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DETERMINING THERMAL ANISOTROPY OF WOODS USING ACTIVE INFRARED THERMOGRAPHY

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Woods can have anisotropic thermal properties whose knowledge can be of importance for applications where heat transfer plays an important role. Here, we use laser-spot active infrared thermography in a front detection configuration to nondestructively quantify the thermal anisotropy in different kinds of woods by determining their entire thermal properties components tensor. The used method takes advantage of heat losses by conduction from the sample to its surrounding air to recover both the thermal conductivity and the diffusivity from a single measurement along any spatial direction. From these parameters, volumetric heat capacity and effusivity can be calculated using well-known relationships.

Experimental

In laser-spot lock-in infrared thermography (LS-IRT) [a] an intensity modulated light beam focused at a few hundred microns is incident directly on the surface of the sample as shown in Figure 1a. The energy absorbed by the sample in the form of heat is diffused radially in the direction r and z. The temperature at the sample surface, i.e. z=0, is measured by an infrared camera which has a lock-in module allowing to process the information in real time to obtain the amplitude and phase thermograms at the sample surface at the beam modulation frequency. From these thermograms, temperature profiles are plotted in the direction r from which the in-plane thermal diffusivity and conductivity in that direction are obtained by a multiparametric fitting to equation 1 in this ref. [b].

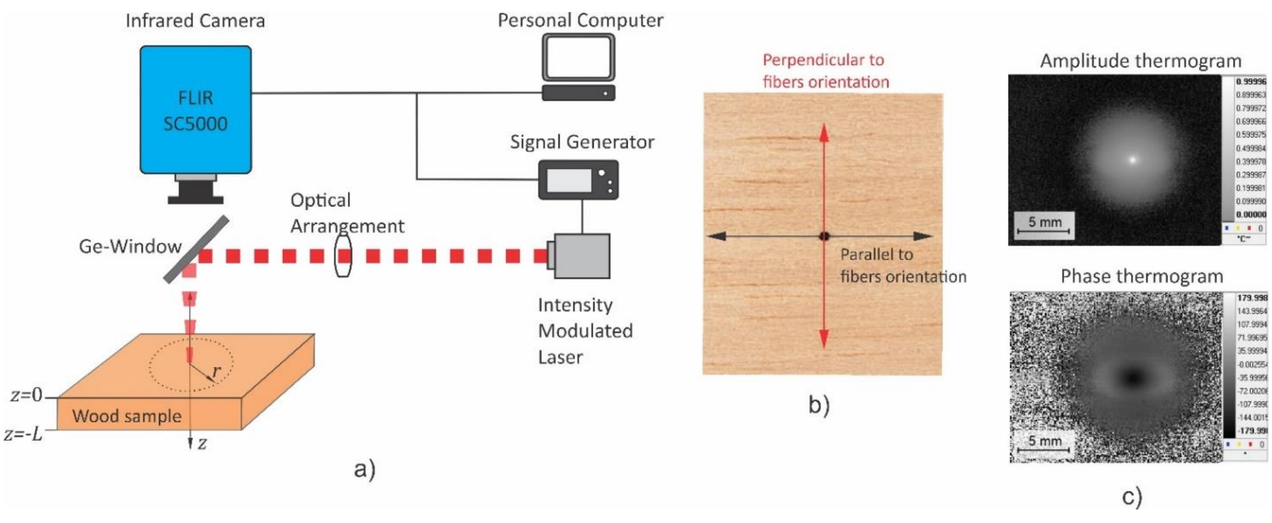

Figure 1. a) Experimental setup of laser-spot active lock-in infrared thermography in a front detection configuration; b) photograph of a balsa wood sample showing reference profiles; c) amplitude and phase thermograms of a balsa wood sample.

LS-IRT was used to retrieve the in-plane thermal diffusivity and conductivity of a set of commonly used woods in the market. Considering the anisotropy in this type of sample, temperature profiles were taken at different angles keeping as reference the profile perpendicular and parallel to the fiber orientation 0° and 90 °, respectively (Figure 1b).

Results and discussions

Figure 2 shows the results of the thermal characterization of a balsa wood sample at different surface angles from 0° to 360° at a step of 22.5°.

