Green Process Aiming at Reduction of Environmental Burden

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Through its Green Process activities, Fujitsu is reforming its manufacturing and production technologies using an evaluation method based on the Cost Green (CG) index, which covers both cost and environmental factors. Green Process activities were first introduced in 2002 at Fujitsu's Mie plant, a semiconductor manufacturing base that succeeded in reducing both its costs and environmental load. Green Process activities have already resulted in a reduction in the volumes of chemical inputs per unit product at semiconductor mass-production bases in Japan, for example, the Iwate, Aizuwakamatsu, and Mie plants.

1. Introduction

The Johannesburg Summit 2002 took place in 2002 to implement Agenda 21, a global action plan for sustainable development, with the participation of governmental, municipal, and business representatives from various countries. The Fujitsu Group has been recognizing environmental issues as important management issues and promoting environment-serving activities under the slogan of "We make every activity green." The Fujitsu Group developed environmental management concepts such as Green Management, Green Products, Green Factories, Green Solutions, and Green Earth and established a Fujitsu Group Environmental Policy. This environmental policy is intended to follow the trends in environmental activities of the world on a global scale and set guidelines for the achievement of sustainable development through the promotion of environmental management systems, environmental technologies, eco-friendly products and solutions, the Green Process, and volunteer activities. Based on these concepts and the environmental policy, the Fujitsu Group has set goals for environmental load reduction at manufacturing bases and implemented zero-emission of waste, reductions in chemical releases, and energy-saving measures. These activities are intended to reduce the environmental load output from manufacturing bases and have so far been promoted by the facilities and environmental management divisions. However, further reductions of environment load require 1) the control of input volumes in upstream processes and 2) a system to enable the manufacturing divisions of manufacturing bases to promote environmental activities at the points where resources and materials are received. Green Process activities are evolving in direct connection with the manufacturing processes and conform to the Ministry of Environment's policy for controlling the volumes of chemical inputs and building a society oriented toward resource recycling.[1)]

2. Outline of Green Process activities

Semiconductor manufacturing requires various resources (e.g., special gases and chemicals

and large amounts of energy), and as microfabrication technology progresses, there is a corresponding call for reductions in the environmental impact of the semiconductor industry. Currently, the entire industry is being asked to reduce its use of substances (in terms of volume) that have a big impact on the environment and its emission of greenhouse gases (e.g., carbon dioxide and perfluorocarbons).

Taking the lead in the industry, the Fujitsu Group started its Green Process activities to reduce its volumes of resource inputs and use of energy through periodic reviews of individual manufacturing lines and thereby reduce the environmental burden. In other words, the Green Process activities are intended to continuously implement environment-conscious manufacturing through the establishment of a system for equally evaluating important aspects of manufacturing such as function, quality, schedule, and cost together with the new aspect of "environment" (**Figure 1**). Moreover, the Fujitsu Akiruno Technology Center has introduced a Green Factory (environment-conscious factory) that is equipped as standard with resource-saving systems for purifying water and collecting and reusing chemicals and also energy-saving air-conditioning and heat-storage systems. Green Process and Green Factory activities will promote the integration of facilities with manufacturing and production technologies and also slow resource depletion, reduce manufacturing costs, and provide a managerial advantage. These activities are also welcomed by environment-conscious customers and are a big step toward achieving a recycling-oriented society.

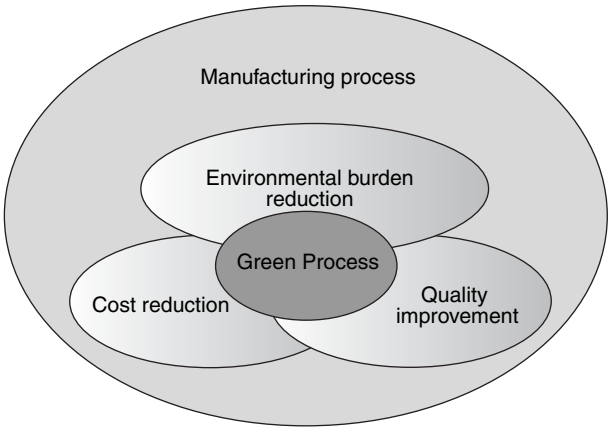

Figure 1
New evaluation index for manufacturing processes.

