The “ IoT ” compatible pendulum hardness tester

IoT 対応非破壊振子式硬さ試験機

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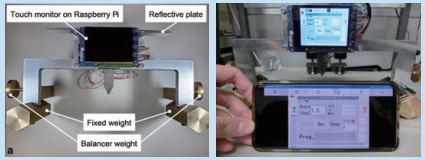
Abstract: A new pendulum hardness tester was developed, which is equipped with an acceleration sensor to detect the swing angle and a microcomputer to evaluate the hardness. The new hardness tester achieves portability because only the pendulum is needed to perform the hardness test. The tester can connect to a personal computer or a smartphone through Wi-Fi to provide remote data transmission. The new tester is used for hardness testing of five Brinell hardness reference blocks. Smooth free decay curve can be observed with the tester and evaluate the hardness. The difference hardness values between with the present tester and laser displacement meters stays within 5%. Thus, the new tester developed can evaluate reasonable hardness of materials.

1. Introduction

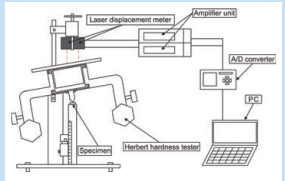
Hardness testing is widely used for evaluating mechanical properties of products for quality management and reliability assurance. Indentation hardness tests are commonly used. It is difficult to carry out these hardness tests on a product with a complex shape because the specimen would not have a smooth and flat surface. A Herbert hardness tester, an pendulum hardness tester, could carry out hardness evaluation of a specimen with a complex shape. In the Herbert hardness tester we previously developed, the swing motion of the tester on a specimen has been observed with two laser displacement meters installed on the outside of the tester for realizing high-precision measurement. The portability of the tester is low because the swing motion observation of the tester needs some large and heavy devices. The portability of the tester has needed better portability to overcome the shortcoming. We designed and developed a new pendulum hardness tester that does not need any external measuring equipment, because all measuring components are mounted on it. Micro computer allows the tester to transmit data by Wi-Fi and is compatible with the Internet of Things, IoT concept. A new tester has been built and used to carry out hardness testing. The free decay curve observed and the hardness values obtained with the new tester were compared with those obtained with a detection method with the laser displacement meters to clarify the accuracy of the new tester.

2. Design and Development



- We used commercially available parts and devices for the new hardness tester. The tester is equipped with the Raspberry Pi 3 Model B+ microcomputer.
- The tester can be operated with a smartphone via the same local network using the remote desktop application, VNC Viewer and Real VNC.

3. Experimental set-up and procedures



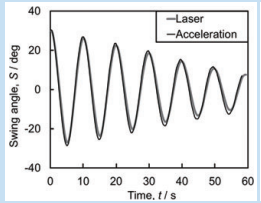
Specimens:
5 Brinell hardness reference blocks, 100HBW, 200HBW, 300HBW, HBW400 and 500HBW

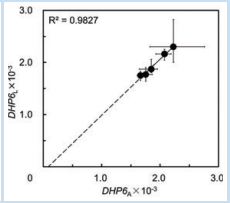
1. Periodic error correction of the pendulum tester.
2. The tester placed on a specimen.
3. The pendulum was tilted up to initial swing angle of 30° and fixed with the fix-and-release device.
4. The tester was released and started to swing.
5. the acceleration sensor and the two laser displacement meters detect changes of a swing angle of the tester.
6. The swing angle S in degrees is obtained using the acceleration sensor, is expressed as

$$S = \frac{180}{\pi} \sin^{-1} \frac{a}{g}$$

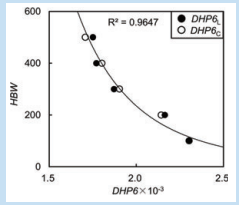
where a : acceleration and g : standard acceleration of gravity

4. Results and Discussion





- The above figure shows a comparison of the free decay curves observed against the 200HBW reference block with the two laser displacement meters and the acceleration sensor. Both free curves are smooth and well synchronized. The measurement of the swing angle of the pendulum with an accelerometer succeeded, but the phase difference between the free decay curves increase with increasing time, by about 0.2 s after 100 s, indicating a higher phase accuracy.
- Plots of the damping hardness obtained with the two laser displacement meters, DHP6L against that obtained with the acceleration sensor, DHP6A are shown above. Both of DHP6L and DHP6A are directly proportional, and the coefficient of determination, R2, is about 0.962. Thus, they have extremely strong correlation.



