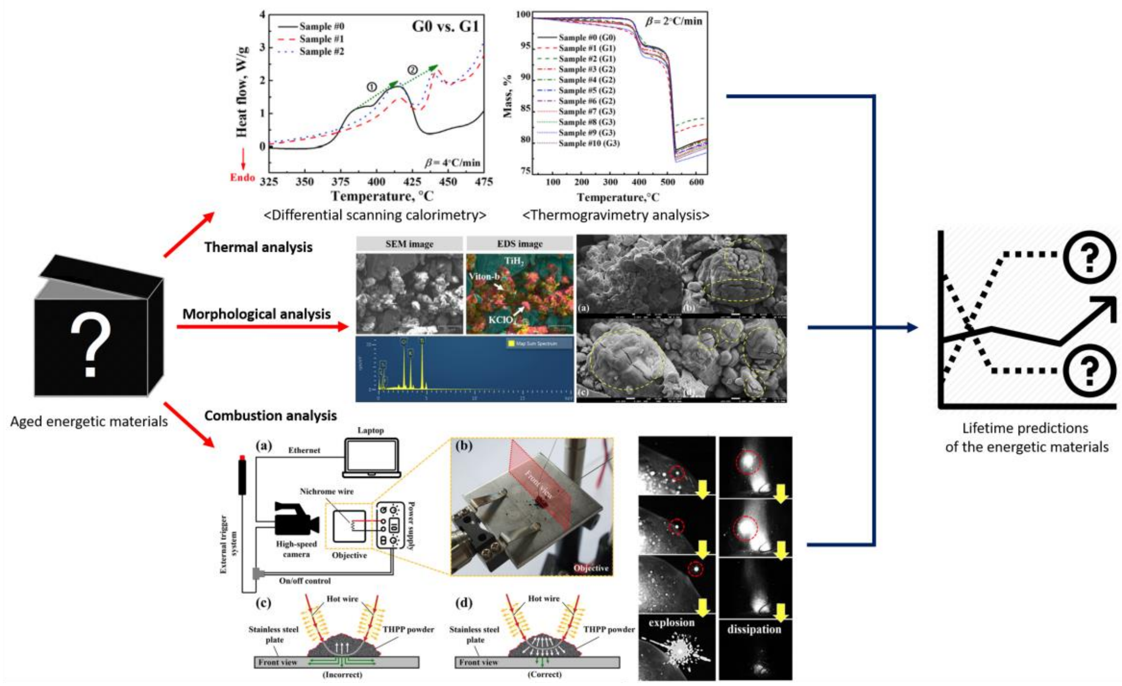

Fig. Illustration of the aging analysis procedure including 'Thermal analysis', 'Morphological analysis', and 'Combustion analysis' for prediction of the lifetime for energetic materials.

담당조교 : 오주영 (5_ju0@snu.ac.kr)

9-10. [실험|expt.] Prediction of thermal runaway characteristics by thermal analysis to secure the battery safety (Ayushi Mehrotra /오주영, Juyoung Oh)

- Research objective
  - Establishment of the prediction model for providing thermodynamic properties with respect to the battery element input
  - Extraction of the chemical reaction kinetics for each element in the battery cell
  - Construction of relationship between thermal properties and the battery elements (anode, cathode, and electrolyte) with various state of charge (SOC) or Ni content

- Experimental approaches
  - Differential scanning calorimetry (DSC)-Thermogravimetric analysis (TGA)

- Calculation method for extracting the reaction kinetics
  - Friedman isoconversional method

$$\ln\left[\left(\beta_i \frac{d\alpha}{dt}\right)_{\alpha,i}\right] = \ln[f(\alpha)A_\alpha] - \frac{E_\alpha}{RT_{\alpha,i}}$$

α: Reaction progress, β: Heating rate (K/min), A_α: Pre-exponential factor (1/s), E_α: Activation energy (kJ/mol), T: Temperature (K), R: Universal gas constant (J/mol·K)

