ESRF	**Experiment title:** Shape evolution of non-capped and buried AlGaAs/GaAs double quantum ring structures	**Experiment number**: HS-3489
Beamline: ID10B	**Date of experiment**: from: 08.04.2008 to: 15.04.2008	**Date of report**: 17.04.2008
Shifts: 15	**Local contact(s)**: Dr. Oleg Konovalov	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Dr. Michael Hanke* — Martin-Luther-University Halle-Wittenberg, Hoher Weg 8, D-06120 Halle/Saale, Germany

Dr. Martin Schmidbauer* — Institute for Crystal Growth, Max-Born-Str.2, D-12489 Berlin, Germany

Dr. Peter Schäfer* — Humboldt-University Berlin, Newtonstraße 15, D-12489 Berlin, Germany

Report:

An interesting development in the self-assembly of semiconductor nanostructures is the growth of quantum rings (QRs) [1], and recently even more sophisticated double quantum ring (DQR) structures [2]. QRs (in particular those with a chemical composition, which depends on the angular position) can be considered as intermediate stages on the trace towards quantum dot molecules – structures, which are frequently discussed as building blocks for future quantum computational devices.

The DQRs for the the study are formed on GaAs(001) substrates by droplet epitaxy [2]. They evolve on an AlGaAs buffer layer from initial metallic Ga droplets (corresponding to 1, 1.5, 2 and 2.5 monolayers) under As_4 flux at 300°C, which causes an indeed remarkable change in topology, such that the original lens-like droplets acquire a hole in their centre and eventually take on a double ring shape. Such a transition is certainly accompanied by interdiffusion, so that the DQRs eventually consist of (Al,Ga)As. Further the micrograph in fig.1(a) indicates slight thickness variations within each individual ring, which are probably related to surface anisotropy. Besides the DQRs shown in fig.1(a) a set of non-capped and covered DQR samples with different DQR heights (1.5 to 7.3 nm), corresponding to different subsequent stages has been investigated.

The formation of DQRs quite generally relies on the mutual impact of the three-dimensional chemical composition (and hence) strain profile in conjunction with crystallographic anisotropy. This common mechanism applies, however, in particular for detailed low-dimensional nanostructures. Nonetheless in contrast to single QRs (which can be explained as a result of a collapsing Ga droplets under As_4 flux), it is not clear yet, how the DQRs evolve and how their shape may change during an overgrowth step. Those structures on the other hand are quite interesting especially from an applicational point of view, since optical modes may couple between the concentric rings within a DQR.

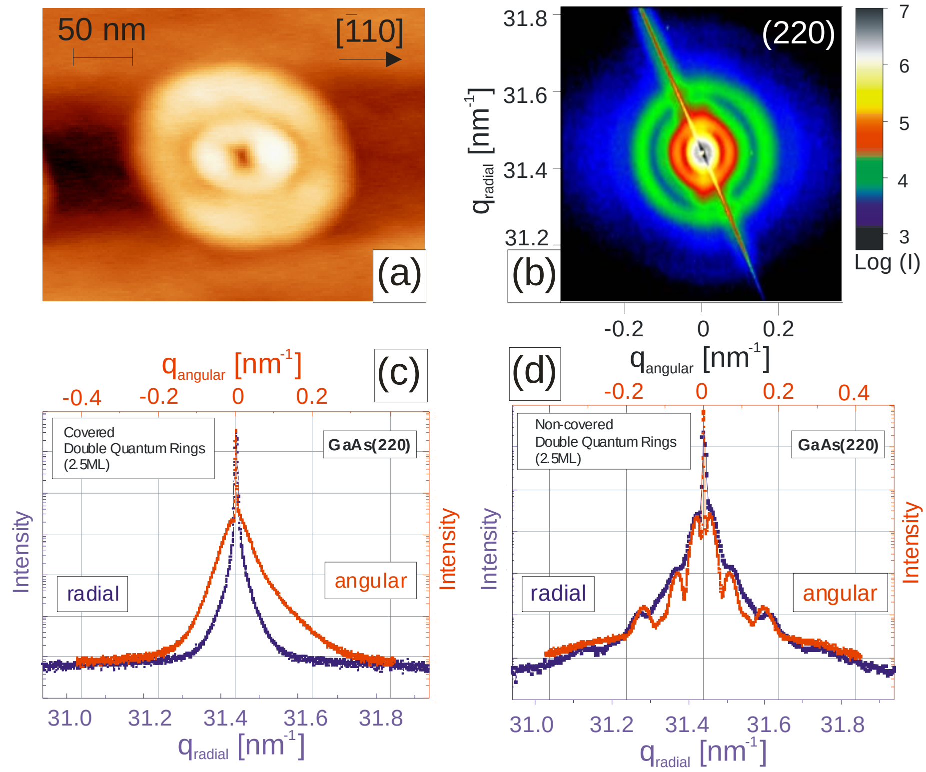

Fig.1: Atomic force micrographs of non-capped (Al,Ga)As/GaAs(001) double quantum ring structures grown by molecular beam epitaxy, grazing incidence diffraction around the (220) reflection (b) and corresponding radial and angular intensity profiles (d). The absence of any sub-structure for the buried DQR sample (c) indicates a dissolving of zero-strain DQR during overgrowth.

Fig.1(a) gives an atomic force micrograph of a non-covered DQR and the corresponding intensity distribution near the grazing incidence (220) reflection (b). Since the circular shaped distribution figures fully centro-symmetric around the substrate reflection we could prove the absence of elastic strain inside the DQR. This observation is well confirmed in (d) while both the radial (strain-sensitive) and angular (strain-insensitive) direction show basically the same behaviour, which is solely due to the DQR shape. Similar shape dependencies have been found at further DQR structures with different heights and amounts of (Al,Ga)As.

Most surprizingly we could not probe any signal due to buried DQRs. Fig.1(c) gives one example for the radial and angular direction through a GaAs(220) in-plane GID distribution, an effect which is probably due to the rather small strain within the buried (Al,Ga)As DQRs.

We may appreciate the assistance of Oleg Konovalov (ESRF) for his help during the experiment.

References:

[1] M. Hanke et al., Appl. Phys. Lett. **91**, 043103 (2007), **cover image**

[2] Z.Y. AbuWaar et al., Jour. Appl. Phys. **101**, 024311 (2007)