Fig.31

Complete change of the lattice periodicity observed in a phonon dispersion of Ga crystal a) below and b) above the phase transition by helium atom scattering (see HAS experimental chapter).

In [5], and [6] the surface state with a binding energy of about -1eV was investigated by photoemission spectroscopy. This surface state did not show up in the point spectra because of (1) tip instabilities at higher voltages and (2) short electron lifetimes [5]. Nevertheless the appearance of the CDW can be explained by the coupling of these surface electrons. Although the experimental STM results suggest a more complicated picture than given in [13], the line of argumentation is plausible and will be reviewed here. The CDW is explained with the nesting of the Fermi surface. In *Fig.32* one can see the bulk Fermi surface projection [13].

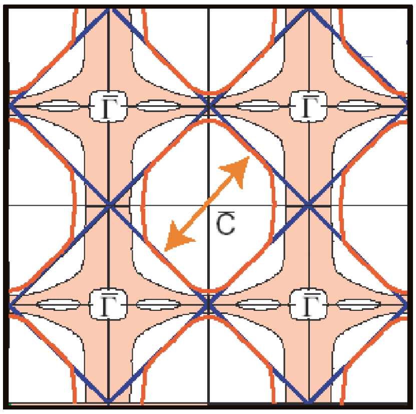

Fig.32

Bulk Fermi surface projection [13].

Here for simplicity the surface structure is assumed to be $\left(\sqrt{2}x\sqrt{2}\right)R45°$. The surface state contour is shown here with the red color. The dark blue colour is the BZ boundary. One can see that large parts of this contour run on the BZ boundary and can couple with each other. Therefore this periodicity favors nesting of parts of the Fermi contour to form a CDW. The observed periodicity is actually a $\left(2\sqrt{2}x\sqrt{2}\right)R45°$, but nevertheless the backfolding in one direction still remains.

The CDW finestructure

The point spectra show up to 6 plateaus, already indicating a more complex situation as proposed in the previous section, possibly caused by a multigap structure. In this section extensive data sets will be shown, giving more information about the appearance and symmetry of the CDW.

From the sequence of the topography images taken at positive voltages starting at +20 mV until +380 mV (*Fig.33*) one can see that at +200 mV there is a change from the `bump` row structure to the `zigzag` row structure. The change occurs exactly at the same voltage where the phase shift in the dI/dV line scan was observed and where there is a shoulder (plateau) in the point spectroscopy.

Fig.33

Sequence of topography images for positive voltages ranging from +20 mV to +380 mV with a step of +15 mV. The `bump` rows are marked with blue arrows. The images where the *change from `bump` row to `zigzag` row occurs are marked with a red frame and the changed rows with red arrows.*

In the dI/dV area maps the electronic structure is shown energy resolved (*Fig.34*). The dI/dV area map image sequence clearly shows that the wave pattern strongly depends on the voltage. Around +200 mV in the dI/dV area map the intensity is at its maximum. Such a behavior is expected for the standing wave at the band gap edge. The intensity is maximum in the dI/dV area maps, but shows up only as a plateau in the point spectra. This is caused by a smoothly increasing intensity background possibly from bulk states (Ga has a pseudogap of 2eV width [7]). One can see also less pronounced wave patterns at higher energies in the dI/dV area maps shifted by one row.

