

TABLE 5. Corrections to Measured and Derived Modulus Derivatives Due to Transducer Phase Shifts, Illustrating the Compounding of Corrections in Derived Quantities

Modulus, M.		$\left(\frac{\partial M}{\partial P}\right)$ corr.	$\frac{\partial M}{\partial P}$
MgF ₂	C ₁₁	.10	5.01
	C ₃₃	.07	5.66
	C ₁₂	.15	6.37
	C ₁₃	.24	4.18
	C ₄₄	-.03	0.79
	C ₆₆	.03	2.90
	K _S ^a	.17	5.05
	μ ^a	-.03	0.55
MgAl ₂ O ₄	C ₁₁	.09	5.15
	C ₁₂	.16	4.76
	C ₄₄	-.08	0.89
	K _S	.14	4.89

a. Isotropic aggregate modulus calculated from the Hashin-Shtrikman bounds [Davies, in preparation].

B. Bond Phase Shifts

Pressure affects the bond phase shift in two ways: directly, by changing the thickness and wave velocity of the bond material, and indirectly, if the carrier frequency is not continuously matched to the transducer resonance frequency to keep the bond phase shift minimal.

The pressure dependence of the properties of bond materials are not well known. For the purpose of assessing the importance of the effect, some representative properties have been assumed. These are shown in Table 3, and the resultant variations in density, velocities, and impedances to 40 kbar are given in Table 6. The variation in density was calculated from the Murnaghan equation

TABLE 6. Density, Velocities, and Impedances of a Hypothetical Bond Material as a Function of Pressure^a

P, kbar	$\rho, \text{g/cm}^3$	$v_p, \text{km/s}$	$v_s, \text{km/s}$	Z_p	Z_s
0	1.00	1.82	1.00	1.82	1.00
10	1.28	2.92	1.53	3.75	1.96
20	1.43	3.61	1.87	5.16	2.67
30	1.53	4.14	2.14	6.35	3.28
40	1.62	4.59	2.36	7.41	3.81

a. Assumed bond properties are given in Table 3.

$$\rho = \rho_0 \left(1 + \frac{K'}{K} P\right)^{1/K'} \quad (16)$$

(where $K' = \partial K / \partial P$), which is derived from the assumption that the bulk modulus varies linearly with pressure. Consistent with this, the longitudinal and shear moduli were also assumed to vary linearly with pressure. The bond was assumed to compress isotropically, so that ℓ is proportional to $\rho^{-1/3}$. The velocities and impedances increase by factors of 2 to 4 in this pressure range, and θ_f (equation 6) decreases by a comparable amount, especially in the first few kbars. The effect of changing thickness on θ_f is relatively minor. This rapid effective thinning of the bond (relative to the sound wavelength in the bond) is important because it means that even if the frequency deviates from the transducer resonance frequency at high pressures, the bond phase shift may still not be large.

The total transducer-bond phase shift, including the indirect effect on the bond phase shift due to the variation of transducer resonance frequency (assuming fixed carrier frequency), has been calculated from equations (3-5), assuming bond properties similar to those in Table 6 and neglecting the variation of sample and transducer impedances. Results for a 10 Mhz quartz transducer on a [100] MgF_2 sample (see Tables 2 and 3) are illustrated in Figures 6 and 7 for fixed carrier frequencies $f = 29, 30$, and 31 Mhz. For $\theta_f = 0$, the variation of phase shift with pressure arises from the variation of the transducer resonance frequency. At $f = 30$ Mhz, the additional bond phase shift is fairly small at all pressures. The curves for $f = 29$ and 31 Mhz are included to illustrate more clearly the effects of pressure on bond phase