A high resolution UHV - 300mK – 10T - Atomic Force Microscope

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Performing atomic force microscopy (AFM) experiments at low temperatures provide many technical advantages like better stability and lower noise. It can be even a prerequisite to study certain sample systems like weakly bound individual atoms or molecules or investigate physical phenomena, which only occur below a critical temperature, e.g., superconductivity.

Usually, low temperature instruments are equipped with bath cryostats, using 4He to cool the AFM down to 4.2 K. In contrast, we present the design of an AFM that can be operated at temperatures as low as 300 mK in ultra high vacuum (UHV). For this purpose a closed evaporative cooling cycle filled with 3He is used. Test measurements demonstrate that the AFM can be run under measurement conditions at base temperature with a holding time of up to 11 h. Also, atomically resolved noncontact measurements were obtained on NaCl(001) at 4 K. Furthermore, clean sample preparation and evaporation of single atoms onto a cold substrate ($T < 30$ K) positioned inside the microscope is possible.

The cryostat of the system is based on the Heliox-design [1] by Oxford Instruments. The main bath of the cryostat is filled with 4He. A solenoid with a maximum flux density of 10 T is positioned inside the main bath. The so-called insert, which is located in the center of the cryostat, contains the components that are necessary for to generate of 300 mK. At the lower end of this unit the microscope is placed. It is based on the Hamburg-design and machined from a single piece phosphorous-bronze. This material shows better thermal properties than Macor, a machinable glass-ceramic, which is often used as the material for the microscope body. Tip and sample exchange are realized by lowering the microscope into a UHV-chamber mounted at the lower end of the cryostat. The temperature of the microscope does not rise above 35 K during tip and sample exchange and base temperature is achieved within 2 h after this procedure. First results show that the performance of the microscope is decreased by low frequency noise coupling into the system. To reduce the impact of noise on the AFM performance, coil springs were included to decouple the insert from the surrounding tube and the microscope from the surrounding 1K-shield. Care was taken to keep the heat load introduced by this construction as small as possible. Furthermore, the insert can be moved laterally and tilted to center the insert in the tube. Realization of the whole system and experimental results regarding the current performance of the AFM as well as the cryostat are presented.

References

[1] G. Batey *et al.*, J. Low Temp. Phys. **113**, 933 (1998).