3. Features of Green Process activities

The Fujitsu Group began introducing Green Process activities to reduce the resource input-volumes and energy consumption at its manufacturing bases. These activities are a new effort by the Group and are the first of their kind in the industry. Up to now, the Group's manufacturing bases have saved energy and resources, recycled, and reduced chemical releases by 1) establishing an environmental management system (EMS); 2) obtaining ISO14001 certification; 3) achieving zero waste emissions; and 4) introducing outdoor air cooling, chilled/hot water storage, ice thermal-storage, and natrium-sulfur (NAS) batteries. Our conventional activities for environmental burden reduction were intended to design and develop Green Products that do not pollute the environment and have a reduced environmental burden. The Green Process activities being introduced distinctively extend the range of environmental burden reduction to include the chemicals, gasses, and energy that are used for product manufacturing.

Green Process activities have been implemented because recent progress in environmental protection has made it difficult to attain the detailed objectives of the activities through individual management of individual factories. Green Process activities in units of manufacturing lines are based on knowledge of the materials and energy required to manufacture each product and making it easy for engineers, assembly line operators, and other employees to understand the improvement goals in detail. Moreover, because Green Process activities aim to reduce both the

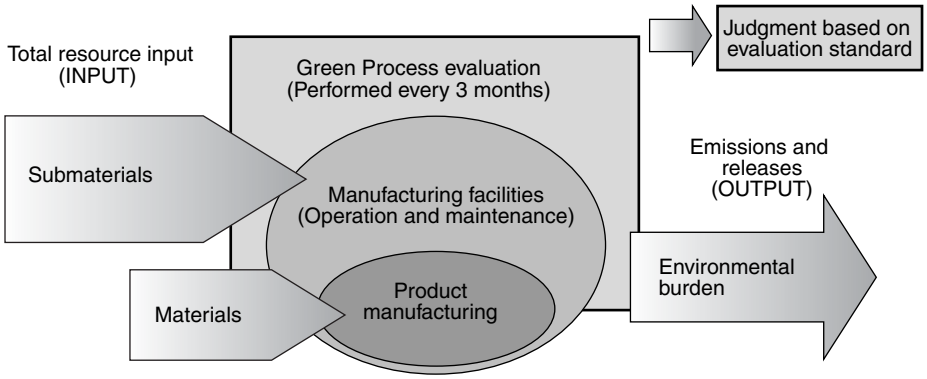

Figure 2
Outline of Green Process activities.

environmental burden and costs, they will characteristically lead to an improvement of our employees' environmental consciousness. Initially, the Fujitsu Group began applying Green Process activities to its semiconductor factories, which use large amounts of chemicals in their manufacturing lines, and then introduced the activities to most of its manufacturing bases by March 2004.

4. Evaluation of Green Process activities

Green Process activities add the new index of "environment" to the important indexes of manufacturing, which include function, quality, schedule, and cost, and these indexes are equally evaluated. Each factory sets quarter-term targets for its manufacturing lines and continuously promotes Green Process activities through achievement evaluations (**Figure 2**). The activities are evaluated based on the linkage between the achievement of environmental-impact targets (environmental indexes) and the achievement of productivity improvements (cost indexes). To calculate an environmental index, resources are generally classified into two categories: resources that impact the human body and resources that impact the global environment (**Tables 1** and **2**). Then, a degree of environmental impact is assigned to each resource, and the input volume of each resource is multiplied by its environmental impact. To calculate a cost index, the input volume of a resource is multiplied by its cost. Regarding impacts on the human body, carcinogenic substances, endocrine disrupters, and substances controlled by the Pollutant Release and Transfer Register (PRTR) Law are given high impact values. Regarding impacts on the global environment, ozone-depleting and global-warming substances are given high impact values. The impact values are currently divided into five levels for easy indexing, but weighting of impact categories should be reconsidered in the future after a review of the degrees of impacts. Finally, the Cost Green (CG) index is expressed numerically by multiplying the environmental index and the cost index by the input volume of the relevant resource (**Figure 3**), detailed measures for improvement are prioritized, and then the measures are implemented efficiently. The designed value of resource volume for an entire manufacturing line can be calculated from the designed value of resource input volume per unit product and the production volume. The designed value can then be used for verifying cost and environmental performance through a comparison with the actual input volume.

By using this system, we can calculate how a cost changes when a resource is replaced with one that has less impact on the environment. Each Green Process activity is evaluated using a

Table 1
Degrees of environmental impact (gasses and chemicals).

Rank	Impact	Impact category 2	Remarks
5	Impact on human body	Carcinogenicity	ACGIH, EPA, EU, IARC, Japan Society for Occupational Health
		Impact on human body outside of factory	Endocrine disrupters, substances controlled under PRTR Law, Fujitsu Group's priority substances for reduction
4	Environmental impact	Impact on global environment (ozone depletion)	ODP
		Impact on global environment (global warming)	GWP
3	Environmental impact	Impact on local environment (water pollution)	Clean Water Act
		Impact on local environment (air pollution)	Clean Air Act
2	Impact on human body	Impact on work environment	LD50, Industrial Safety and Health Law (preventive measure available, e.g., protective equipment)
1	Others	Energy saving	

Table 2
Degrees of environmental impact (periodic replacement of equipment parts).

