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Microwave Penetration Depth Measurements of Plant Materials in Reverberation Chamber

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Introduction

- Electromagnetic properties of **plant materials** (sesame, rapeseed, and peanut) are measured in **reverberation chambers**(RC) at Industrial Scientific Medical (ISM) band.
- Under **high power microwave**, we tried to find better conditions (electric field intensity and time) for plant materials to achieve the **Maillard reaction**, and measure the **absorption cross section**(ACS) of plant materials in different states.
- We compared the **electromagnetic loss** at **different depths** of plant materials in the reverberation chamber.

Maillard reaction and ACS measurement

In this part, a measurement system has been set up as Fig. 1. The internal structure is shown in Fig. 2. We use the computer to record and analyze all the data including time, mean electric field intensity, power, temperature, and S-parameters. We can get $\langle \boldsymbol{ACS} \rangle$ ($\langle \quad \rangle$ means the average) by using:

$$\langle \mathrm{ACS} \rangle = V/c_0 \left(\frac{1}{\langle \tau_l \rangle} - \frac{1}{\langle \tau_u \rangle} \right) \quad (1)$$

where V is the volume of the RC, c_0 is the speed of light, $\langle \tau_l \rangle$and $\langle \tau_u \rangle$ are the average decay constant for the load RC and unload RC.

We change the time of heating in RC and count the ⟨ACS⟩ of materials including **3 states**, that respectively are the materials at room temperature, the materials after heating for **different times** and the materials after cooling to room temperature, as shown in Fig. 3.

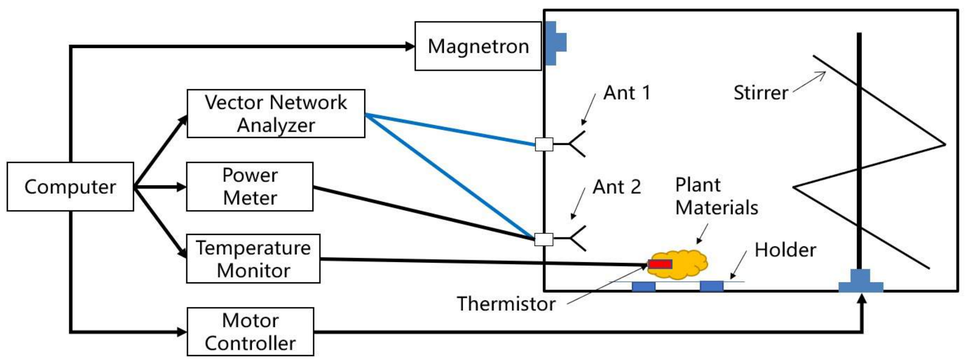

Fig 1. Schematic plot of an RC measurement system.

