Microwave-Based Oxidation Process for Carbon Fiber

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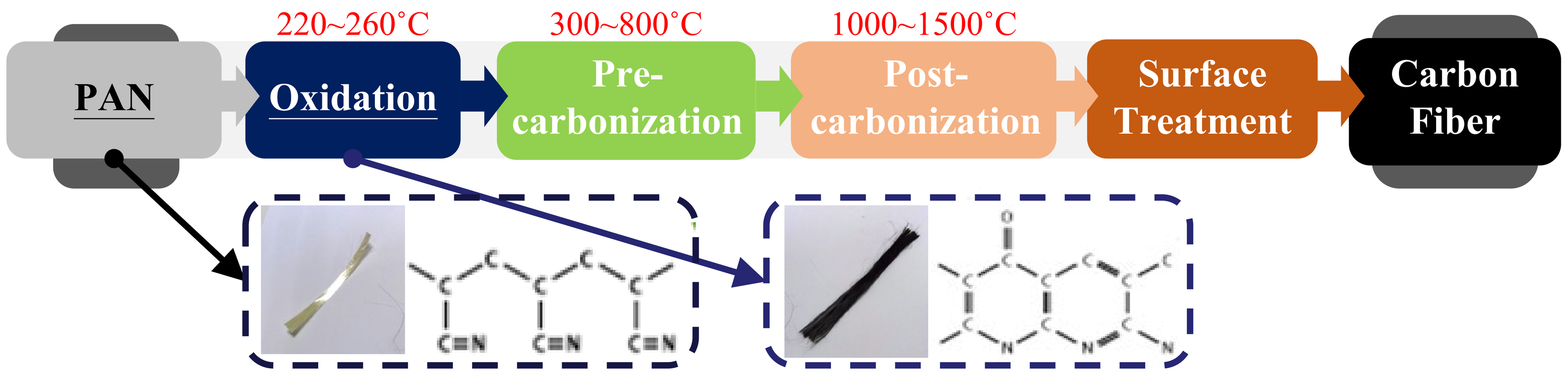
Abstract The conventional process of carbon fiber has several stages, including oxidation, pre-carbonization, and carbonization. The oxidation is the most time-consuming one, taking approximately 90-120 minutes at temperatures ranging from 200-300°C. According to previous research, using the properties of microwaves can significantly reduce the oxidation process time to a total of 13 minutes (8+5 minutes) with a two-step process. The goal of this experiment is to design a small-scale yield continuous microwave system to efficiently transform the precursor, PAN fiber, into oxidation fiber. The cavity design used HFSS to simulate the electromagnetic and thermal field distributions, ensuring that the cavity parameters meet the desired specifications. Following the experiment, samples will undergo various measurements, including density and dielectric properties, among other tests, to confirm that the degree of oxidation matches the required level for oxidized fibers.

