nanoHUB.org – The ABACUS Tool Suite as a Framework for Semiconductor Education Courses

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***Abstract* — More than 170,000 users annually in 180 countries use nanoHUB.org for web-based access to simulation programs as well as a vast selection of related content, including online presentations and lectures, teaching materials, curated topic pages, podcasts, and downloads. With over 2300 resources including 193 simulation tools, the science gateway nanoHUB.org is the world's largest nanotechnology user facility. Over 10,000 research and educational users utilized nanoHUB's simulation programs to run over 364,000 simulations last year. In 2010, nanoHUB.org content was used in 135 undergraduate and graduate courses at 81 institutions. From the time of its inception, nanoHUB.org has been cited 719 times in the literature. Analysis of these citations indicated a dual-use of nanoHUB content in both education and research, with educational tools seeing usage by researchers and research tools migrating into the classroom. Taking leverage from the existing capabilities, we have developed the Assembly of Basic Applications for Coordinated Understanding of Semiconductors (ABACUS) suite of simulation tools and supporting educational content that can serve as an aid to an introductory semiconductor course.**

Index Terms – nanotechnology, simulation, nanoHUB, semiconductor education, science gateway.

I. Introduction

nanoHUB.org is a science gateway site, utilized for web-based research, education and collaboration in nanotechnology. Over 2300 educational and research-related resources are deployed on nanoHUB.org, including 193 simulation tools, 53 courses, 1589 online presentations (many available as Podcasts through nanoHUB.org as well as accessible through ITunes U), 395 teaching materials, and other content. From March 2010 to February 2011, over 170,000 users from 180 countries accessed nanoHUB.org [1]. We define a user as a logged-in, self-identified individual, an IP address that is using interactive seminar content for more than 15 minutes, or an IP address that downloads (not just views) a content item. nanoHUB is receiving 5 – 6 million web sites hits monthly. Most of our users come from academic institutions and use nanoHUB.org as part of their research and educational activities. But we also have users from national labs and from industry.

Access to nanoHUB.org is free, requiring only a simple registration process before utilizing simulation tools. One of the unique aspects of nanoHUB.org is its web-based structure, allowing powerful tools to be run from anywhere in the world through an ordinary browser window, utilizing a sophisticated backend to distribute the computational load to powerful computing resources at Purdue and on the grid. This structure allows for deployment of real research and production codes rather than simple java applets, providing both educational and research users non-typical access to real world code. nanoHUB.org also provides opportunities for collaboration through the use of shared tool sessions, workspaces, online meetings, group functionality, and wiki development pages. nanoHUB.org is breaking down barriers, allowing access to resources formerly available to only the elite few to anyone with access to a computer with a web browser, expanding educational opportunities to many.

II. Semiconductor Device Education Materials

Most Electrical Engineering programs typically offer courses related to the fundamentals of semiconductor devices. Concepts covered may include lattices, crystal structure, bandstructure, carrier distributions, drift, diffusion, PN junctions, solar cells, light-emitting diodes, bipolar junction transistors (BJT), metal-oxide semiconductor capacitors (MOS-cap), and metal-oxide semiconductor field effect transistors (MOSFETs). The Assembly of Basic Applications for Coordinated Understanding of Semiconductors (ABACUS) [2] has been put together from individual tools on nanoHUB.org to provide educators and students with a one-stop-shop in semiconductor education.

The ABACUS tool suite is supported by a main curated topic page [3], providing easy access to basic information related to the education concepts ABACUS was designed to enhance. Each tool in the ABACUS tool suite is further supported by its own topic page that includes related supplementary material for the tool. The intended audience for the topic pages includes both the instructors as well as students who would like to do some self-learning. The individual tool topic pages include the following:

(a) Objectives of the tool
(b) Recommended reading
(c) A video demonstration of the tool
(d) Links to theoretical background related to the tool
(e) Verification of the tool against analytical calculations
(f) Worked examples based on the tool
(g) A quiz based on the topic
(h) A real life problem pertaining to concepts learned

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Many of the tools in the ABACUS suite are also some of the most highly-used tools on nanoHUB.org. Usage statistics for the individual tools as well as for the tool suite itself are shown in Table 1. A user and the related simulations are counted based on how they access the tools. That is, if a user accesses the Crystal viewer tool through the ABACUS suite, he is counted as an ABACUS user. If another user accesses the Crystal Viewer tool directly, she is counted as a Crystal Viewer Tool User.