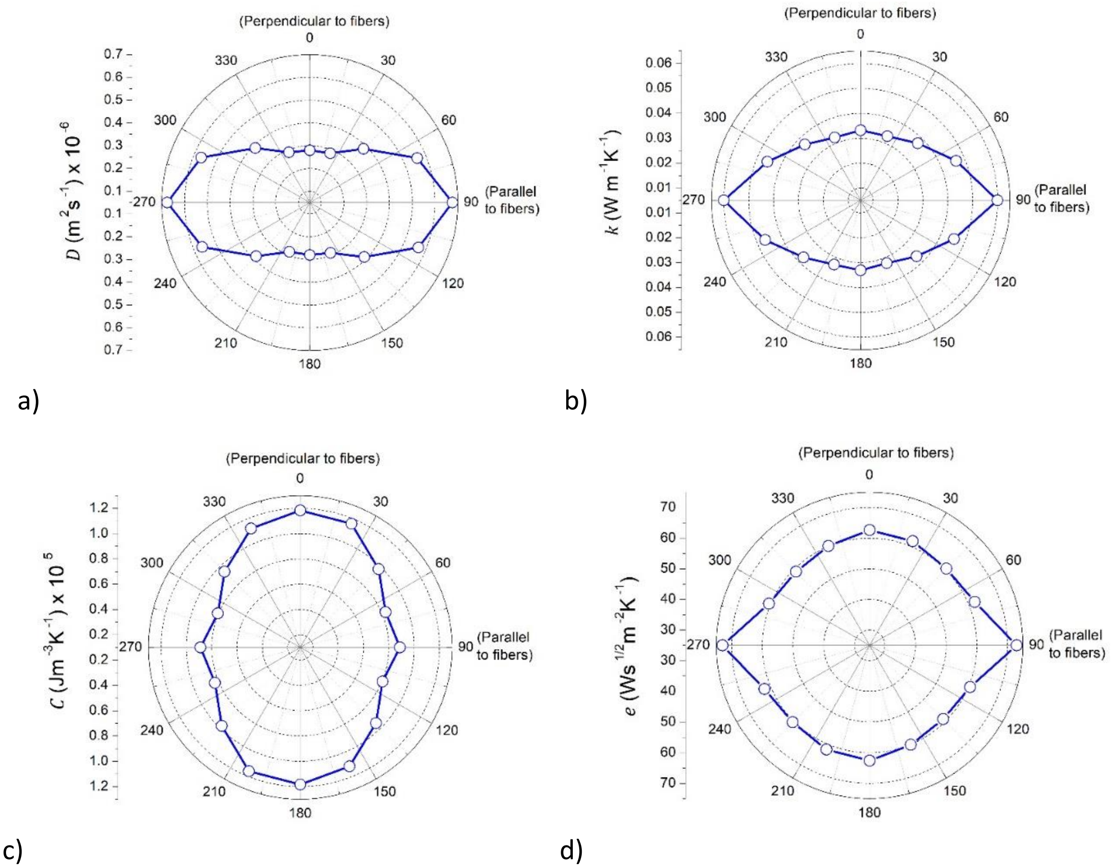

Figure 2. Angular distribution of the in-plane thermal a) diffusivity, b) conductivity, c) effusivity and d) heat capacity tensors components (Polar representations) from a balsa wood sample.

The results in the direction parallel to the fibers conform very well to the values reported in that direction [c,d,e]. In this work, 15 types of wood have been characterized in a similar way to what has been done with balsa wood, but for reasons of space they were not included in this summary.

Conclusions

A set of commonly used woods was thermally characterized using the LS-IRT method by measuring thermal diffusivity and conductivity directly and calculating thermal effusivity and heat capacity. The heat conduction to the air was exploited as a dynamic that allowed measuring the thermal conductivity simultaneously with the thermal diffusivity while maintaining the efficiency of the method in the determination of the latter as it is regularly used.

References

[a] M. Colom, A. Bedoya, A. Mendioroz, and A. Salazar, Int. J. Thermal Sci. 151, 106277 (2020).

[b] A. Salazar, A. Mendioroz, and R. Fuente, Appl. Phys. Lett. 95, 121905 (2009).

[c] A. Bedoya, J. González, J. Rodríguez, A. Mendioroz, A. Sommier, J.C. Batsale, C. Pradere, and A.Salazar, Measurement 134, 519 (2019).

[d] MakeItFrom.com at https://www.makeitfrom.com/material-properties/Balsa (Visited at 10-18-2021).

[e] N.J. Kotlarewski, B. Ozarska, and B.K. Gusamo, Bioresources 9, 5784 (2014).