Procedure of Carbon Fiber

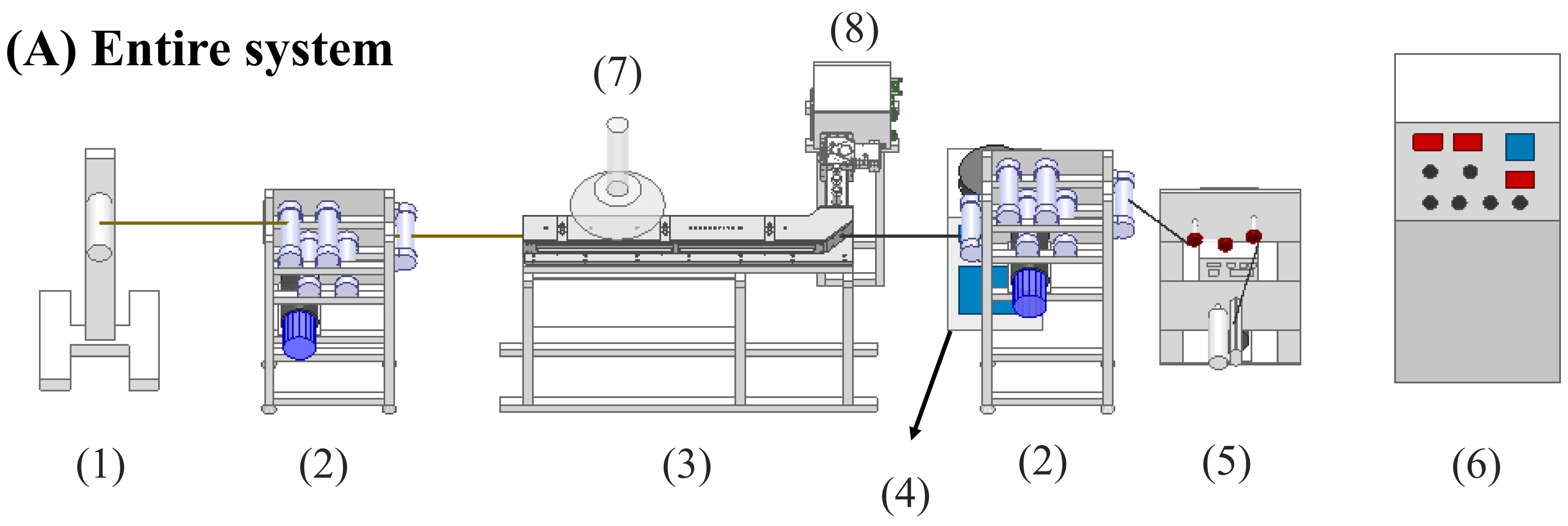
The heating procedure in the manufacture of carbon fiber includes oxidation, pre-carbonization, and carbonization. Among these steps, the oxidation process constitutes 70% of the total electricity consumption for the entire procedure. Consequently, employing the microwave approach holds the potential to save significant amounts of time and energy.



