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Towards self-assembled nanodielectrics on Ge

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The aim of this work is to design new self-assembled molecular monolayers (SAMs) grafted on Ge exhibiting the best properties of insulation and passivation as Self-Assembled Molecular Nanodielectrics (SANDs)[1]. We used thiol molecules that have been shown to form SAMs on Ge[2], with either alkyl/fluorinated/or a conjugated part with specially synthesized bithiophene-based push-pull molecules. Indeed, thanks to their dipole that can be aligned by the SAM deposition strategy, such chromophores are able to form highly polarizable insulating films 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. 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. The passivation ability of the various SAMs is assessed by XPS to follow the oxidation of Ge surface functionalized by dodecanethiol and perfluorodecanethiol SAMs. The electronic properties and insulation characteristics of the various SAMs are investigated by current-voltage and capacitance-voltage measurements, at the nanoscale using scanning tunneling microscopy and at the microscale using electrical contacts - either Joule evaporated using an interfacial protective layer such as Alq3 that has been characterized, or softly deposited using GaIn droplets - and analyzed notably by transition voltage spectroscopy[3] in correlation with UPS spectroscopic analyses. Further work will address multilayers of aligned organic molecules. 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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NANOELECTROMECHANICAL SWITCHES: Opportunities and Challenges

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Abstract

Nanoelectromechanical relays are actuated by applying a potential difference between a fixed electrode and a movable electrode which are separated by an air gap. Therefore, they have an infinitely on-off transition and, virtually zero leakage current. Their intrinsic hysteresis behavior can be used as advantage for non-volatile applications, such as look up table, data searching, nonvolatile SRAM, reprogrammable logic FPGAs and etc. NEMS relay can be fabricated with low-temperature process, consequently they are CMOS compatible. Therefore, nanoelectromechanical switches can be exploited to obtain highly hybrid energy efficient circuit. However, NEM relays still have some major roadblocks. They present a mechanical delay which physically cannot be below 1-10ns, limiting their performance. Scalability is also an issues, to keep a low voltage is often required to increase the device size. They also shows a poor endurance (~10^6) and low reliability caused mainly by the contact surface variation during cycling.
In this poster, we will present a study on NEMS relay potential as a nonvolatile element in energy-efficient applications and discuss scaling considerations for hybrid CMOS-NEM circuit.

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NEED for IoT

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Anticipate and support sustainable transition in nanoelectronic industries.

NEED for IoT develops research methods and advanced demonstrators for connected objects and their components, integrating an economic analysis that includes the acceptability and sustainability of the proposed new solutions.

With the exponential growth in the number of connected objects, estimated at 20 billion devices by 2020, access to raw materials becomes a major economic and geopolitical stake for the field of nanoelectronics. The ambition of this project is to develop the organizations and technologies that underpin sustainable nanoelectronics by using considerably less or even substituting critical materials in key IoT devices such as sensors, memories, optoelectronic and spintronic devices.

CHALLENGES

The environmental and social impact of the objects serving an IoT use has never before been studied, neither regarding the design nor the risk of supply chain disruptions. Some of the raw materials used for IoT are becoming rare and therefore expensive. Thus, there are major stakes to study how to replace some of these materials by others that are more accessible, and also to better understand the value chain by comprehensively integrating disruption risks.

INTERDISCIPLINARITY

A main goal of the NEED for IoT project is to achieve a better understanding of research practices to facilitate the evolution towards sustainable thinking and propose new technologies for IoT accordingly. This requires an interdisciplinary approach which involves: supply chain studies to develop predictive tools in anticipation of strategic evolutions, social sciences to anticipate and adapt to a rapidly evolving context, materials and engineering sciences to propose new technological solutions, etc.

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PROJECT'S ORGANIZATION...

The project develops methodologies applied to advanced research integrating economic analysis, geopolitics issues, and the acceptability and durability of new technological solutions. It will develop a global approach for the design of products for IoT and their components, the technological processes and the management of the innovation. The project proposes disruptive solutions and methodologies to push the development of an alternative economic sector which values sustainable raw materials.

... AND ITS INTERNATIONAL VISIBILITY

Sustainable technologies are developed in several institutions around the world. France and Europe bring together manufacturers of different sizes and research teams that need to work together to maintain their leadership in the sector. NEED for IoT aims at offering integrable solutions for sustainable electronics and opportunities for its partners, so they develop a leading position to maintain the competitiveness of the European electronics industry against global competitors.

The project's goal is to stimulate effective cross-disciplinary efforts by integrating academic and industrial communities that share a common economically realistic vision of what sustainable electronics could be. Grenoble, with its highly advanced research facilities, universities, and leading industries, is well positioned to become the pilot of a European network on these topics, giving a real benefit for national and European industry players in the field of IoT devices.

