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Acoustic characterization of superconductor material Pr123

[1]N. Sayoud[1]*

Department of Physics, Facultyof science, Badji Mokhtar University, Annaba 23000, Algeria

** Corresponding author: E-mail address: nawalphysique@yahoo.fr*

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Abstract

Our study consisted in the characterization of the superconducting material Pr123 using the acoustic method and the non destructive testing (NDT). Our work was performed at high working frequency of 600MHz. We studied the superconducting bulk system with the use of a coupling fluid to obtain propagation modes. The determination of these modes according to the Brekhovskikh model and the modeling of the reflection coefficient $R(\theta)$ and the acoustic signature $V(z)$, allows us to determine the moduli of elasticity of the studied superconducting material: Young's modulus (E) and shear modulus (G) in order to determine the critical angles: longitudinal (θ_L), transverse (θ_T) and Rayleigh critical angle (θ_R) which correspond respectively to the longitudinal acoustic wave, the transverse acoustic wave and the Rayleigh acoustic wave propagating in the superconducting material Pr123.

Keywords: Superconducting material, mechanical properties, acoustic signature V (z), reflection coefficient R (θ), Young' modulus.

1. Introduction

Superconducting materials have properties of conducting electric current without any resistance at very low temperatures near absolute zero [1-3].These materials are used in many fields such as medical and military...etc. This use requires the characterization and quantification of the mechanical properties of this type of materials. Therefore, our study consists in the characterization of the superconducting material Pr123, by acoustic techniques or ultrasonic method because of their non-destructive aspect (NDT). Our study was done at high working frequency of 600MHz and with the use of a coupling liquid.

2. Method

The acoustic microscope is a characterization device that consists of four distinct parts. In an acoustic microscope, the part of emission and reception of the acoustic wave represents the acoustic part. It is essentially composed of a sensor, the delay line and the acoustic lens.
In the case of a massive material, liquid-substrate system, the expression reflection coefficient was given by a calculation method, using the mechanical balance, the continuity of stresses and displacements at the interface, was developed by Brekhovskikh [4] :

$$R(\theta) = \frac{Z_L\, cos^2\, 2\,\theta_T + Z_T\, sin^2\, 2\,\theta_T\, - Z_0}{Z_L\, cos^2\, 2\,\theta_T + Z_T\, sin^2\, 2\,\theta_T\, + Z_0} \qquad (1)$$

where Z_L and Z_T are respectively thelongitudinal and transverse acoustic impedances of the solid.Z_0 is the acoustic impedance of liquid.
The expression for the acoustic signature V(z) is of the form [4]:

$$V(z) = \int_0^{\theta_{max}} p^2\,(\theta) R(\theta) exp(2jk_0 zcos\theta) sin\theta cos\theta d\theta \qquad (2)$$

Wherez is the defocusing of the sensor.
The acoustic signature V(z) is formed by periodic signals. The periodicity Δz of the interference gives information about the surface acoustic wave, this periodicity calculated by Bertoni is of the form:

$$\Delta z = \frac{V_{Liq}}{2f(1-cos\ _R)} \qquad (3)$$

The different moduli of elasticity are: the Young's modulus (E), the shear modulus (G), the bulk modulus (B). These moduli can be determined according to the following relationships:

$$G = \rho\, V_T^2 \qquad (4)$$

$$E = 2G(1 + v) \qquad (5)$$

$$B = \frac{E}{3(1-2v)} \qquad (6)$$

3. Results

The results of the modeling of the reflection coefficient (modulus and phase) that we obtained for the system: methanol-Pr123 are presented in the figures 1, 2.From the modulus (figure 1) we obtained the longitudinal critical angle $\theta_L$and the transverse critical angle θ_T. And from the phase (figure 2) we obtained the critical angle of Rayleigh θ_R. The results are grouped in table 1.

The determination of the critical angles of the propagating waves, (longitudinal, transverse and Rayleigh) from the amplitude and phase of R(θ), allows us to determine the different velocities of the modes that propagate in this material superconductor according to the Snell-Descart law. The results obtained are summarized in table 2.

The results of the acoustic signature V(z) and its FFT that we obtained for the considered system are presented in the figures 3, 4.

The results that we have obtained, of the different elastic moduli of the studied superconducting material are summarized in table 3.

