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Feature Article: SQUID – Medical Equipment -Measuring Magnetic Distribution to Visualize the Electrical Characteristics of Solar Cells Using HTS-SQUID

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1. Introduction

Greater performance and tolerance attributes are required by solar cells, rechargeable batteries and fuel cells to address current energy issues. Typical methods to ascertain the characteristics of such batteries involve measuring the voltage and current generated at the battery terminals. Further improvements in performance can be attained by internally mapping the battery to evaluate the electrical properties. The author's group have developed a current distribution mapping system using HTS-SQUID to visualize the electrical characteristics, and reported measurements conducted on solar panels [1),2)]. Measuring the magnetic field components parallel to the panel, and using an arrow map to indicate the current flow allowed the artificial defects introduced in a solar cell to be determined.

2. A summary of the measurement system and the distribution in the electrical characteristics of solar cells

Figure 1 shows the measurement system configuration developed to determine the electrical characteristics. A pick-up coil detects and transmits the field signal generated by the current through the solar panel to a superconducting coil. The superconducting coil is magnetically coupled to an HTS-SQUID. The signal acquired at the pick-up coil can be therefore detected by the HTS-SQUID. The HTS-SQUID is a ramp-edge Josephson Junction type developed at ISTEC [3)]. To automate the measurement system, the solar cell is secured on a PC-controlled XY stage to scan each point of the surface. The x (B_x) and y (B_y) magnetic field components parallel to the solar cell surface are detected by the pick-up coils, as shown in Figure 1. Actual measurements of the solar panel involved applying an ac voltage, and using a lock-in amplifier, detecting the same frequency component of the applied voltage. The signals generated here are dB_x/dV and dB_y/dV, differentials of two independent magnetic field components B_x and B_y with applied

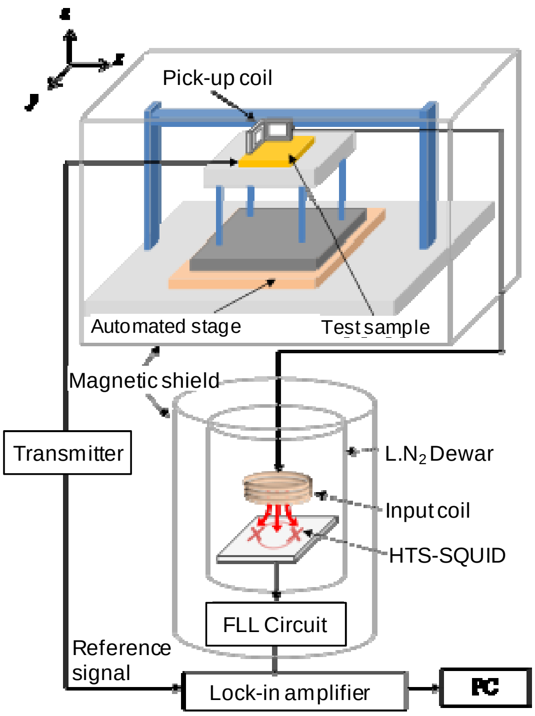

Fig. 1 Measurement system developed to visualize the electrical characteristics

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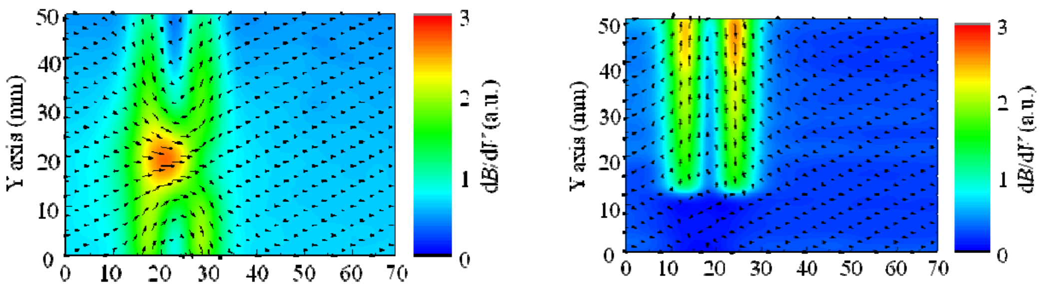
voltage V. The combined amplitude of all these signals is proportional to the current I flowing directly under the pick-up coil. Therefore, this will also be proportional to the differential conductivity dI/dV directly under the pick-up coil. The resulting map demonstrates the distribution in electrical characteristics of the solar panel.

This measurement system has visualized the electrical distribution characteristics of amorphous silicon solar panels. Two solar cell panels have been tested. One of the panels was intentionally delaminated and an artificial defect about 1 mm-square introduced on the back electrode. Measurements were made at a central area around 70 mm x 50 mm of a solar cell sized as 150 mm x 110 mm. The measurement spacing was 1 mm. An 8.8 V-offset voltage was applied together with an ac signal at a frequency of 1.7 kHz and 0.5 V_{pp}. Measurements were made on the backside of the panel under dark conditions. The electrical distribution characteristics of the panel with defects produced large differential conductance at the defect areas, as shown in Figure 2(a). The mapping vector comprising of the two magnetic field components demonstrated the current direction and also highlighted the significant current change observed around a defect. The mapping partially highlighted non-uniform current phases in a solar panel without artificial defects. Such non-uniformity implies variations in electrical characteristics for those solar cells even without defects.



(a) (b)

Fig. 2 Electrical Distribution of amorphous silicon solar cell (a) Delamination of electrode at backside and (b) without defect

3. Conclusions

A measurement system to visualize the distribution in electrical characteristics and current direction has been developed by detecting the magnetic field component parallel to a test sample utilizing two-pick up coils. The system was successful in visualizing the non-uniform distribution in electrical characteristics of a defect-induced solar cell as well as in a supposedly healthy solar panel. Future studies will include the development of a system employing a SQUID for direct detection and not via pick-up coil, as well as being able to evaluate solar cells other than the Si-type solar cells.

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