7.7 M€ consolidated budget

PARTICIPATING RESEARCH DEPARTMENTS

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NEED for IoT

Univ. Grenoble Alpes

Anticiper et soutenir la transition durable dans les industries nanoélectroniques

Le projet NEED for IoT développe des méthodes de recherche et des démonstrateurs technologiques avancés pour les objets connectés et leurs composants, intégrant une analyse économique incluant l'acceptabilité et la durabilité des nouvelles solutions proposées.

Avec la très forte croissance du nombre d'objets connectés, estimé à 20 milliards objets en 2020, l'accès aux matières premières devient un enjeu économique et géopolitique majeur pour le domaine de la nanoélectronique. L'ambition du projet NEED for IoT est de développer les organisations et technologies qui sous-tendent une nanoélectronique durable en réduisant l'utilisation ou en substituant les matériaux critiques utilisés dans les dispositifs clés de l'IoT tels que les capteurs, les mémoires, les dispositifs optroniques et spintroniques.

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LES ENJEUX

La conception et la réalisation des composants pour les objets connectés doit prendre en compte, outre les progrès scientifiques et technologiques, les exigences environnementales et sociétales, actuelles et à venir. Certaines des matières premières utilisées actuellement deviennent rares et donc chères. Il y a donc des enjeux majeurs économiques, écologiques et sociétaux pour remplacer certains de ces matériaux par d'autres plus accessibles, et ainsi mieux maîtriser la chaîne de valeur dans sa globalité en intégrant les préoccupations du consommateur à l'industriel.

L'INTERDISCIPLINARITÉ

L'objectif principal est de parvenir à une meilleure compréhension des pratiques de recherche afin de faciliter l'évolution vers la pensée durable et de proposer de nouvelles technologies pour l'IoT. Cela ne peut se faire que par une approche interdisciplinaire qui implique : la chaîne logistique pour développer des outils prédictifs anticipant les évolutions stratégiques, les sciences sociales pour favoriser l'adaptation à un contexte en évolution rapide, les sciences de la matière et l'ingénierie pour proposer de nouvelles solutions technologiques.

LABORATOIRES IMPLIQUÉS

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LA STRUCTURATION DU SITE...

Le projet développera des méthodologies appliquées au domaine en plein essor de l'internet des objets intégrant l'analyse économique, les enjeux géopolitiques, l'acceptabilité et la pérennité des nouvelles solutions technologiques. Il mettra en œuvre une approche globale pour la conception de dispositifs connectés, les processus technologiques et la gestion de l'innovation. Il propose des méthodologies nouvelles pour favoriser les transformations nécessaires à l'émergence de solutions durables dans le domaine de la nanoélectronique.

... ET SA VISIBILITÉ INTERNATIONALE

Les technologies durables se développent dans plusieurs institutions dans le monde entier. La France et l'Europe rassemblent des industriels de différentes tailles et des équipes de recherche qui ont besoin d'être mobilisés conjointement afin de maintenir leur leadership dans la filière. Le projet présente l'ambition de proposer des solutions intégrables pour l'électronique durable et offre la possibilité à ses partenaires de développer une position de premier plan afin de maintenir la compétitivité de la filière électronique européenne face aux concurrents mondiaux.

En occupant un domaine de recherche interdisciplinaire promis à un développement rapide, le projet NEED for IoT permettra de promouvoir le pôle grenoblois au niveau européen en favorisant de nouvelles collaborations à caractère interdisciplinaire. À terme, Grenoble peut devenir le pilote d'un réseau européen sur ces thématiques, ce qui constitue un réel avantage pour les acteurs industriels nationaux et européens du domaine des objets connectés.

7,7 M€ budget consolidé

PÔLES DE RECHERCHE IMPLIQUÉS

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Ferrocenyl Triazole derivatives: Interesting candidates for application in molecular electronics

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Rectification of current by molecules is a subject that attracts many attentions nowadays because it would permit to reduce the size of the electronic devices. Theorized by Aviram and Ratner, the rectification can be achieved by an asymmetric molecule, enabling the electrons to be transferred in a preferential direction through the molecule. The state of the art of the organic molecular rectifiers shows rectification ratios up to 10^5. Such rectification ratios were obtained with molecules composed of a ferrocene, which is the key of the rectification process, linked to an insulating alkyl chain. At present, few studies have been devoted to control the orientation of the molecular rectifiers, relative to the electrode. More precisely, the possibility to anchor the molecular rectifier to the two electrodes while controlling the orientation has only been scarcely investigated. In our case, such a control of the molecular orientation has been obtained by developing a two-step process based on Click Chemistry.

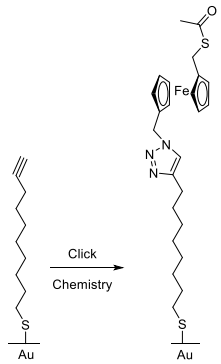

Figure: Importance of position of ferrocene in the rectification

Here, we present unprecedented works on the synthesis of new ferrocene derivatives designed as molecular rectifiers. Especially, a special effort is devoted: firstly, to allow the molecule to be covalently linked to two metal electrode and secondly to definitely control the orientation of the molecular rectifier relative to the electrode.