RESEARCH REPORT

INTERNATIONAL RESEARCH COLLABORATION AND SCIENTIFIC PUBLICATION

ATOMISTIC STUDY OF MATERIAL DYNAMICS INDUCED BY LASER AND ION IRRADIATION

Year 3 from 3 years research duration

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1 Introduction

As electronic devices are getting smaller and smaller, the nano-fabrication technology has to be continually improved to operate in this scale with reliably high precision. In this order of size the fabrication is beyond the capability of conventional chemical etching techniques. This situation urge the exploration of new methods, among those are ion-assisted etching with *Focused Ion Beam*, femto-second laser ablation, and laser-assisted particle deposition [Gierak et al., 2001, Watt et al., 2005, Ahn et al., 2012]. However, the atomistic processes and mechanism occurs in nano-scale lithography are not completely explored. Those demanding applications trigger a more intensive study in the field of theory, computation, as well as experiment, with the expectation that more effective and economical method can be discovered.

From the theoretical point of view, the process occurs at surfaces is one of important discussions. Mechanisms at surfaces due to energy deposition by ion beam and photon (LASER) are still becoming question marks that have to be answered. Phenomenon, such as *Laser Induced Surface Structure* (LIPSS), has not been fully understood. Studies on this issue is still ongoing. Although the phenomenon is actually discovered more than a decade ago[Sipe et al., 1983, Zhakhovskii et al., 2008, Skolski et al., 2010].

With another method, ion-beam energy deposition induced also characteristic pattern on surfaces. Nevertheless, the mechanism is completely different compared to those induced by LASER. Some models have been proposed to explain the pattern formation, such as the Bradley-Harper theory [Bradley and Harper, 1988], and also a more recent *crater function* theory. These theories need to be examined in various conditions, in order to find out the limitations on different materials and different amount of energy deposition.

For a much smaller ion fluence, one finds a completely different mechanism. Here, the so called ion channeling plays role. The pattern induced by single ion has been able to visualized using recent microscopy technique, i.e. *Scanning Tunneling Microscopy*. The phenomena was discovered from both computational method and STM measurement [Redinger et al., 2010]. In this regime, it is discovered that the preexistent surface damage has important effects in ruling the damage at surface [Rosandi and Urbassek, 2006, Rosandi and Urbassek, 2007, Redinger et al., 2009].

The research collaboration funded by this KLN program of DIKTI has brought our broader view into the detailed mechanism in this subject. The collaboration that we carried out has become a very fruitful collaboration, which gives benefit to both of the institutions. We have to emphasize that the importance of our collaboration is due to the high requirement to perform the computational study and experiment, which is up to now inaccessible in Indonesia. We require high density processors in order to run atomistic simulations. The so-called *High Performance Computer* (HPC) is mandatory in our large scale simulation[1]. From experiment point of view, the atomic scale microscopy, such as STM, is not yet available in Indonesia. We have made collaborations with German universities, in order to have access to the frontier measurement instruments. Indeed we still can be able to analyze and do theoretical study in Indonesian university. As the

[1] In the world of Molecular-Dynamics, the scale is defined by the number of particles to simulate. Already hundreds of nano-meter length scale is too large for the computer to simulate.