Improvement of scanning SQUID microscope for higher spatial resolution and future prospect

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We have been developing scanning SQUID microscope (SSM) for paleomagnetic studies from 2015 [1-2]. We could untangle paleoenvironments with the precise analyses of paleomagnetic information recoded in geological archives using the SSM. Higher sensitivity and higher spatial resolution measurements are suitable for analyzing remanent magnetization of geological archives, which requires the reduction of the sensor-to-sample distance (lift-off). The minimum attainable lift-off for the previously developed system could was 200 μm. One of the reasons for the limitation is the bumps of conductive paste used to connect electronically with the SQUID chip attached to the tip of the sapphire rod for thermal conduction cooling. Another issue was the large and variable contact resistance between the terminals and conductive paste. Here, we report the results of cooling experiments with an improved mounting method of SQUID chip aiming at reducing the lift-off and stabilizing the contact resistance. Further, we will show the operational status of the SSM and the future prospect.
The new mounting method was achieved by dividing the sapphire rod into upper and lower parts. The sapphire rod for mounting a SQUID chip (the second rod) has a diameter of 6 mm, whose end for mounting a SQIID chip has a conical shape. The tip of the cone has a circular plane with a diameter of 1.2mm, where 0.8 mm rectangular hollow (depth=0.1mm) was made in the center. From the hollow, flutes were made along the side of the sapphire rod. SQUID chip is a washer type and has a 0.75 mm rectangle shape with a thickness of 0.25 mm. Two or more aluminum wires with a thickness of 25 μm and a length of 10 mm were bonded before wiring.
The SQUID chip with aluminum wires was fixed to the rectangular hollow with grease, and the aluminum wires were aligned along the flutes and fixed with conductive paste. The second rod was connected to the first rod, which is thermally anchored to the liquid helium reservoir. The ends of aluminum wires were connected electronically to gold wires with a thickness of 0.3 mm with conductive paste, and the gold wires were further connected to the copper wires coming from electric circuits.
We tested the SSM with an improved sapphire rod and a SQUID chip after cooling with a liquid helium. While operating with the existing low drift FLL circuit, the noise in the magnetic field was about 4pT/√Hz@1Hz with a sensitivity of 660nT/V. The resistance including the wires were stable and the contact resistance was quite low. Line current scans provided a lift-off value of 187 μm, which is smaller than the previous minimum lift-off. The discrepancy of the magnetic field values from the theoretical values for the line current were 1%.

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