Manuel Cardona Conferences

This series of Conferences offer the opportunity to interact with some of the most prominent researchers in nanoscience-related fields. At the same time, they are a tribute to Prof Manuel Cardona, a key figure in the history of this Institute.

Luigi Colombo
Texas Instruments Inc.
Dallas, Texas, USA

Monday March 9, 2015, 12:00h

ICN2 Seminar Hall
ICN2 Building, UAB

Short Bio

Luigi Colombo is a *Texas Instruments Inc.* (TI) Fellow responsible for research and development of new materials and devices for analog and logic applications at Texas Instruments. He joined TI in 1981 to work on infrared detector materials where among other materials he performed research on II-VI compounds and developed a HgCdZnTe liquid phase epitaxy process which he also put in production in 1991, and it is still in production today. Since then he has been responsible for the development of high-k capacitor MIM structures for DRAMs, research & development of SiON/poly-Si and Hf-based high-k gate/metal transistor gate stacks for the 45 nm node. He is currently responsible for the development of new materials such as graphene and its integration in new device flows for new devices as part of the Nanoelectronics Research Initiative.

The speaker has also developed the first CVD graphene process on Cu in collaboration with UT Austin. He has authored and co-authored over 140 refereed papers, made over 160 invited and contributed presentations, has written 4 chapters in edited books, and holds over 109 US and international patents. He is a member of the APS, IEEE, ECS, and MRS. He is also an IEEE Fellow, APS Fellow, and is an Adjunct Professor in the Department of Materials Science & Engineering at the University of Texas at Dallas.

Don't miss this opportunity to know him personally!

2D Materials Growth:
Prospects and Challenges

Luigi Colombo
Texas Instruments Incorporated, Dallas, TX

The isolation of graphene[1] now almost a decade ago has given rise to the revitalization of an old full set of materials, two-dimensional materials (2DM), that have exceptional electrical, chemical and physical properties. Some of the materials under investigation in addition to graphene are hexagonal boron nitride (h-BN), semiconducting, metallic, and superconducting, transition metal dichalcogenides (TMD) with a general chemical formula, MX_2 where M is for example equal to Mo, W, Ta, Nb, Zr, Ti, and X = S, Se and Te, and others. While h-BN is an excellent 2D insulator, TMD materials provide what neither graphene nor h-BN can, bandgap engineering that, in principle, can be used to create devices that cannot be fabricated with h-BN and graphene. A number of devices are being investigated today to try to address the problem of power dissipation in integrated circuits; however, while there are aspects of these devices that are attractive no device has come out as a clear winner yet. There is also hope that materials can be used for numerous other device types in addition to replacement of the switch, e.g. inkjet printing, photonic applications, flexible electronics, etc. However, whether the materials are going to be used for high performance integrated circuits or other less demanding applications, **before the engineering community can develop these products that use 2DM, basic material properties for each application needs full definition so as to select and develop the most appropriate techniques for material preparation and growth.**

A number of deposition techniques have been used to prepare large area graphene, growth on SiC through the evaporation of Si at high temperatures[2], precipitation of carbon from metals[3], and chemical vapor deposition on Cu[4]. Direct growth of good quality graphene on dielectrics/semiconductors other than SiC has only been reported recently on Ge[5], but not on others. Considering that before 2004 only small flakes of isolated graphene could be grown, the community has made significant progress on large area continuous graphene films on Cu and Ge[6]. In addition, there are numerous chemical exfoliating techniques used to form graphene with a range of sizes[7]. CVD graphene and graphene on SiC have been shown exceptional transport properties, equivalent to the best graphene exfoliated from mined graphite. Thin film growth of h-BN on the other hand has been found to be more difficult than graphene nevertheless there are many reports on large area growth on metals but the quality is still not equivalent to h-BN exfoliated from “bulk grown h-BN” when used as a substrate or as a gate dielectric for graphene devices.

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Transition metal dichalcogenides present altogether different opportunities and difficulties in the preparation of low defect density large area single crystals. Of the many TMDs to select from, a lot of attention has been dedicated to MoS_2 because of its long history in rheological applications and availability of naturally occurring crystals and at this time it is used as a platform for materials growth development techniques. Vapor transport, chemical vapor deposition, and molecular beam epitaxy are being developed to produce these materials for initial studies of materials physics device fabrication[8,9].

I will present the state of the art results of graphene, h-BN, and a few TMD materials and their prospects for future electronic device applications.

References

1. Novoselov, K. S. *et al.* Two-dimensional atomic crystals. *Proceedings of the National Academy of Sciences of the United States of America* **102**, 10451-10453, doi:10.1073/pnas.0502848102 (2005).
2. Berger, C. *et al.* Ultrathin Epitaxial Graphite: 2D Electron Gas Properties and a Route toward Graphene-based Nanoelectronics. *The Journal of Physical Chemistry B* **108**, 19912-19916, doi:10.1021/jp040650f (2004).
3. Karu, A. E. & Beer, M. Pyrolitic Formation of Highly Crystalline Graphite Films. *Journal of Applied Physics* **37**, 2179, doi:10.1063/1.1708759 (1966).
4. Li, X. S. *et al.* Large-Area Synthesis of High-Quality and Uniform Graphene Films on Copper Foils. *Science* **324**, 1312-1314, doi:10.1126/science.1171245 (2009).
5. Lee, J.-H. *et al.* Wafer-Scale Growth of Single-Crystal Monolayer Graphene on Reusable Hydrogen-Terminated Germanium. *Science* **344**, 286-289, doi:10.1126/science.1252268 (2014).
6. Lee, J. H. *et al.* Wafer-Scale Growth of Single-Crystal Monolayer Graphene on Reusable Hydrogen-Terminated Germanium. *Science* **344**, 286-289, doi:10.1126/science.1252268 (2014).
7. Bonaccorso, F. *et al.* Production and processing of graphene and 2d crystals. *Materials Today* **15**, 564-589 (2012).
8. Zhan, Y., Liu, Z., Najmaei, S., Ajayan, P. M. & Lou, J. Large-Area Vapor-Phase Growth and Characterization of MoS_2 Atomic Layers on a SiO_2 Substrate. *Small* **8**, 966-971, doi:10.1002/smll.201102654 (2012).
9. Lee, Y.-H. *et al.* Synthesis of Large-Area MoS_2 Atomic Layers with Chemical Vapor Deposition. *Advanced Materials* **24**, 2320-2325, doi:10.1002/adma.201104798 (2012).