Towards Self-Assembled Molecular Nanodielectrics on Ge and GaAs

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(1) IM2NP, CNRS UMR 7334 Aix-Marseille Université, ISEN-Toulon, Maison des Technologies, Pl. G. Pompidou F-83000 Toulon, France
(2) Laboratory of Innovation in Surface Chemistry and Nanosciences (LICSEN), DSM/IRAMIS/NIMBE CEA Saclay, F-91191 Gif-sur-Yvette Cedex, France
(3) Aix-Marseille Université, CINaM UMR CNRS 7325, case 913, 13288 Marseille cedex 09, France
contacting e-mail: virginie.gadenne@isen.fr, lionel.patrone@im2np.fr

Abstract

In the field of microelectronics, due to their high intrinsic mobility, germanium (Ge) and III-V semiconductors appear as promising alternative channel materials to replace silicon in the next generation of high mobility and high frequency transistors. However, contrary to silicon dioxide, those material oxides are neither stable nor of good quality. Preparing proper interfacial layer allowing to passivate and insulate Ge and III-V is one of the challenges still needed to be addressed. A promising way consists in using self-assembled molecular monolayers (SAMs) with a high dielectric constant, since it leads to uniform and nanostructurally well-defined robust thin film over large areas. It has been developed on silicon [1] but still remains to be applied on Ge and III-V.

Therefore, the aim of this work is to design new SAMs grafted on Ge and GaAs exhibiting the best properties of insulation and passivation. Since thiol molecules have been shown to form SAMs on Ge [2] and GaAs [3], we use alkyl/ fluorinated/ and conjugated -thiol molecules. Specially synthesized conjugated molecules bear thiophene units either with a bithiophene-based push-pull polarizable molecule or a terthiophene-based model compound since push-pull monolayers are able to form a highly polarizable insulating film with dielectric constant (k = 7-8) significantly higher than that of silicon dioxide (k = 3.9) [1]. Obtained SAMs are first evaluated regarding their structure and organization. Moreover, since the interface has a direct influence on the electrical characteristics, it is essential to limit surface roughness to obtain a better interfacial layer with low defects. For this reason, as confirmed by scanning probe microscopy we have successfully developed a grafting process without acid treatment, contrary to most of Ge functionalization methods exploited in the literature, either in one-go [2], or within two steps, i.e., oxide removal followed by SAM grafting.

The passivation ability of the various SAMs is first assessed by following by XPS the oxidation of Ge or GaAs surface functionalized by dodecanethiol and perfluorodecanethiol SAMs. Second, the electronic properties and insulation characteristics of the various SAMs (conjugated and alkyl or fluorinated with and without inserted conjugated molecules) are investigated by current-voltage and capacitance-voltage measurements, either at the nanoscale using scanning tunneling microscopy or at the microscale using eutectic GaIn electrical contacts, and analyzed notably by transition voltage spectroscopy [4]. We believe these results will help paving the way to developing new alternative high k dielectrics for the future generation of transistors.

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