Rank	Main component	Remarks
2	Nonmetals and amalgams	Examples: O-rings, plastics, printed-circuit boards, electric bulbs
1	Metals and quartz	Examples: SUS parts, silica tubes

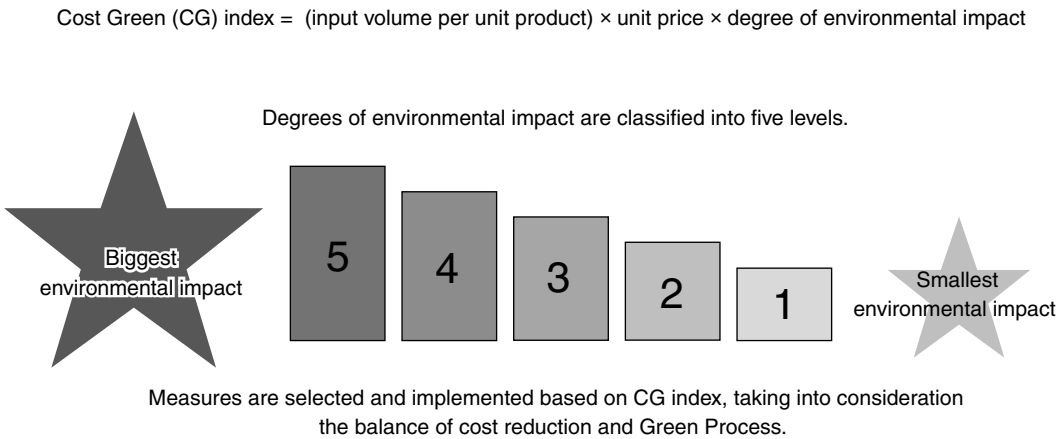

Figure 3
CG index.

percentage score. Targets are set for factors such as legal compliance, environment protection, energy saving, resource saving, and the environmental impact of recycling; then, the extents to which the targets have been met are evaluated. Among the targets, especially high scores are given to measures for replacing resources with ones that have less environmental impact (not merely for reducing the resource input volume) and the horizontal deployment of new measures in other factories and manufacturing lines. Based on the targets and the designed values and results of resource input volumes, the measures are prioritized and implemented. After implementation, the evaluation scores are totaled, and the factories that meet the specified standards are awarded Green Process certification. However, to earn Green Process certification, a factory must perform Green Process activities continuously; that is, it must continue to improve its manufacturing processes through the above methods with the constant aim of reducing its environmental burden.

5. Introduction and results of Green Process activities

Green Process activities were first introduced at the Mie semiconductor-manufacturing plant on a trial basis. The Mie plant was selected as the first model factory to introduce Green Process activities before their full deployment because the semiconductor division produces more than half of the Group's total environmental burden (i.e., energy consumption, waste emission, release of chemicals, etc.). Corrective measures were prioritized for the manufacturing lines at the Mie plant based on the CG index values of each resource. The results indicated that fluorine gasses, including greenhouse gases, amine chemicals, and silicone chemicals, were at the higher levels in the CG index ranking (**Figure 4**). Accordingly, to reduce environmental burden and costs, measures were taken to minimize the resource input volumes and replace the current processes with more environment-friendly alternatives. We have obtained good results through these measures; for example, the chemical and gas input volume per

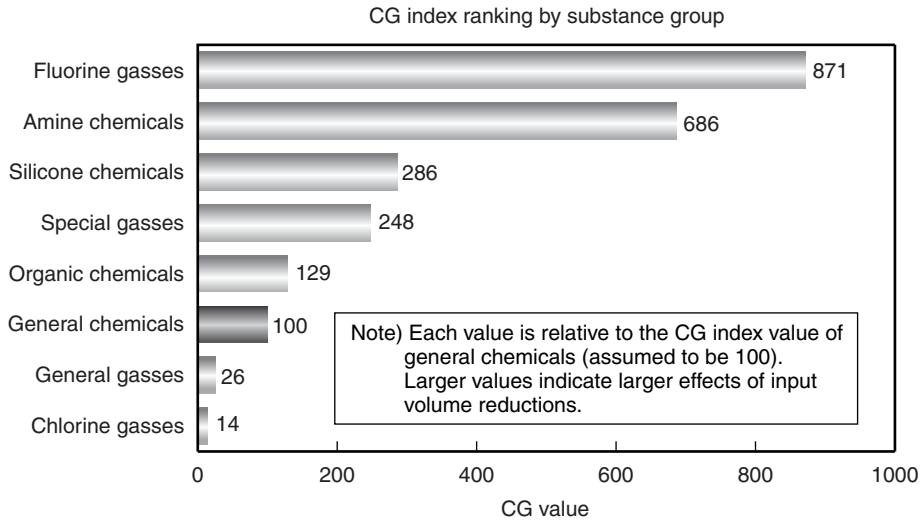

Figure 4
CG index ranking.

