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Single Carrier Spectroscopy of Bisolitons on Si(001) Surfaces

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Switching an elementary excitation by injecting a single carrier would offer the exciting opportunity for the ultra-high data storage technologies. However, there has been no methodology available to investigate the interaction of low energy discrete carriers with nano-structures. In order to map out the spatial dependency of such single carrier level interactions, we developed a pulse-and-probe algorithm, combining with low temperature scanning tunneling microscopy. The new tool, which we call single carrier spectroscopy, allows us to track the interaction with the target nanostructure with tunneling carriers on a single carrier basis. Using this tool, we demonstrate that it is possible not only to locally write and erase individual bi-solitons, reliably and reversibly, but also to track of creation yields of single and multiple bi-solitons. Bi-solitons are pairs of solitons that are elementary out-of-phase excitations on anti-ferromagnetically ordered pseudo-spin system of Si dimers on Si(001)-c(42) surfaces.

We found that at low energy tunneling the single bisoliton creation mechanism is not correlated with the number of carriers tunneling, but with the production of a potential hole under the tip. An electric field at the surface determines the density of the local charge density under the tip, and band-bending. However a rapid, dynamic change of a field produces a potential hole that can be filled by energetic carriers, and the amount of energy released during filling process is responsible for the creation of bi-solitons. Our model based on the field-induced local hole gives excellent explanation for bi-solion yield behaviors. Scanning tunneling spectroscopy data supports the existence of such a potential hole. The mechanism also explains the site-dependency of bi-soliton yields, which is highest at the trough, not on the dimer rows. Our study demonstrates that we can manipulate not just single atoms and molecules, but also single pseudo-spin excitations as well.