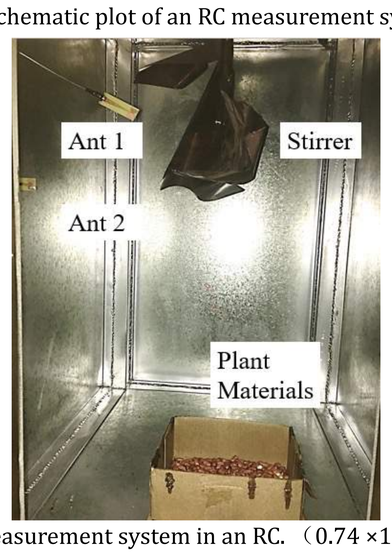

Fig 2. Measurement system in an RC. （0.74 ×1.12×0.95 m^3 ）

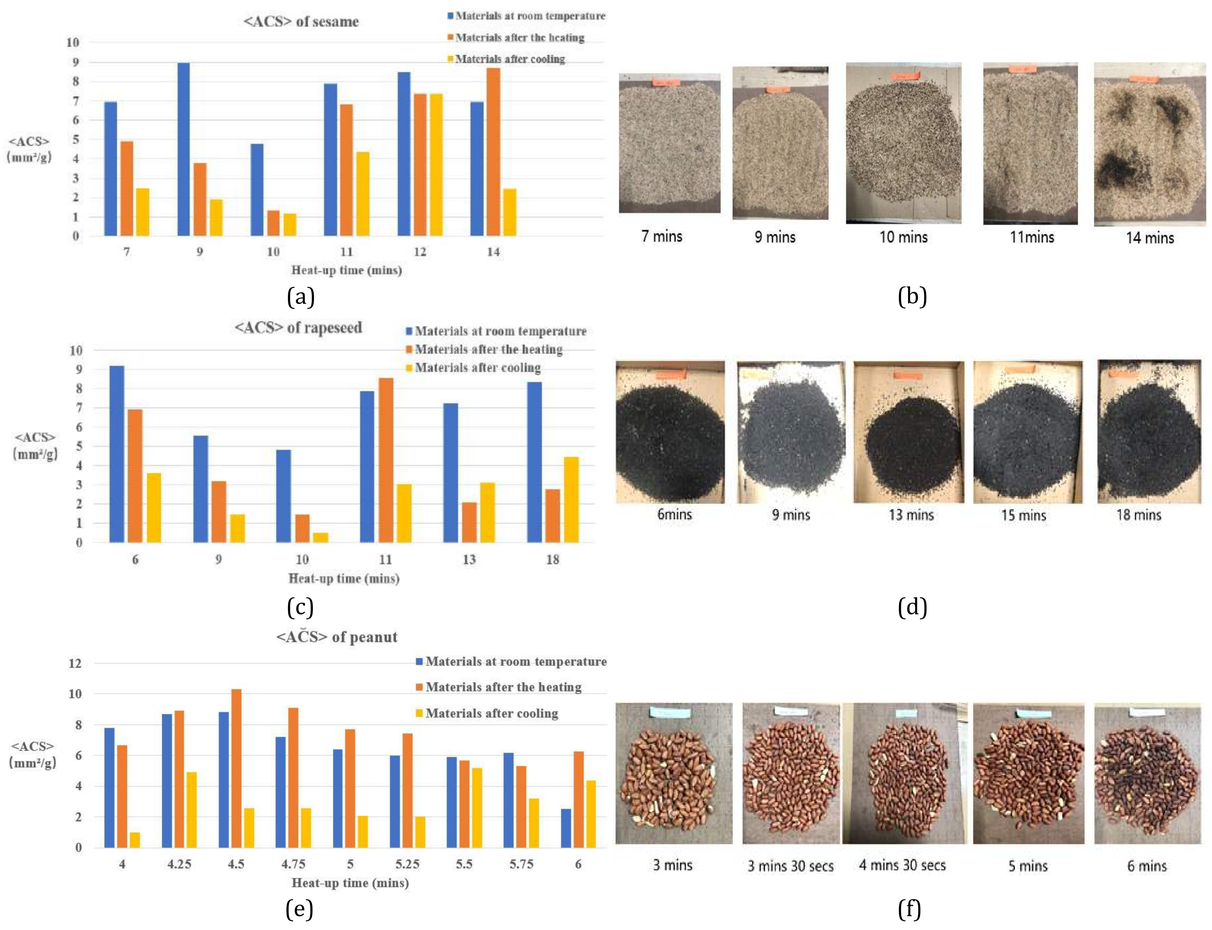

Fig 3. <ACS> of materials in three states and materials after heating (a) <ACS> of sesame; (b) sesame after heating; (c) <ACS> of rapeseed; (d) rapeseed after heating; (e) <ACS> of peanut; (f) peanut after heating.

Penetration depth measurement

A measurement system for Microwave penetration depth measurement has been set up as Fig.4 and Fig.5. An antenna has been put in the plant materials at different depths, while the whole depth of plant materials is 15 cm. In this part, we record the S-parameters from VNA to analyze the loss for the stirrers stirring 360 degrees while the antenna insides the plant materials is located at different depths.

Fig. 4. Schematic plot of a RC measurement system for microwave penetration depth measurement.

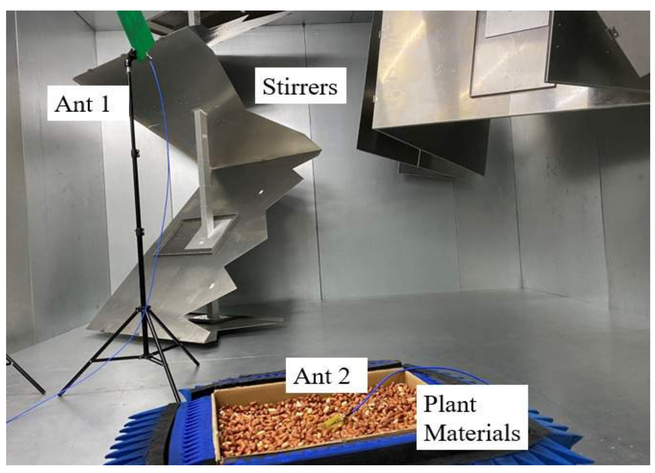

Fig. 5. RC（3.9 ×6×2.8 m^3） measurement system for microwave penetration depth measurement.