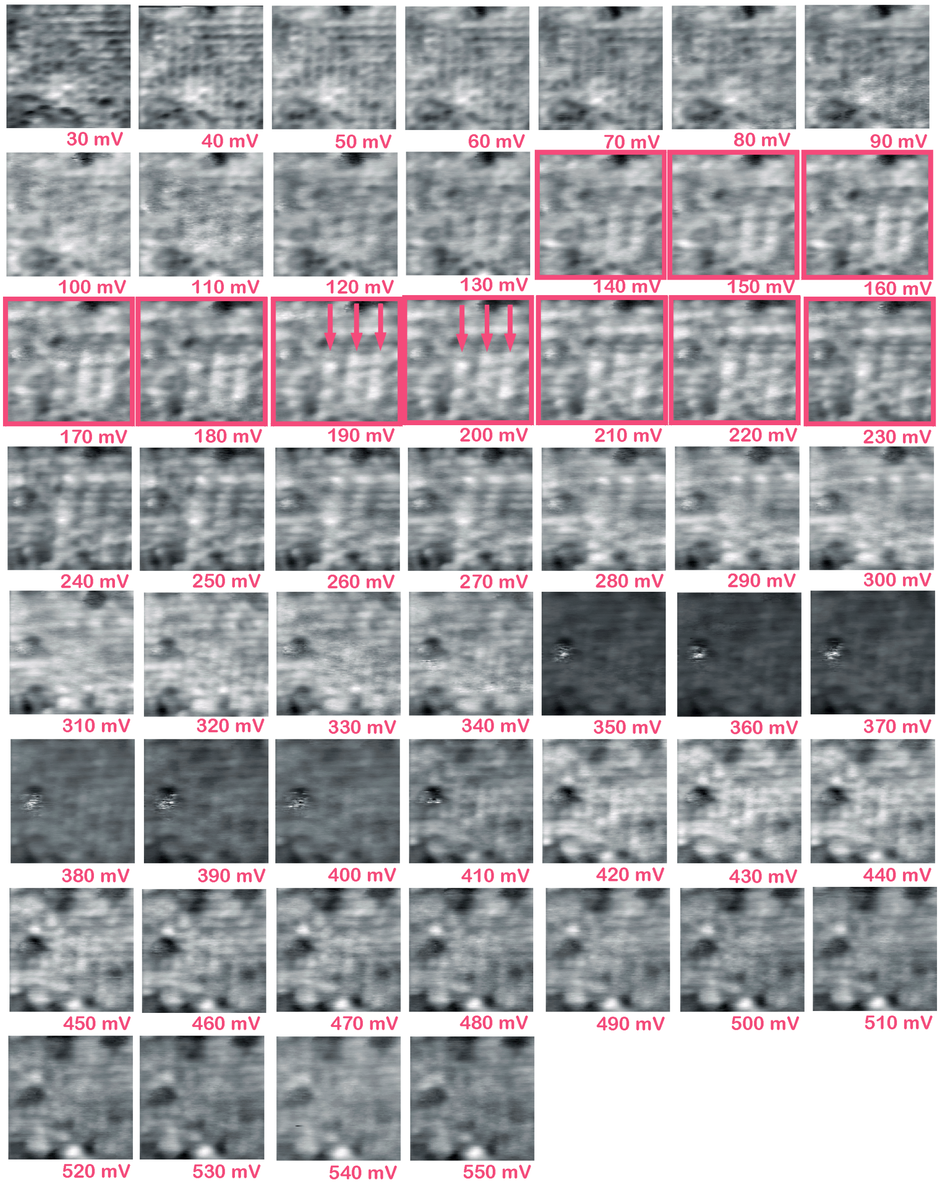

Fig.34

Sequence of dI/dV area maps for positive voltages ranging from +30 mV to +550 mV with a step width of +10 mV. Around +200 mV in the dI/dV area map the intensity is maximum (marked by red frames and arrows) . This can be explained from the existence of a standing wave at the band gap edge.

At negative voltages (the topography image sequence starting at –20 mV till –455 mV is shown on *Fig.35*) there is no change in topography from `bump` to `zigzag` row structure appearance.

