Laser Ultrasound Velocity of material with a surface coating layer

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The velocity and dispersion of laser surface acoustic wave (SAW) for sample Fe2TiO5/Steel is investigated. The group velocity and the phase velocity spectrum of laser SAW are obtained. The elastic constants of the Fe2TiO5 coating are evaluated by curve fitting of the velocity dispersion between the calculated and experimental results. Investigation results show that: the calculated curve for the Fe2TiO5 coating with 100 µm is close to the experiment curve. The elastic constants of the Fe2TiO5 coating are as that: C_{11}=153.5 GPa, C_{44}=70 GPa, and C_{12}=12.8 GPa.

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Thin and thick surface films and coatings play an increasingly important role in many areas of technology. Mechanical and elastic properties of films are important characteristics of their microstructure and the evaluation of their quality. Usually, the qualities of films and coatings depend on the materials that are fabricated on the substrate, and their fabrication conditions. Surface acoustic wave (SAW) has the advantage of characterization of properties of films, coatings, subsurface defects, layered structure etc., due to the fact that the wave amplitude decays rapidly with depth on the scale of one or two wavelengths. Thus, more than 90% of the elastic energy remains concentrated within one wavelength of the surface. In addition to the advantage of SAW properties, the SAW generated by Laser technique can make located and contactless measurements. It has been used as ultrasonic spectroscope\(^1\) for determination of the sound, elastic properties of materials including surface coating. A coating of iron titanate (Fe2TiO5) sprayed on a 45# steel (Steel) disk is vital for increasing the wearabilities (abrasion hardiness) of its supporting substrates. However, no report is related to their sound and elastic properties. We measure the SAW dispersion of this material. We calculate the SAW dispersion for this material based on the theory of elastic wave propagation in thin layer\(^2\). The detailed results, discussions are presented in this paper.

Experiments

Sample

A material of Fe2TiO5/Steel prepared by plasma spray method is used as sample. A coating of iron titanate is sprayed on a 45# steel disk with thickness of about 3.5 mm. The thickness of the coating layer is about 150 µm to 250 µm. The density of Fe2TiO5 coating is 4404.11 kg/m.

Experimental system

The laser ultrasonic system used here has been reported previously by us\(^3\) and shown in Fig. 1. An Nd:YAG Q-switched laser with duration 8 ns and adjustable pulse energy from 1 µJ to 10 mJ is used as excitation source (point or line source). A laser heterodyne interferometer (SH-120) with frequency bandwidth of 18 MHz and a PVDF transducer with a frequency bandwidth of 125 MHz are used as point and line receivers respectively. The layered sample is placed on a precision translation stage to accurately control the distance between the source and the receiver. The ultrasonic signal received by detector then is amplified by a preamplifier and recorded by a 300 MHz digital oscilloscope (HP54510B), which has a sampling rate up to 1 Gbits/s. A trigger signal synchronized with the laser source is utilized to trigger the digital oscilloscope. The recorded signals are sent to a computer via GPIB, Then the signal is processed by the computer.
PVDF transducer when the line source exiting and line receiving method is used.

We detect waveforms at different place of surface and at different time at same place, as well as record each waveform after a few hundreds times average for ensuring the ratio between signal and noise. Fig. 2 shows the measured waveforms of SAW for Fe₂TiO₅/steel by laser probe as the example. We can see that there are both of the pulses of SAW and the longitudinal (L-) wave existing within this waveform.

Results and discussions

The group velocity of SAW

From Fig. 2 and Fig. 3, we can see that the waveforms detected at the surface of the coatings are more complex than that detected at the substrate surfaces. From the waveform we can obtain both the propagating times \( t \) of SAW pulse directly arriving and the round trip time \( t_{trtp} \) from the reflection plane. We calculate the group velocity of SAW by equations \( \frac{d}{t} \) or \( \frac{2d}{t_{trtp}} \) for these samples. The average group velocity \( v_R \) of SAW and group velocity \( v_L \) of L-wave sweeping over the surface of coating are obtained by taking an average of the individual velocity value measured from each waveform. We only pay our attention to the SAW.

The \( v_R \) for the Fe₂TiO₅/steel sample measured is 3235 m/s. The \( v_R \) of 45# steel measured is 2895 m/s. We can see that the value of the SAW velocity propagating along the coating layer surface is higher than that along the surface of steel. The relative velocity change of SAW is up to 12%. It means the Fe₂TiO₅ coating increases the stiffness of steel.

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References