System Design

We've conformed that using microwave-based oxidation could shorten the energy and time consumption. Therefore, we are proposing a prototype design heading towards industrial production.

(A) Entire system



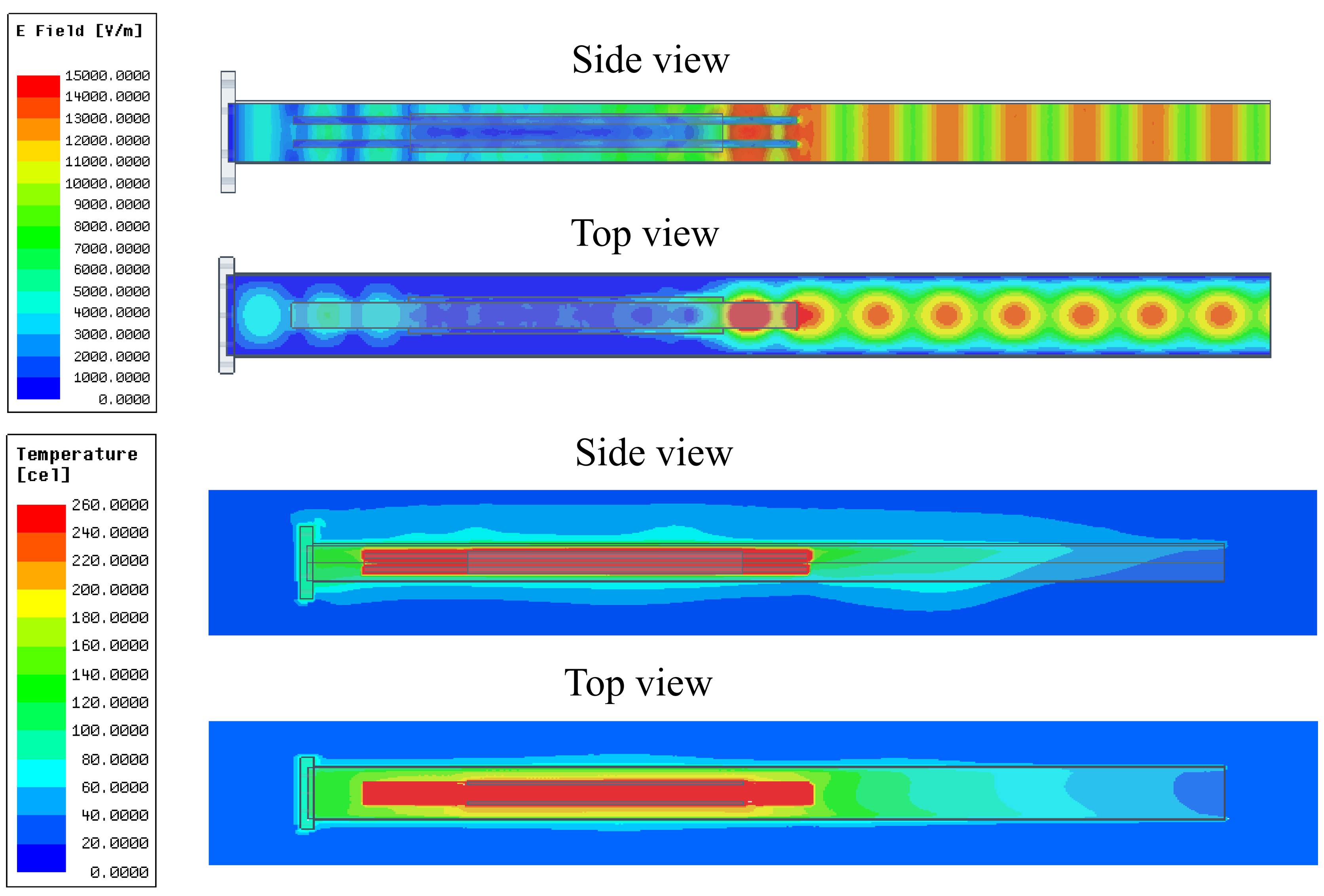
(1) Wire guider (2) Transmission (3) Reaction cavity (4) Water cooler (5) Wire coiler (6) Transmission controller (7) Air extraction (8) Microwave system