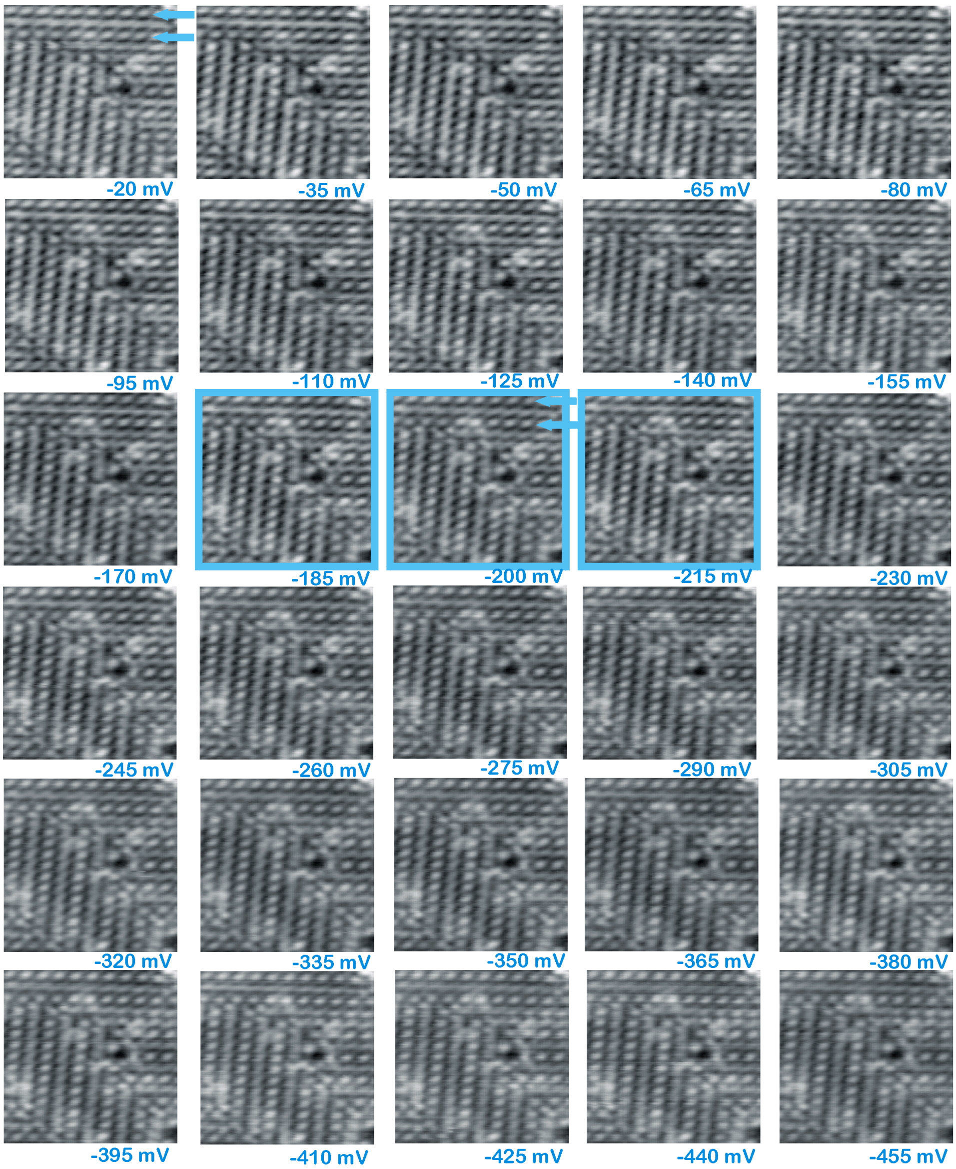

Fig.35

Sequence of topography images for the negative voltages ranging from -20 mV to -455 mV with a step of -15 mV. At -200 mV no change from `bump` to `zigzag` row appearance is observed (marked by the blue frames and arrows).

The dI/dV area maps for negative voltages are shown in *Fig.36*. Again the observed wave pattern is voltage dependent, the most pronounced change one can see by comparing the map for -40 mV and -200 mV. The amplitude of the intensity is maximum at -200 mV (images around -200 mV are most clear). A shift of the wave pattern as in the dI/dV line maps is not observed in these area maps.

