ACOUSTIC PROPERTIES OF ISOTROPIC SILICON ALLOYED PYROLYTIC CARBONS

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Introduction

Silicon carbide alloyed isotropic pyrolytic carbons (PyC) which are deposited by means of chemical vapor deposition (CVD) in a bed of fluidized particles are the principle materials used in the manufacture of mechanical heart valves.

Traditionally, the elastic properties of these carbons have been determined by means of mechanical testing. This work represents an effort to calculate the elastic properties from the measured longitudinal and transverse acoustic wave velocities.

Experimental

PyC samples were coated in a fluidized bed reactor process described previously [1]. In order to vary the silicon carbide alloy concentration, the amount of methyltrichlorosilane was varied in the different coating runs. The graphite substrate onto which these coatings were deposited were subsequently removed. The substrate free samples were lapped and polished in order to provide a flat polished surface to which an ultrasonic transducer could be reliably coupled.

The acoustic velocities were measured using a UTEX Scientific UT340 square wave pulser/receiver, a 1 GHz oscilloscope, and two Panametrics piezoelectric transducers: 50 MHz for longitudinal velocities and 20 MHz for transverse velocities. The transducers were coupled to the PyC samples using Sonotech Shear Gel.

When the transducers are appropriately coupled to the slabs, a number, n, of back wall echoes will be evident on the oscilloscope. The average time-of-flight, t_{ave}, of these back wall echoes can be determined by

$$t_{ave} = \frac{1}{n}\sum_{1}^{n} t$$

where t is the time-of-flight between each individual echo. The sonic velocities can be calculated using

$$c_{L,T} = \frac{2d}{t_{ave}}$$

where d is the measured slab thickness and c_L and c_T represent the longitudinal and transverse velocities, respectively.

This PyC is a uniform isotropic linear elastic solid [2]; therefore, Young's modulus E, the shear modulus G, and Poisson's ratio υ can be calculated from the following equations [3]:

$$E = \frac{\rho c_T^2\left(3c_L^2 - 4c_T^2\right)}{c_L^2 - c_T^2}$$

$$G = \rho c_T^2$$

$$\upsilon = \frac{1 - 2\left(\frac{c_T}{c_L}\right)^2}{2 - 2\left(\frac{c_T}{c_L}\right)^2}$$

where ρ is the density determined by sink-float method.

Silicon alloy concentrations were determined by wavelength dispersive x-ray fluorescence analysis.

Results and Discussion

For all the samples, at least five back wall echoes were averaged to determine the sonic velocities. Figures 1 and 2 show the longitudinal and transverse acoustic velocities as a function of silicon alloying concentration.

Using the data from Figures 1 and 2 and the above equations, the Young's modulus, shear modulus, and Poisson's ratio were calculated and are summarized in Figures 3, 4, and 5.

Pyrolite® carbon, the PyC used for the manufacture of medical heart valves has a silicon concentration of 5 – 14 weight percent. The Young's modulus for Pyrolite® carbon ranges between 28 – 32 GPa as measured by four-point bend tests [4]. The data on Figure 3 shows that for this alloy concentration range Young's modulus ranges between 26 – 33 GPa.

Conclusion

The velocities of the longitudinal and transverse acoustic waves were measured for PyC samples with varying silicon alloy concentrations. Using these values and the measured density of the samples, the Young's and shear moduli and Poisson's ratio were calculated.

References

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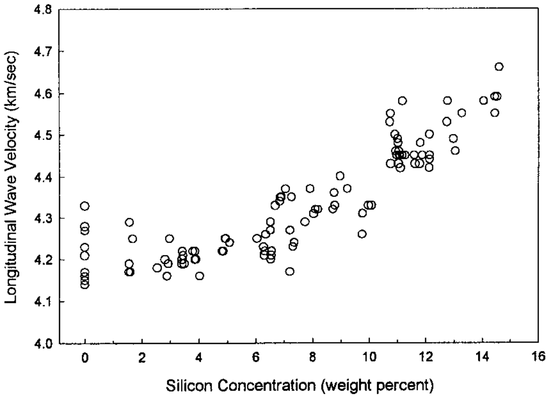

Figure 1 Longitudinal wave velocity as a function of silicon alloy concentration.

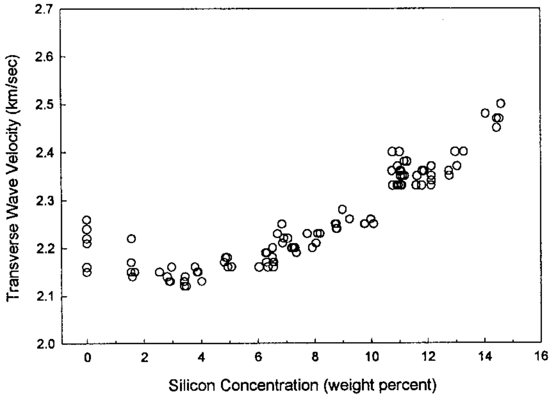

Figure 2 Transverse wave velocity as a function of silicon alloy concentration.

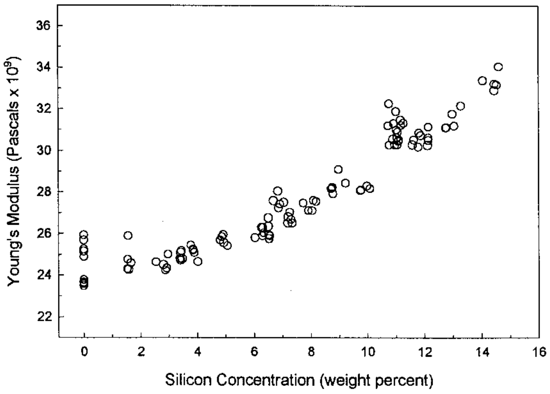

Figure 3 Young's modulus as a function of silicon alloy concentration.

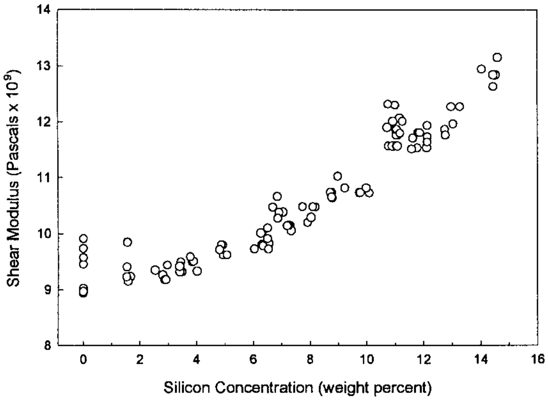

Figure 4 Shear modulus as a function of silicon alloy concentration.

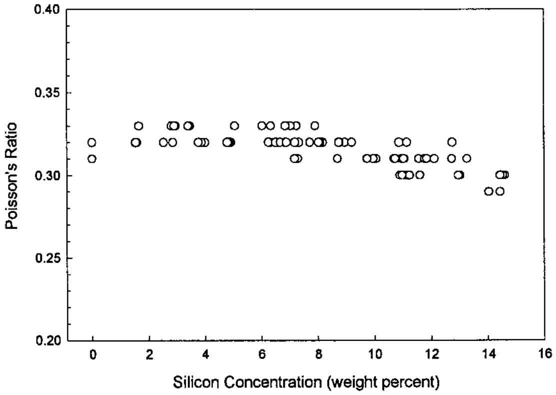

Figure 5 Poisson's ratio as a function of silicon alloy concentration.