ESRF	**Experiment title:** **XAFS study of GeSi heterosystems with QDs modified by addition of metal impurities (Mn, Ag)**	**Experiment number**: MA-3675
Beamline: **BM20**	**Date of experiment**: from October 17 to October 24(22), 2017	**Date of report**: 16.02.2018
Shifts: **21(15)**	**Local contact(s)**: Kvashnina Kristina	*Received at ESRF:*

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Report:

The discovery of a ferromagnetic semiconductor (FMS) may provide potential advantages of new device functionality and low power dissipation in semiconductor and spintronic applications[1, 2], due to the unique ability to control ferromagnetism through an electric field. Mn-doped Ge FMS has attracted special attention because of its compatibility with mature Si microelectronics technology and the potential to have a higher Curie temperature (Tc) than that of group III–V materials[1].

Based on the results obtained during the MA-3675 experiment on the BM20, a study of the microstructure and element composition of multilayer Ge/Si containing quantum dots (QDs) was carried out in the framework of the methods XANES and EXAFS spectroscopy.

The microstructure of the samples obtained as a result of irradiation of Ge quantum dots (QDs) by ions in a silicon matrix was analyzed. For the first time, from an analysis of the shape and position of MnK XANES spectra reliably established that manganese in the sample is essentially positively charged. From the analysis of the GeK EXAFS spectra, a significant presence of Mn in the first sphere of the Ge environment is determined (coordination numbers and interatomic distances are determined). Thus, for such systems, direct contacts of germanium atoms with manganese ions were first discovered.

The other kind of systems were obtained by the method of simultaneous molecular beam epitaxy (MBE) of Ge and Mn under different synthesis conditions, in particular, ensuring different impurity content of Mn. From the analysis of the GeK EXAFS spectra, coordination numbers and interatomic distances were determined. In all samples, intensive mixing of Ge / Si atoms was found, in a ratio close to 50/50.

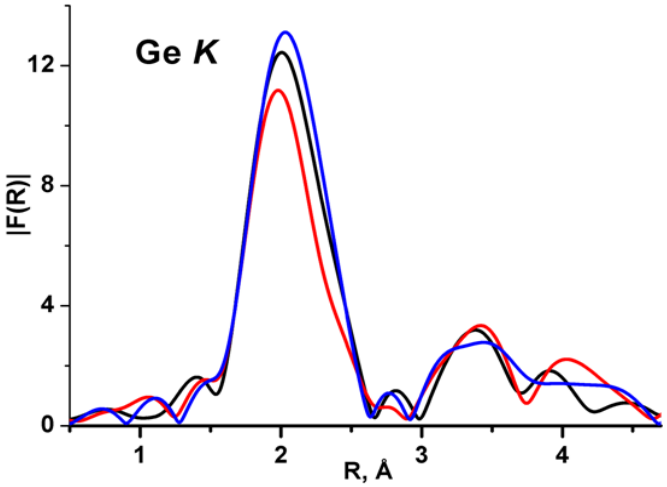

Figure 1. Fourier transform magnitude |F(R)| without phase shift corrections of $k^2\chi(k)$ for Ge K EXAFS spectra of samples containing GeMn QDs with different growth temperatures: blue line - 400°C; black line - 500°C; red line - 550°C.

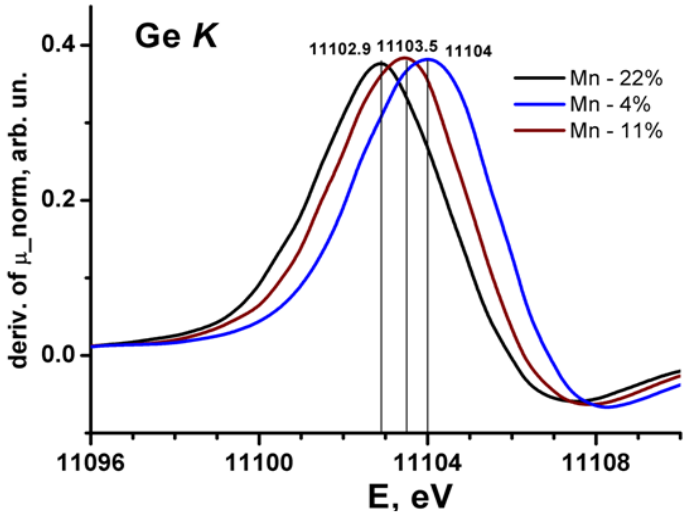

Figure 2. First derivatives of Ge K experimental normalized XANES spectra for samples GeMn ODs with different concentrations of manganese: blue line – 4%; brown line – 11%; black line – 22%.

The degree of diffusion correlates with the temperature growth of QDs (400°C-550°C). Correlations of the coordination numbers Si and Mn in the Ge sphere were established with the temperature of QDs growth (Fig.1) and with other synthesis conditions, in particular resulting in a change in the amount of manganese in the QDs. Analysis of XANES spectra showed that the charge state of germanium in the samples also is very sensitive to the synthesis conditions: to the manganese content (Fig. 2), to the presence of a protective low-temperature Si coating, and also to the synthesis temperature.

An attempt was made to investigate the nanostructures with Ag for plasmonics on the steps in the process of formation Ag nanoislands over the epitaxial structures Ge/Si containing QDs. From the studies of the *K*Ge EXAFS and XANES spectra, no effect was observed of the presence of surface silver on the GDs microstructure.

Unfortunately, we were not able to complete our experiments in full, because of the lack of a beam, beginning in the morning of October 22 until the morning of October 24.

References

[1] F. Xiu, Y. Wang, J. Kim, H. Augustin, J. Tang, A. P. Jacob, J. Zou and K. L. Wang, Nat. Mater., 2010, 9, 337–344.

[2] T. Nie, J. Tang, X. Kou, Y. Gen, S. Lee, X. Zhu, Q. He, L.-T. Chang, K. Murata, Y. Fan and K. L. Wang, Nat. Commun., 2016, 7, 12866.