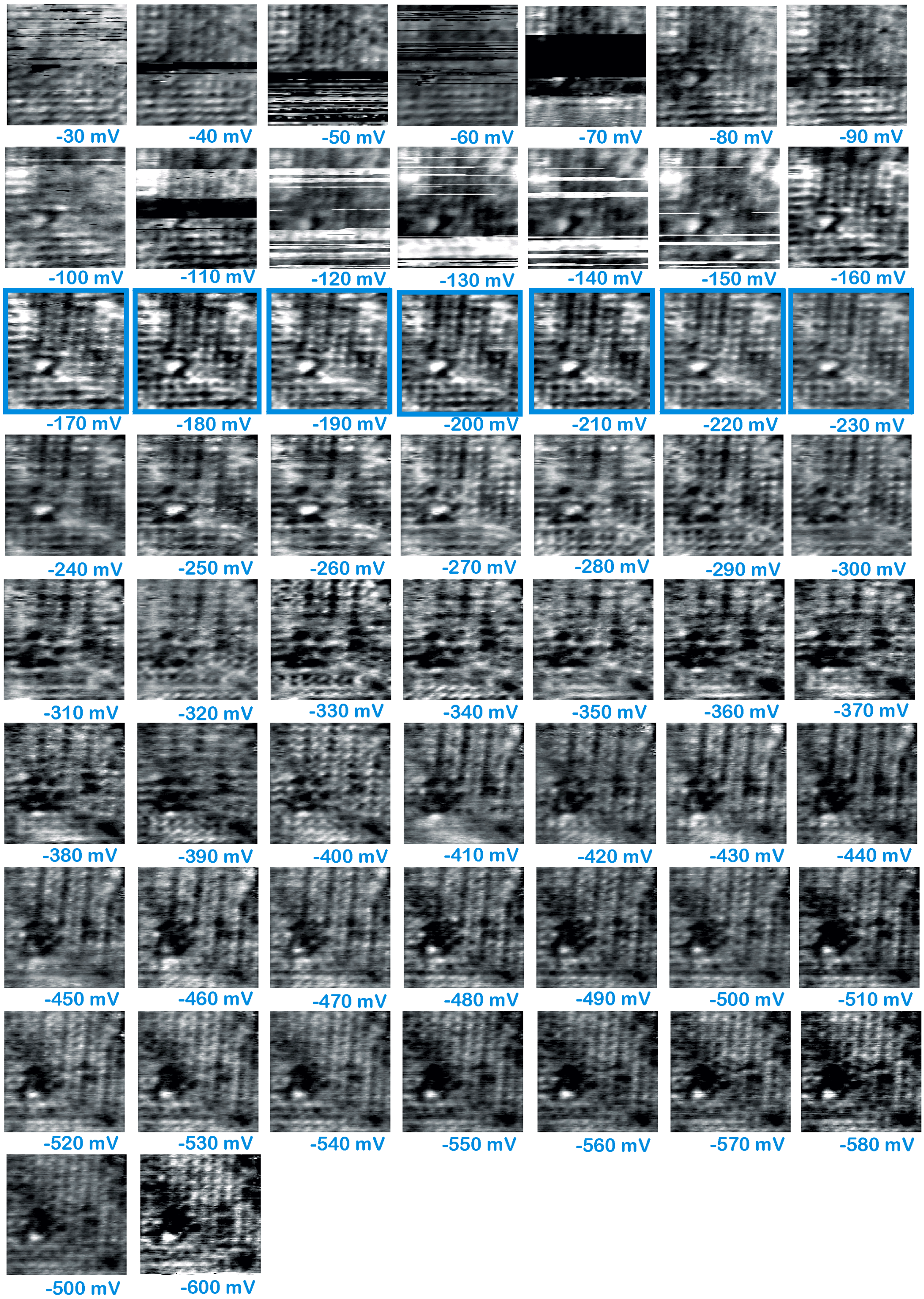

Fig.36

Sequence of dI/dV area maps for the negative voltages ranged from -30 mV to -600 mV with a step of -10 mV. With a blue frame the scans with more pronounced intensity are marked.

