Joule-Thomson SPM for in situ sample analysis in extreme environments

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Due to miniaturization of modern devices down to the nanoscale the importance of knowledge and control of surface properties at this level is continuously increasing and necessary for the correct device operation. Often such devices are working at elevated or near ambient pressures of defined working gas mixtures, in liquid media, or electric potentials or magnetic fields have to be applied. Also extremely low or high temperatures might be necessary.

To contribute to advanced materials analysis and development in future means using scanning probe microscopy (SPM) and related techniques in highly demanding requirements as a key tool for nanotechnology. In UHV applications strong emphasis lies on the spectroscopic methods such as scanning tunneling spectroscopy and inelastic tunneling spectroscopy as well as single atom and molecule manipulation. For this kind of applications a system operating sample and sensors in thermal equilibrium at 1K and magnetic field up to 3T is a huge advantage over standard SPM instruments which do not work under these extreme environments. With the new Joule-Thomson SPM [1] working at 1K the thermal broadening of the Fermi edge is reduced significantly compared with what is typically observed at 4 K. As a result the resolution in spectroscopic measurements is increased significantly. The modular design allows for various experimental configurations and for the usage of different sensors as well as of the high magnetic field.

This work summarizes and presents existing solutions based on a combination of the Joule-Thomson cooling stage with extremely stable SPM heads. Future development routes to new instruments for materials analysis being functional under extreme working conditions, opportunities and limits will be discussed. Finally applications and examples will be presented.

[1] L. Zhang, T. Miyamachi, T. Tomanic, R. Dehm, and W. Wulfhekel, Rev. Sci. Instrum. **82** (2011) 103702