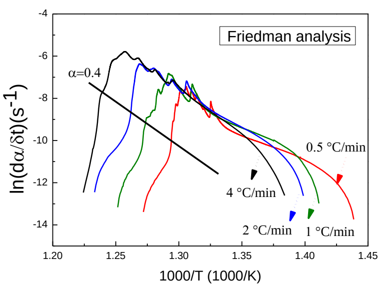

Fig. Friedman isoconversional method (α=0.4)

- Predictions of the thermal runaway event of battery cells based on the established models from the thermal analysis

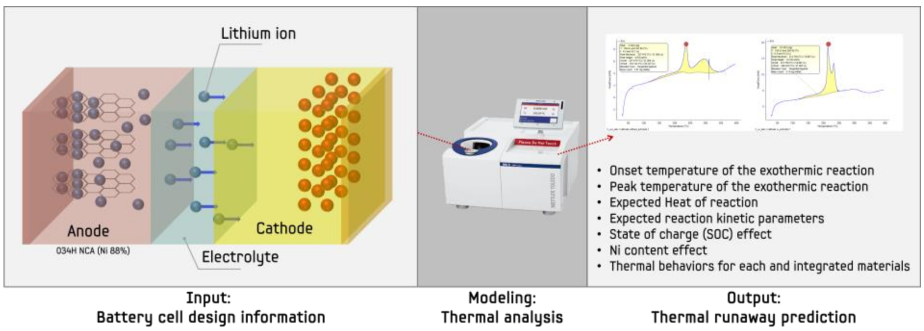

Fig. A flow chart for prediction of thermal runaway of the battery system

담당조교 : Ayushi Mehrotra (am7997@snu.ac.kr) / 오주영 (5_ju0@snu.ac.kr)

9-11. [실험|expt.] Metal fuel combustion for the generation of carbon-free renewable energy (이예준, Yejun Lee)

- Research for ...
  - Identifying the feasibility of using metal fuels instead of fossil fuels
  - How environmental factors (heat, moisture) and oxygen-rich condition affect to metal fuels?

- Objectives
  - Energetic materials (pyrotechnics, propellants, and explosives)
  - Identification of effect of environmental factor (heat, humidity) to metal fuel
  - Identification of influence of oxygen-rich condition to metal fuel oxidation

- Experiments
  - Thermal analysis (DSC/TGA)
  - Calculating kinetic parameters by Friedman isoconversional method

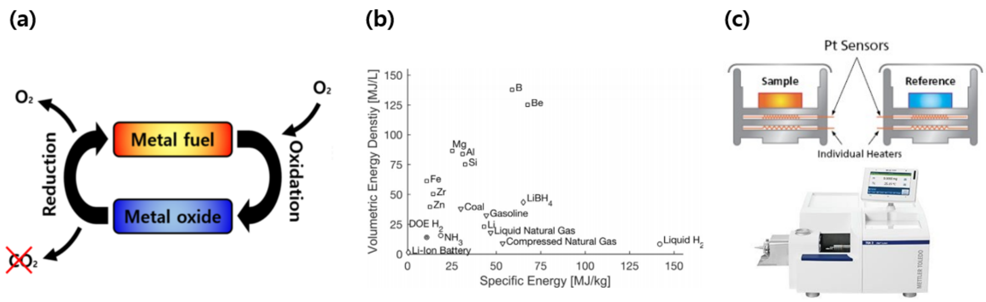

Fig. (a) Recycling mechanism of metal fuels, (b) Energy density/specific energy of several fuels, and (c) Experimental equipment (DSC / TGA)

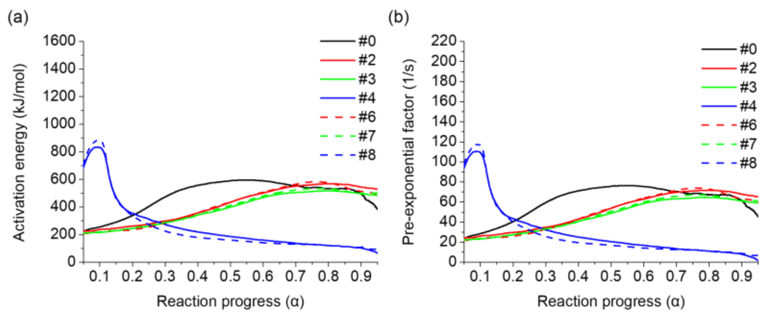

Fig. Calculated kinetic parameters according to reaction progress (a) activation energy (b) pre-exponential factor