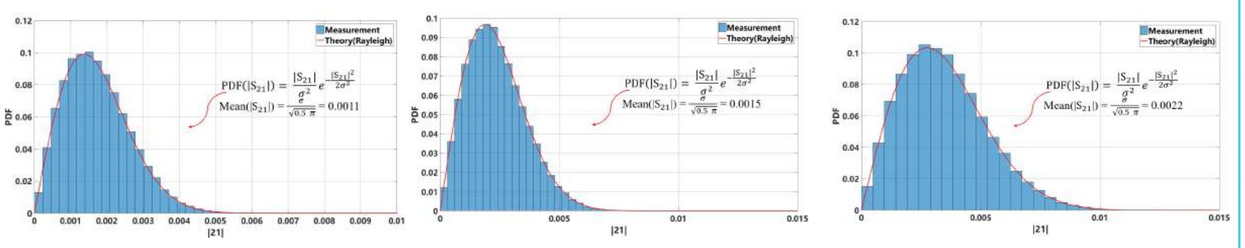

Fig. 6. | S21 | of measurement (a) 3 cm in rapeseed at 915 MHz; (b) 9 cm in sesame at 2.45 GHz; (c) 12 cm in peanut at 915 MHz.

The electric field intensity of typical states in different depths of plant materials in RC is shown in Fig. 6. We can clearly draw a conclusion that the field in RC fitting results is broadly in line with Rayleigh distribution.

Focus on two frequency bands (915 MHz and 2.4 GHz) of ISM, we carry out the microwave penetration depth measurements of three materials. The results are shown in Fig. 7.

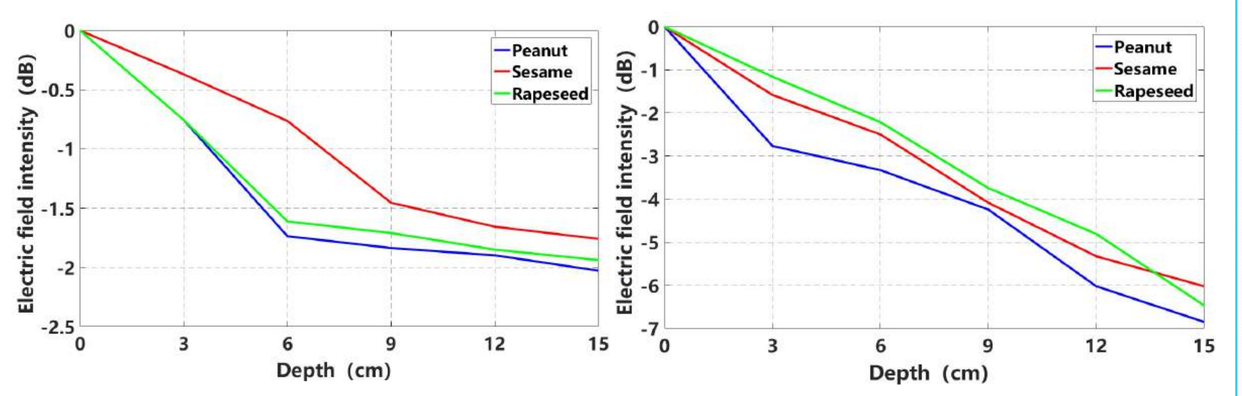

Fig. 7. Received power in different depth (a) :915 MHz ;(b) 2.4 GHz.

Conclusions

- The measurements of ACS of plant materials and microwave penetration depth in RC have been presented .
- It is found that different degree of heating has an impact on the ACS of plant materials. To attain a better Maillard reaction, in 2000 W, sesame need 10 mins; peanut need 5.5 mins; rapeseed need 9 mins.
- Furthermore, the microwave (2.4 ISM bands) can easily penetrate into these three materials which make it possible to apply microwave to plant materials treatment.
- The electric field intensity influenced by the depth of plant material more slightly in 2.4 GHz than in 915 MHz. The loss of the three materials under microwave from large to small is as follows: peanut, rapeseed, sesame.