(B) Cavity

We use SiC plates to transfer microwave to thermal field. The position and number of SiC plates would significant effect the system.

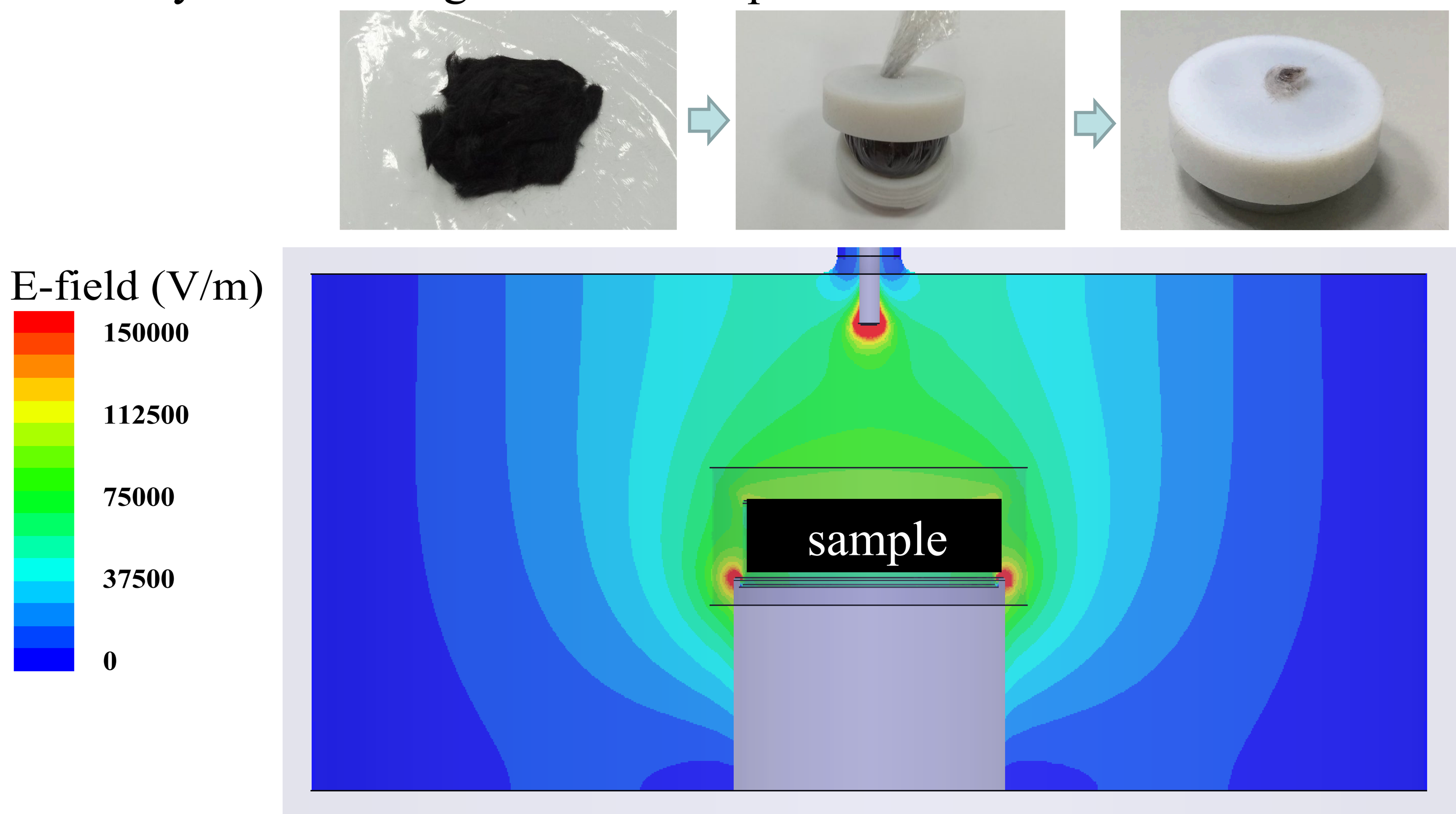
Electromagnetic/Thermal Simulation

It is a microwave sensitive system. By simulation, we could understand how the actual electromagnetic and thermal field would be while doing experiment.



Field-Enhancement Cavity

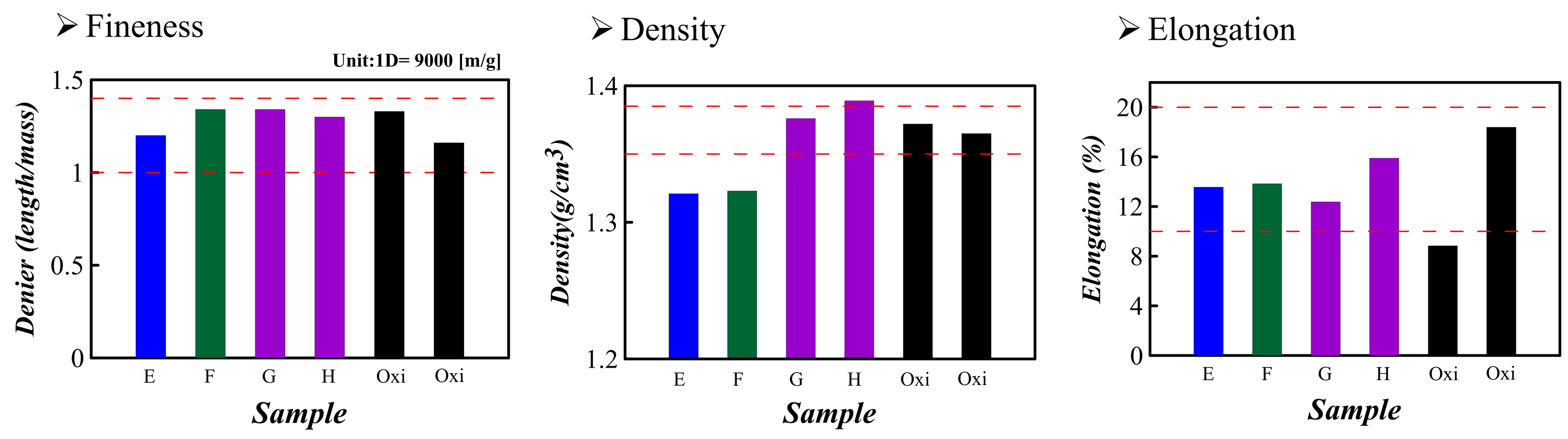
We use field-enhancement cavity to measure the resonant frequency and quality factor. By using stimulation and contour mapping, we can confirm the permittivity and loss tangent of the samples.