- The following correcting formula of the approximated straight line can give DHP6C. reducing the error of DHP6A.

$$DHP6_C = -0.0558 + 1.0610 \cdot DHP6_A$$

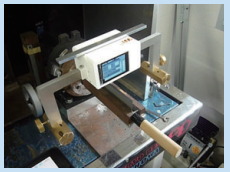
- DHP6C shows good agreement with DHP6L.
- The following formula, a function of DHP6C can give HBW values.

$$HBW = 7.8823 \times 10^6 DHP6_C^{-5.067}$$

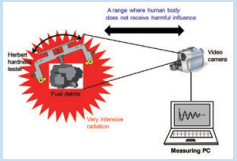
Conclusions

1. The new IoT compatible pendulum hardness tester is equipped with all the devices required for hardness evaluation of materials. A smooth free decay curve can be observed using the acceleration sensor installed in the pendulum.
2. The damping hardness obtained with the acceleration sensor shows good agreement with those obtained with the two laser displacement sensors.
3. The pendulum hardness tester developed has greater portability and superior and operability compared to the testers we have used before.

Future applications !



Hardness evaluation of the cutting edge



Hardness evaluation of a fuel debris

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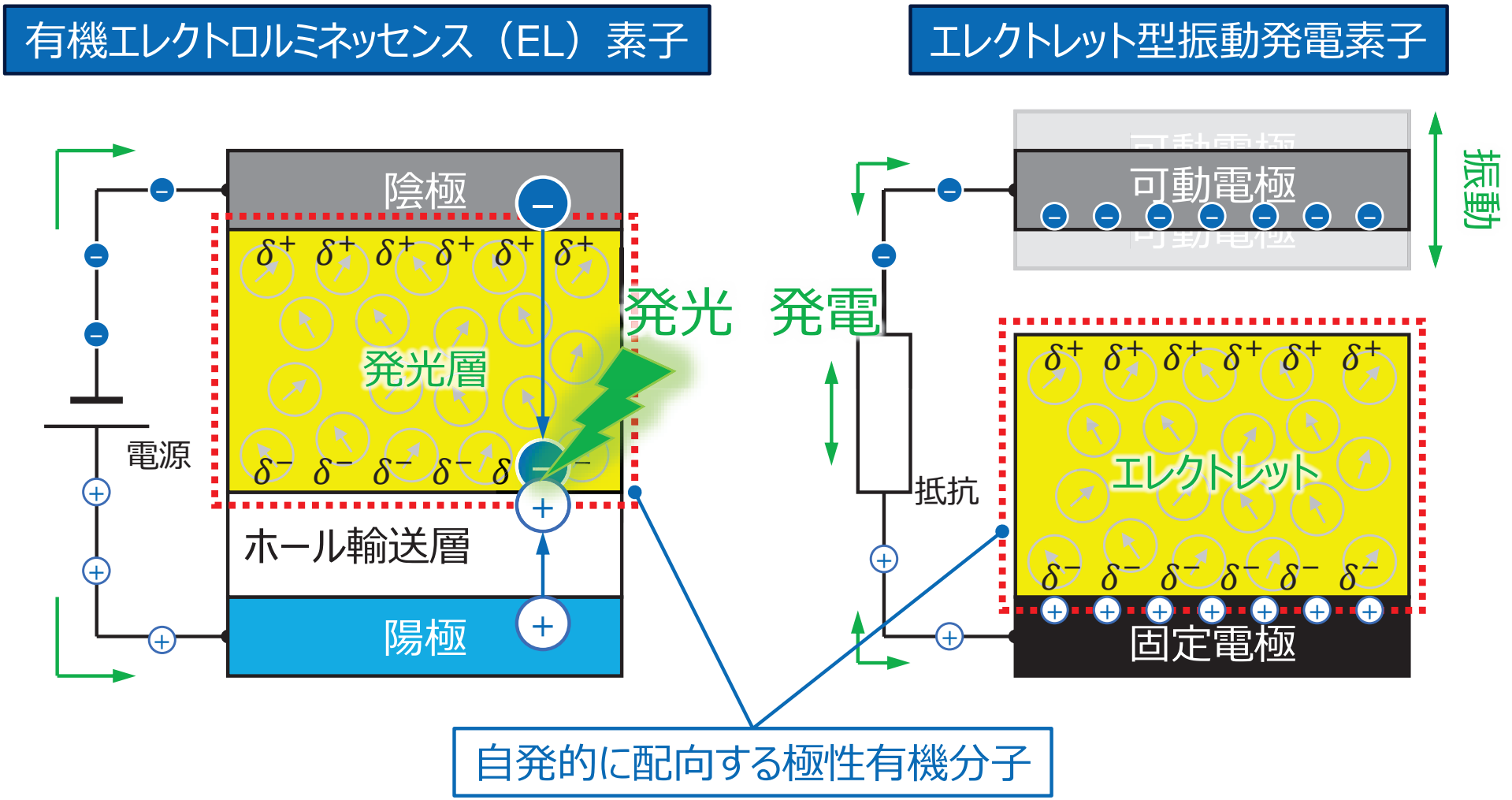
極性有機分子の力で発光と発電：　有機EL × 振動発電



分子の力で振動を電気に，電気を光に！

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田中ら，“自発的に配向する極性有機分子を利用した荷電処理が不要なエレクトレット型振動発電素子”，表面と真空 64, 16 (2021).

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