4. Discussion

The curves in the figure 3show that the acoustic signature V (z) is formed by periodic signals Δz. The determination of the periodicity Δz, allows us to deduce the different velocities of the modes propagating in the superconducting material.

The elastic constants of a superconducting material (E, G and B) can be determined by various experimental methods. Among these methods is the ultrasonic technique which gives similar results to those obtained by other investigative techniques. However, the ultrasonic method, which is based on the propagation of acoustic waves generated at high frequency, is a non-destructive method, unlike the so-called classical techniques.

The obtained results of the elastic moduli of the studied material are in good agreement with those of the literature [5].

Figures and Tables

Figures

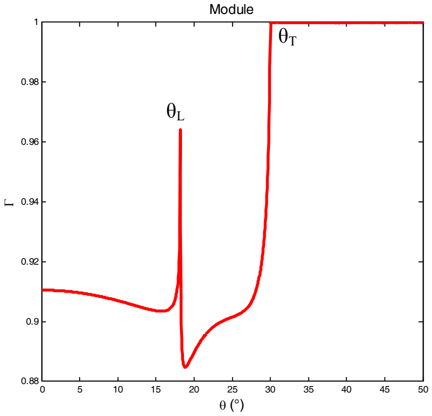

Figure 1: Modulus of the reflection coefficient of Pr123.

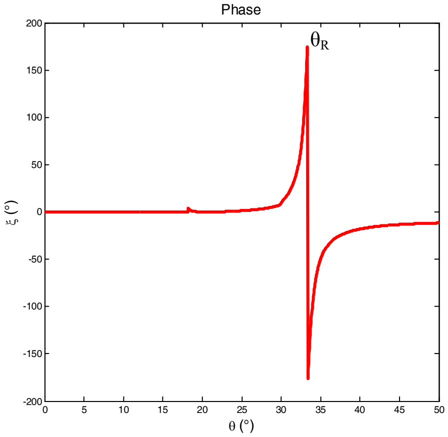

Figure 2: Phase of the reflection coefficient of Pr123.

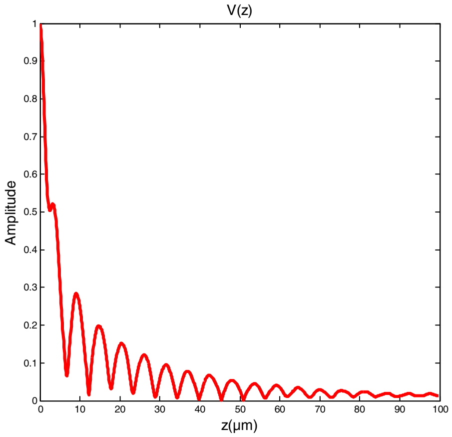

Figure 3: Acoustic signature V(z) of Pr123.

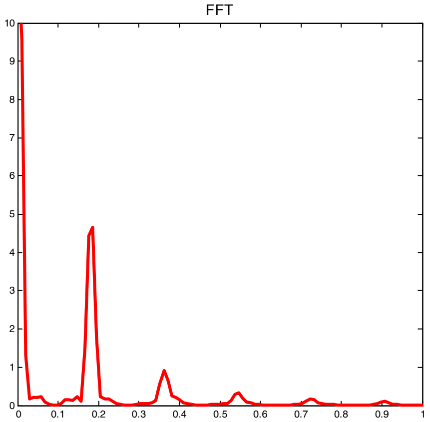

Figure 4: FFT of the acousticof Pr123.

Tables

Table 1. The critical longitudinal, transverse and Rayleigh angles.

θ_L (°)	θ_T (°)	θ_R (°)
18.2229.9833.35		

Table 2. The velocities of the propagation modes in Pr123.

$V_L(m/s)$	$V_T\ (m/s)$	$V_R\ (m/s)$
3479.742177.311979.07		

Table 3. Elastic moduli of the studied superconducting material.

E(GPa)	**E_{lit}(GPa)**	**G(GPa)**	**G_{lit}(GPa)**	**B(GPa)**
59.19	59.4 [5]	25.13	25 [5]	30.60

5. Conclusion

The acoustic method used allowed us to characterize the superconducting materials and to determine their mechanical properties.

The results obtained concerning the elastic moduli of the studied material are in good agreement with the experimental results quoted in the literature, which testifies to the validity of the proposed homogenization method.

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