Scanning probe microscopy (SPM) plays a crucial role in the research field of surface science and condensed matter. The SPM system in our lab (Figure 1) is a low temperature scanning tunneling microscope (LT-STM) allowing imaging, manipulation and tunnelling spectroscopy at the atomic level. It provides great opportunities *for in-situ* studies of on-surface reactions, as well as the underlying physics. Our newly installed Unisoku STM system is equipped with a few world’s most advanced capabilities for studying reactions. The system can be routinely connected to a variety of gas lines, such as H2O, O2, H2, CO or CO2 providing means for well controlled reaction studies with individual or mixture of gases. Atomic C, H and O crackers are available for studies involving reactions induced by radicals which may include controlled generation of defects at surfaces or synthesis of larger molecules. Finally, the attached metal and molecular evaporators allow us to investigate the growth of epitaxial layers but also to study e.g. molecular self-assembly as a function of surface temperature and the type of the surface. Controlled deposition down to 20K is possible. Further specific features of the system are:

**Figure 1.** Unisoku LT-STM at the Department of Physics and Astronomy, Aarhus University, Denmark.

1. *Ultra-low temperature and high magnetic field*

The SPM system can be operated at 300 mK and 16 T. The ultra-low temperature, together with the atomic-resolution microscopy and spectroscopy provides an excellent platform for studies of variety of inter-molecular reactions, in particular on a weakly bound surfaces such as graphite or graphene. Additionally, one can determine preferential adsorption sites; image the orientation of the molecule on the surface; follow the diffusion on the surface; image molecular orbitals and consequently induce particular reaction by injecting the tunnelling electrons into the specific orbital – *site-selective chemistry*. The *state-of-the-art in STM induced reactions* include both, the site selective bond rapture as well as synthesis of a new molecule via bond formation [1]. On the other hand, the capability of applying high magnetic field opens opportunities for new type of selective reactions, such as magnetic field induced ordering of magnetic molecules or synthesis of larger molecules from the individual magnetic constituents.

1. *Study of cleaved air-sensitive samples.*

The SPM system contains a sample preparation chamber with a base pressure at 10-10 mbar, which is important for the air sensitive samples. For sample that cannot be cleaned by standard Ar+ sputter/anneal cycles, the system is equipped with a cleaving stage allowing us to break the sample in vacuum and thus obtain a clean pristine surface. Sample cleavage is also possible at temperatures down to 20K as for some materials the cleaved surface may undergo phase transition at RT or may become rapidly contaminated due to the high reactivity at RT.

Two experienced group members, namely, Asst. Prof. Richard Balog and Dr. Lina Liu have strong expertise in studying on-surface reactions by STM but also by other surface sensitive techniques (ARPES, XPS, LEED, HREELS) and both are presently available for reaction studies using Unisoku STM. They have strong background in multidiscipline research, especially in the field of surface chemistry and physics. Asst. Prof. Richard Balog is proficient in electron induced reactions in pure and mixed molecular ices, reactions induced by atomic species as well as on-surface synthesis of 2D layers by means of chemical vapor deposition (CVD) and molecular beam epitaxy (MBE). His major discoveries in surface reactions include - complete transformation of freon (C2F4Cl2) ice into Cl2 and Teflon through site-selective reaction [2], bandgap opening in monolayer graphene via surface-assisted hydrogen reaction (Figure 2) [3] or surface assisted formation of ordered pattern of graphene quantum dots embedded in BCN layer [4]. Dr. Lina Liu obtained a PhD degree of chemistry and she is an expert in surface chemistry reaction. She reported the first synthesis of monolayer PdTe2 and patterned PtTe2 by direct tellurization of Pd(111) and Pt(111) surfaces (Fig. 3) [5].

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**Figure 3.** Atomic-resolution STM images of monolayer PdTe2 and *patterned PtTe2*

**Figure 2.** STM and ARPES data of CVD graphene grown on Ir(111)surface before (a, b) and after (c,d) surface-assisted hydrogenation. The STM data show topographic image while the ARPES data show band structure of graphene around the Dirac point.

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