# PHOTOCONDUCTIVITY IN BONE AND TENDON

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ABSTRACT Ultraviolet light can be used to stimulate electrical current flow in bone and tendon. This stimulated photocurrent is directional. In tendon the photocurrent parallel to the fibrils is greater than the photocurrent perpendicular to the fibrils. In bone, the longitudinal photocurrent is less than the transverse photocurrent.

Many insulators yield small photocurrents under proper photon excitation (1). These photocurrents may be used as probes of the electronic structure of the insulator (2). Since photoconductive effects in bone have been reported (3) and disputed (4), we decided to search for photoconductivity in bone and tendon.

Samples of bovine tendon, bovine femur, frog tibia, and human tibia were studied. We used a modulated input and a lock-in detection system (5). A 450 W xenon lamp was focused through a 200 Hz chopper onto the sample. The voltage across the sample was supplied by a DC power supply. The dark current was measured using a DC micromicroammeter. The fluctuating photon induced current was put through the input impedance of a lock-in amplifier. A reference signal from the light chopper was used to synchronize the current detection to the light modulation at 200 Hz. With this system we were able to detect photocurrents down to 1 part in $10^7$ parts of dark current.

All samples showed photoconductive properties. The photocurrents ranged from 2% to 0.0005% of dark current values. Oven drying resulted in dark current reductions of two to four orders of magnitude, and a corresponding reduction in the photocurrents by factors of 2 to 30. The possible orientational properties of photocurrents in directions parallel to the tissue fibrils and perpendicular to the fibrils were detected. In bovine tendon the photocurrent parallel to the fibrils exceeded the photocurrent perpendicular to the fibrils by factors from 5 to 10. An opposite effect was found in human bone. In human bone the transverse photocurrent exceeded the longitudinal photocurrent by factors from 3 to 9. The resulting conductivities are shown in Table I.

The photon energy required for exciting photoelectrons in these samples was found to be more than 4.1 eV but less than 6.5 eV. This determination was made using colored glass filters and the known spectral output of the xenon lamp. Optical absorption measurements performed on bovine tendon agree with this result. Bovine tendon exhibits optical absorption which rises sharply beginning at 4.3 eV.

This is a true photoconductivity effect. The glass filter transmits all energies lower

TABLE I

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All values were measured at 2,500 V unless otherwise indicated. The number of samples, if more than one, is indicated in parentheses. Oven-dried samples were dried at 100°C for 1 day. Typical samples were 10 × 6 × 2 mm. The data are for fibrils parallel to the flow of photocurrent, unless specified by 90° for transverse photocurrent.

| Samples | Air dried | | Oven dried | |
|---|---|---|---|---|
| | Dark conductivity | Photo-conductivity | Dark conductivity | Photo-conductivity |
| | ($10^{-10}/\Omega\cdot cm$) | ($10^{-15}/\Omega\cdot cm$) | ($10^{-13}/\Omega\cdot cm$) | ($10^{-15}/\Omega\cdot cm$) |
| Bovine achilles | 0.2 | 8 | 2 | 2 |
| Bovine patella sheath | --- | --- | 5 | 10 |
| Bovine patella sheath, 90° | --- | --- | 2 | 1 |
| Bovine patella | --- | --- | 8 | 2 |
| Bovine patella, 90° | --- | --- | 2 (2) | 0.4 (2) |
| Frog tibia | 30 | 300* | 7 (2) | 10 (2) |
| Bovine femur | 10 | 7* | 2 (2) | 2 (2) |
| Human tibia | 5 (5) | 1 (5) | 30 | 0.7 |
| Human tibia, 90° | 4 (5) | 9 (5) | 4 | 2 |

*2000 V.

than 4.1 eV, allows more than 98% of the incident spectral energy to reach the sample, and yet completely extinguishes the photocurrent. In addition the thermal inertia of the bone and tendon samples prohibits their temperature from being in phase with the 200 cycle/s fluctuations of the exciting light.

These results suggest that photoconductivity can be used to probe the electronic properties of connective tissues.

We acknowledge helpful discussions with Dr. John Cowlishaw, on leave from the Department of Biological Sciences, Oakland University.

R. G. Fuller was on leave from the University of Nebraska at the time of this study.

*Received for publication 16 January 1976 and in revised form 9 April 1976.*

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