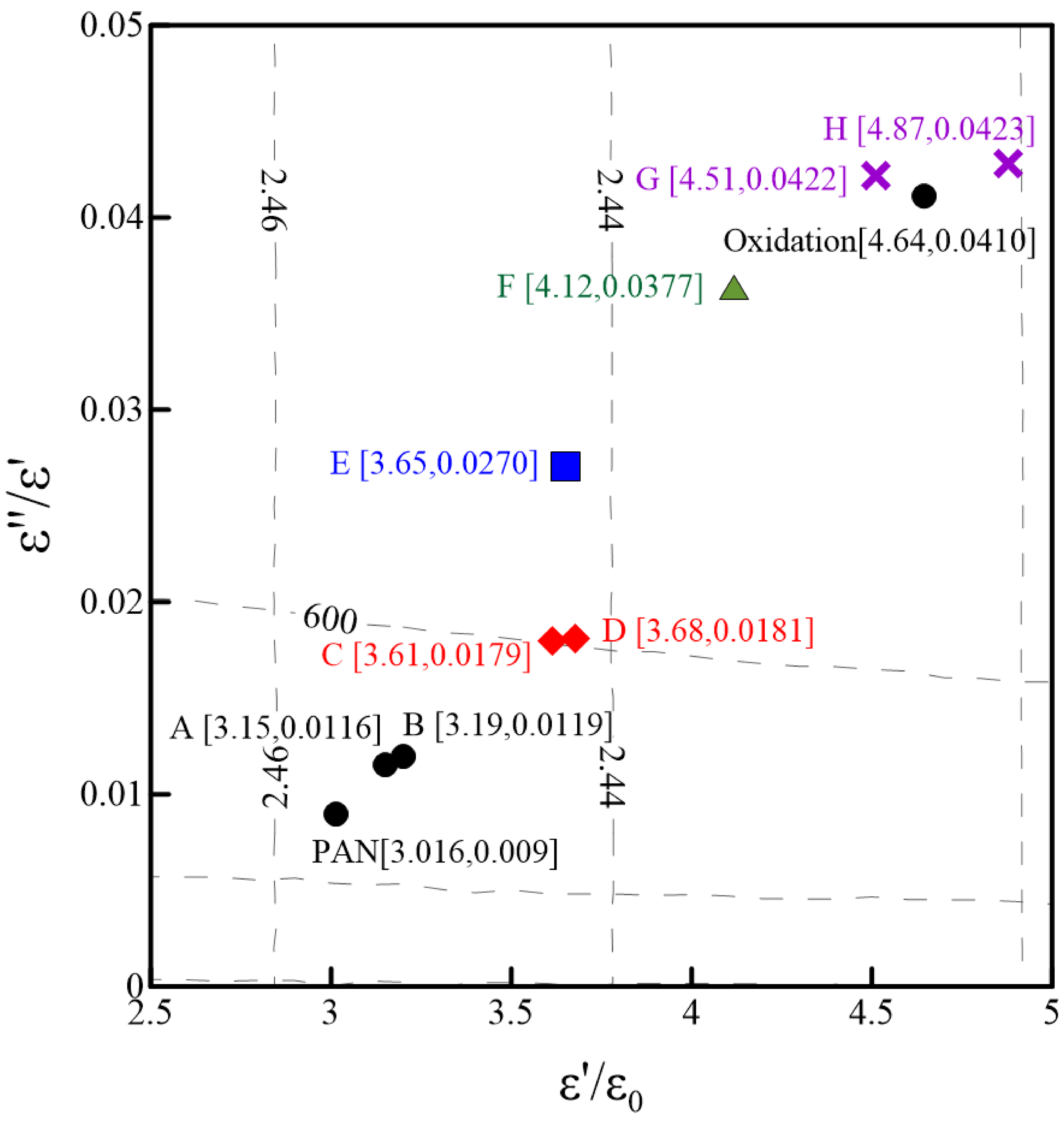
Results

We've shortened the manufacturing process to the range of thirty to forty minutes and the sample had been confirmed by the partner cooperation.

Sample \ Step(°C)	1st	2nd	3rd	4th	5th
E	205	206	222	X	X
F	205	206	222	232	X
G	200	205	205	223	233
H	200	205	205	223	233 (0.03)



Dielectric Constant and Loss Tangent



Unit:°C
A: One step (186)
B: One step (191)
C: Two step (191/191)
D: Two step (191/194)
E: Third step (205/206/222)
F: Four step (205/206/222/232)
G: Five step -0.07m/min (200/205/205/223/233)
H: Five step -0.03m/min (200/205/205/223/233)

Reference

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