The fact that in the topography images and dI/dV maps at negative voltages the effects are less pronounced in comparison with topography and dI/dV maps for positive voltages can be explained with the fact that at negative voltages there are filled states below the Fermi level, and these states are more localized between the atoms. Unfilled states at positive voltages are less localized between the atoms and contribute more to the STM images [17], therefore the intensity is higher.

Also at negative voltages one cannot see the changes in the topography because the wave pattern is located in between the rows. The comparison of the topography image and the corresponding dI/dV area map is shown on *Fig.37* for positive voltages and on *Fig.38* for the negative voltages.

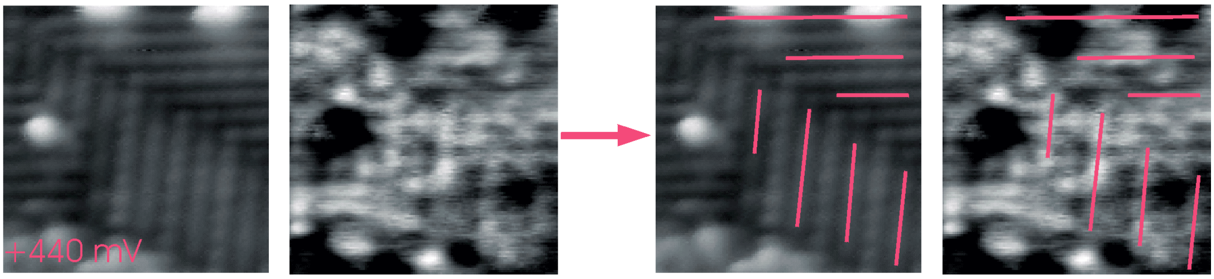

Fig.37

Topography image and a corresponding dI/dV area map taken at +440 mV. From the two right images it is clearly seen that the rows on the topography image (rows are marked with the pink lines) are corresponding to the maxima on the dI/dV area map.

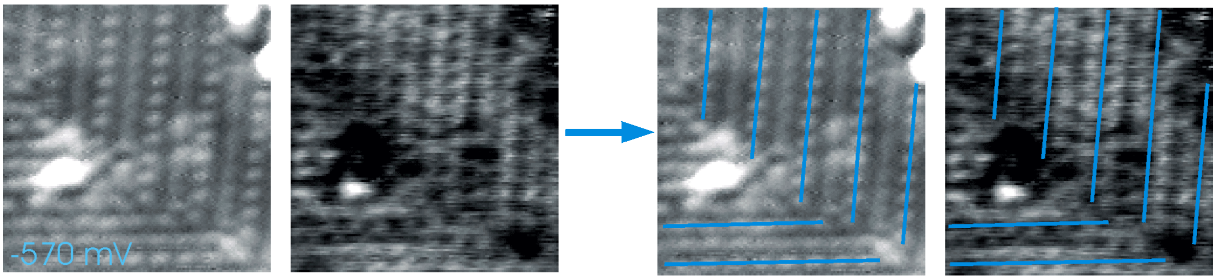

Fig.38

Topography image and a corresponding dI/dV area map taken at -570 mV. From the two right images it is clearly seen that the rows on the topography image (rows are marked with the blue lines) correspond to the minima on the dI/dV area map.

Comparing topography image and the dI/dV area map for the negative voltage one can clearly see that the intensity maxima on the dI/dV area maps occur in the areas which correspond to the interrow positions in the topography images. Comparing the same images for positive voltages, one can see that the wave pattern is located on the rows. That is why it is possible to see the `bump` - `zigzag` change in the row appearance.

In conclusion, all the observed spectroscopy features, i.e. plateaus or shoulders which are observed at point spectroscopy, phase shifts observed in the dI/dV line maps, changes in topography and the contrast inversions in the dI/dV area maps are the sign of an existence of a charge density wave at the low temperature phase of $\alpha - Ga$ (010).