담당조교 : 이예준 (log987@snu.ac.kr)

9-12. [실험|expt.] Developing a prototype of FEEP Thruster for Nano-Satellite
(Pravendra Kumar/ 권찬얼, Chanearl Kwon)

- Field Emission Electric Propulsion (FEEP)
  - FEEP thruster is a form of electric propulsion based on field ionization of liquid metal, and subsequent acceleration of the ions by a strong electric field
  - FEEP thruster has high specific impulse and it is easy to minimize, which is most suitable thruster for nano-satellite
  - There are three different types of emitter (needle, capillary, slit type), and they operate different thrust level
  - In current study, FEEP thruster with annular type slit emitter, which has advantage of higher thrust level and minimizing is presented

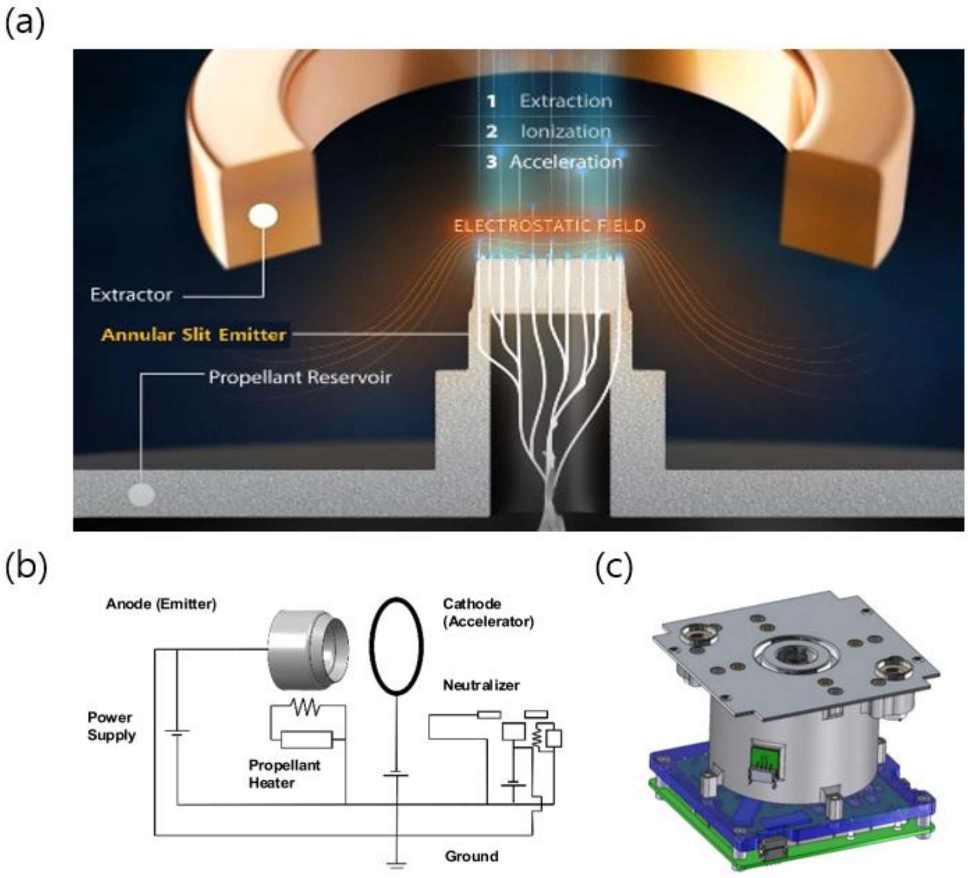

Fig. (a) Visualization of field emission, (b) Electrical schematic of FEEP thruster, and (c) 3D modeling of FEEP thruster

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