Group develops world's first DMA for hard materials

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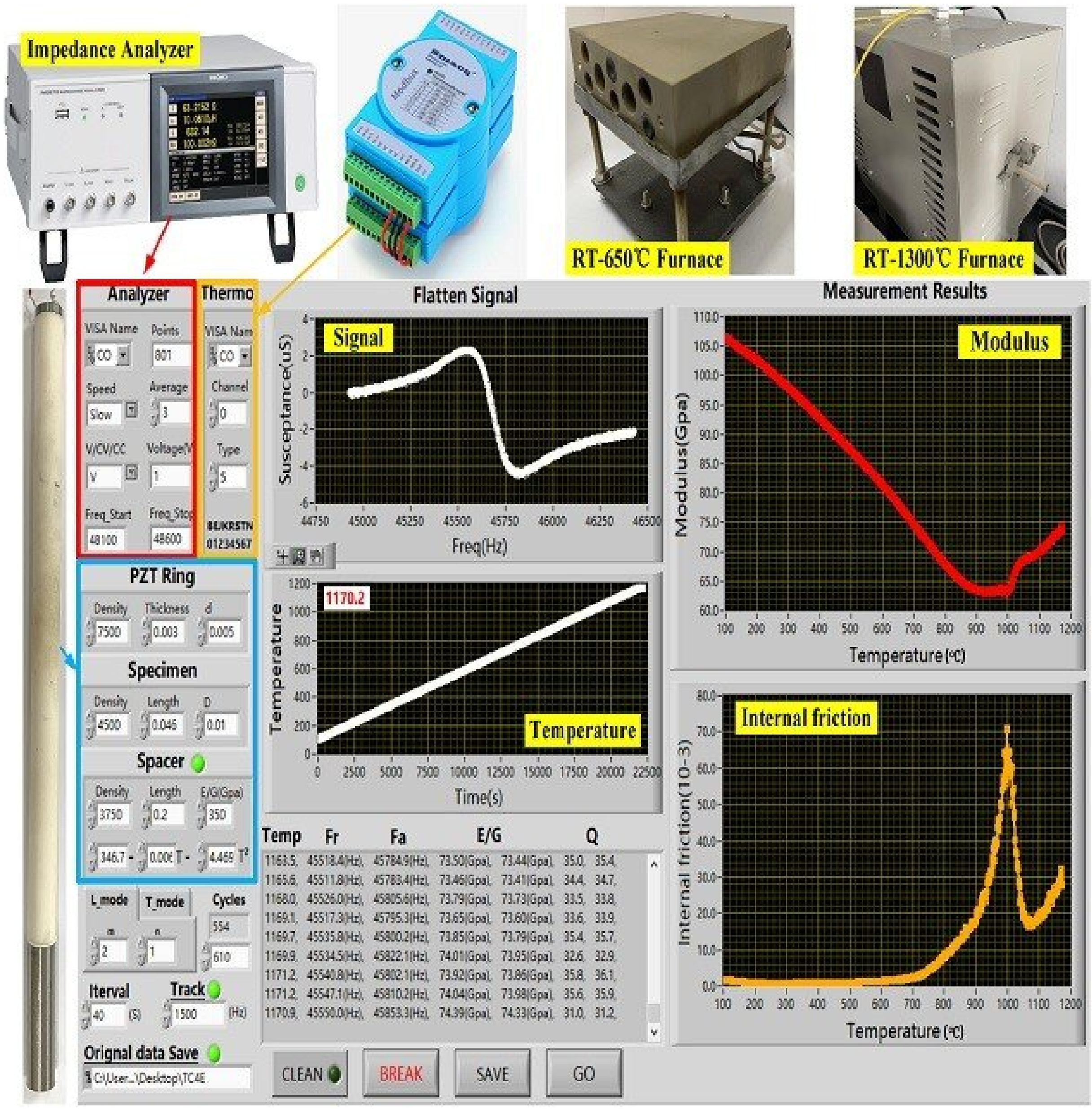
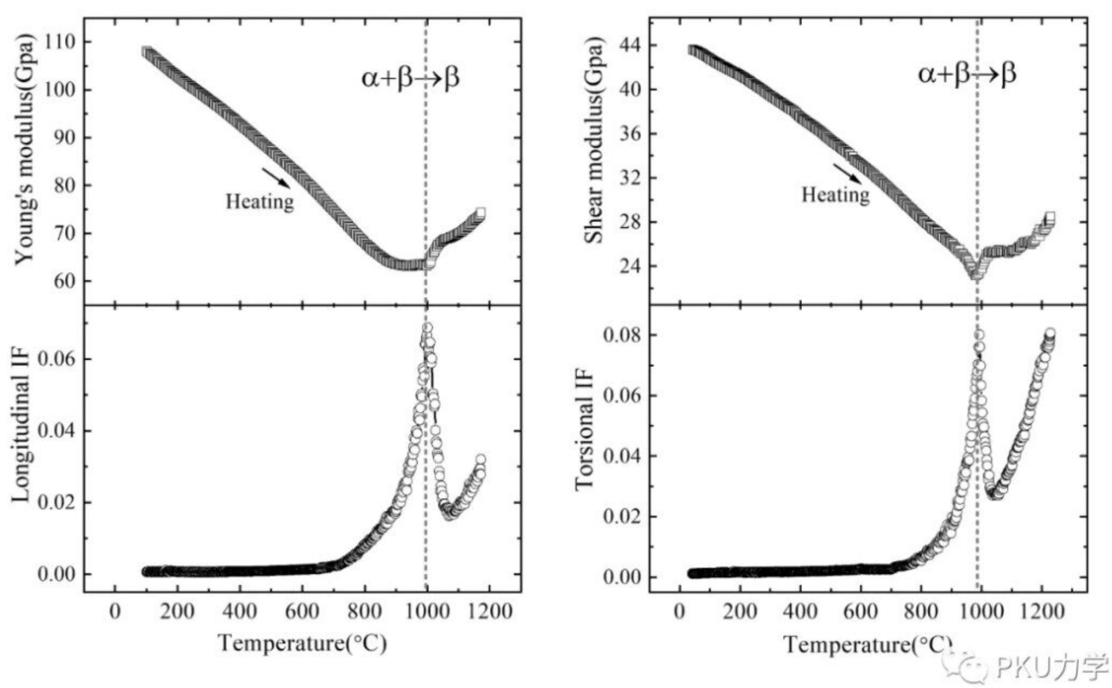