The ABACUS suite is comprised of the following simulation tools:

- Crystal Viewer Tool
- Piece-Wise Constant Potential Barriers Tool
- Periodic Potential Lab (Kronig-Penney)
- Band Structure Lab (Brilloin Zone)
- Carrier Statistics Lab
- Drift Diffusion Lab
- PN Junction Lab
- BJT Lab
- MOSCap
- MOSFet

Figure 1 illustrates a sample outline for a semester long course in semiconductor devices utilizing tools in the ABACUS suite while following a typical topic progression in semiconductor education [4].

III. Conclusions

nanoHUB.org is a growing nanotechnology community dedicated to both education and research. The ABACUS tool suite and supporting materials represent a unique resource for students and instructors, providing access to production level simulation code in an easily accessible environment along with supporting materials that provide the framework for a full-semester graduate level course in either a formal education environment or for self-learners. In the full paper, we will provide a detailed discussion of the use and impact of the ABACUS suite in education.

Acknowledgment

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References

[1] nanoHUB.org usage statistics, http://nanohub.org/usage.

[2] Xufeng Wang; Dragica Vasileska; Gerhard Klimeck (2010), "ABACUS - Assembly of Basic Applications for Coordinated Understanding of Semiconductors," DOI: 10254/nanohub-r5065.7. (DOI: 10254/nanohub-r5065.7).

[3] Gerhard Klimeck and Dragica Vasileska, "ABACUS – Introduction to Semiconductor Devices," http://nanohub.org/topics/EduSemiconductor.

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Tool Name	Annual Users	Sim. Runs	Total Users	Sim. Runs
ABACUS	1,020	2,835	2,252	10,645
Crystal Viewer Tool	826	5,632	2,093	16,144
Piece-wise Constant Potential Barrier	212	2,030	428	5,774
Periodic Potential Lab	257	2,041	801	8,571
Band Structure Lab	1,097	16	3,818	58,378
Carrier Statistics Lab	414	4,538	951	10,461
Drift-Diffusion Lab	351	1,928	987	9,739
PN Junction Lab	896	6,460	4,111	38,644
BJT Lab	373	565	809	4,408
MOSCap	602	3,781	1,963	20,093
MOSFet	517	9,910	2,959	43,260

Table 1 ABACUS Tool Usage Statistics

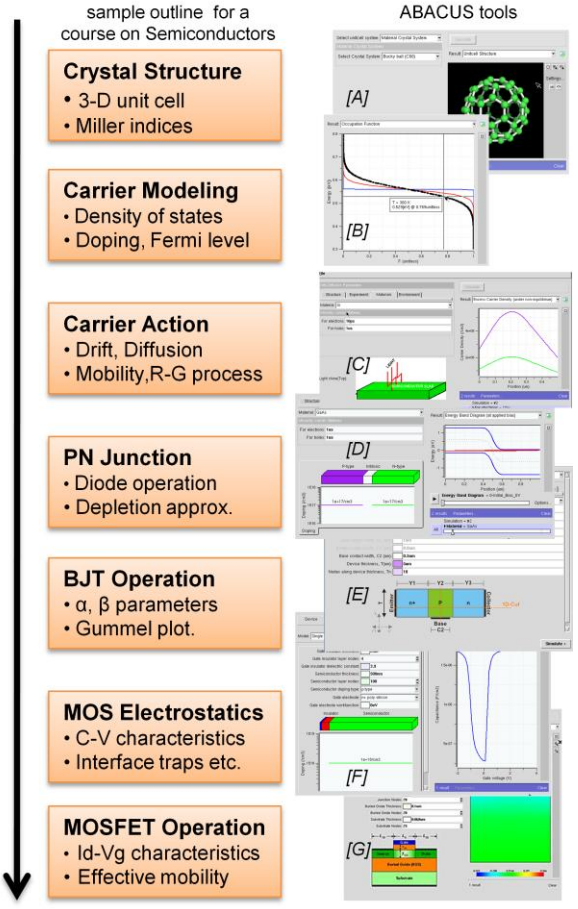

Figure 1 Sample outline for a course on Semiconductors along with related ABACUS tools.