Hard material DMA based on electro-mechanical impedance method and its automatic measurement software interface. Credit: Peking University College of Engineering

Recently, the Li Faxin Research Group of Peking University College of Engineering developed the world's first dynamic mechanical analyzer (DMA) suitable for hard materials (metals, ceramics, etc.). The instrument is based on the electro-mechanical impedance method which can quickly, accurately, and automatically measure Young's modulus, shear modulus, and corresponding internal friction of materials under variable temperature conditions. The advent of the instrument has brought good news to the high and low-temperature mechanical analysis in the fields of superalloys (ceramics), composites, functional materials, and amorphous alloys. It also means that China has achieved an internationally leading position in this field. The first author to complete the work is Xie Mingyu, a 2018 doctoral student of the same research group.

Modulus and internal friction (or damping) are the basic physical properties of all solid materials. Their changes with temperature can accurately reflect the internal evolution of materials, such as atomic diffusion, grain boundary sliding, solid-state phase transition, etc. However, there is a lack of methods and instruments that can accurately measure material modulus and internal friction at the same time. Commercial DMA can only be used to measure polymer soft materials with small modulus and large damping, but the measurement results of hard materials are inaccurate, especially since the measurement deviation of internal friction is very large. At present, the measurement method of hard material modulus is mainly the free beam vibration method of the American ASTM standard, but the accuracy of this method is very poor. The internal friction of hard materials is mainly measured by the Ke-type pendulum method proposed by the famous metal physicist Ke Ting-sui, but this method can only measure the torsional internal friction of filament samples. Its measurement of shear modulus is not accurate, and the measurement process is cumbersome, so it is difficult to realize automatic measurement.

Prof. Li Faxin's group proposed a modulus and internal friction measurement method based on electro-mechanical impedance method, which can accurately and quickly measure the Young's modulus, shear modulus, and corresponding internal friction of materials . On this basis, they realized automatic measurement, increased the measurement temperature to 1300^0 C, and developed this high-temperature DMA suitable for hard materials. In fact, this method is not sensitive to temperature, as long as the temperature of the heating furnace can be reached, there is no problem if the measurement range is above 2000^0 C.



Moduli and internal friction spectrum of TC4 titanium alloy from room temperature to 1200 ^{0} C. Young's modulus and longitudinal vibration internal friction (left); shear modulus and torsional internal friction (right). Credit: Peking University College of Engineering

Using this new DMA, the research group obtained the grain boundary sliding internal friction peak in polycrystalline pure aluminum under high-frequency vibration (tens of kHz) for the first time, and the peak temperature reached nearly 500 ^{0} C, which is much higher than the low-frequency internal friction peak (285 ^{0} C) discovered by academician Ke Ting-sui in 1947.

The results of measuring the modulus and internal friction of TC4 titanium alloy from room temperature to 1200^0 C using the new DMA show that near 990^0 C, both moduli reach the minimum and both internal friction peak, indicating that the material has undergone a solid-state phase transition (transformation from the α+β mixed phase to β phase). It can also be observed that when the material temperature rises above 700^0 C, the internal friction begins to rise sharply, which indicates that the working temperature of TC4 must not exceed 700^0 C.

The research was published in *Scripta Materialia*.

More information: Mingyu Xie et al, Anomalies in the ultrahigh-temperature elastic moduli and internal frictions of Ti-6Al-4V alloys revealed by M-PUCOT, *Scripta Materialia* (2021). DOI: 10.1016/j.scriptamat.2021.114435

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