unit product at the Mie plant in the July-September term of 2004 was 41 % less than the volume in the January-March term of 2003 (when the activities were initiated). Similarly, a 14% reduction was achieved at the Aizuwakamatsu plant and a 17% reduction was achieved at the Iwate plant.

We will now describe some major case examples of environmental burden reduction. LSI manufacturing uses a large amount of amine chemical solution in the post-processing for etching. This solution includes a large amount of 2-aminoethanol, a Type 1 chemical under control of the PRTR Law. Emission and transfer volumes of this chemical are controlled because it has a large impact on the environment. The Mie plant reduced the input volume of this solution per unit product by 33% in the July-September term of 2004 compared to the volume in the same term of the previous year. The main measures taken at the plant were changes in the processing conditions and operations and a reduction in the use of the chemical solution. This is a good example of how Green Process activities using the CG index can identify a chemical solution that is hard to identify using the existing environmental management system. As a result, use of this chemical solution was reduced, and the Green Process activities were accelerated. The Mie plant completed construction of a new building in November 2004 and is preparing to start operations there. The plant will introduce Green Process activities to the new building as soon as possible.

The Iwate plant focused on the volume of resist that it used and succeeded in reducing the volume by 20% as the result of a Green Process project. The Aizuwakamatsu plant reduced the dispense amount of planarizing material by 53%. Both achievements were very effective in reducing the environmental burden.

Although the current Green Process activities target only mass-production factories, they will also be introduced to development lines. It is effective to apply environment-conscious specifications to development lines because the gas and chemical specifications applied to mass production are basically decided in the development phase. The current evaluation specifications will be applied to the development phase at the Fujitsu Akiruno Technology Center to confirm their effect in an actual application in fiscal 2005.

Green Process activities were introduced to every semiconductor manufacturing base, including the Iwate and Aizuwakamatsu plants (the production bases for pre-processes), and the associated factories for assembling processes by March 2004. These activities have also been very productive in terms of cost reduction, and the cost-reduction effect will be extended to the entire Fujitsu Group when Green Process activities are deployed in the assembly factories for information equipment (e.g., personal computers) and various other fields.

6. Evolution toward Group-wide activities

Green Process activities were started at the Mie plant, an electronic device manufacturing base, and are now established in every manufacturing base of the Electronic Device Group. Green Process activities were first introduced to the pre-processes and then to the post-processes for IC chip packaging of manufacturing lines. The original evaluation standards for the pre-processes of IC chip manufacturing could not be applied to the post-processes, which use far less chemicals than the pre-processes. Therefore, the Gifu plant of Fujitsu Integrated Microtechnology (FIM) Limited was selected as a trial facility, and the evaluation standards for pre-processes were established by the staff of the Gifu plant in cooperation with the Environment Management Division. The evaluation standards for the post-processes formed the basis for the evaluation standards for the assembly processes. Based on the evaluation standards for post-processes created by the Gifu plant, Green Process introduction was extended to the manufacturing bases

for assembly, which cause less environmental burden than pre-processes and post-processes. Assembly factories are the most numerous type of manufacturing base in the Fujitsu Group. The evaluation standards and evaluation system for assembly processes were established after some trial efforts in collaboration with Shimane Fujitsu Limited, which manufactures laptop computers. Details of the above operation will be described on another occasion.

7. Future issues

Conventional environment-protection activities target only the environmental cost and are difficult to establish in manufacturing divisions, which constantly need to reduce their production costs. Green Process activities, on the other hand, are proving to be effective for reducing both costs and environmental burdens at manufacturing bases. Also, Green Process activities help us achieve the important goal of linking environmental protection with business, and they can be extended to manufacturers outside of the Fujitsu Group.

Green Process activities focus on wasteful resource inputs at the Group's manufacturing divisions. However, the number of manufacturing bases in the Group that make products from raw materials has decreased, and the number of assembly bases that purchase manufactured components and assemble them into products has increased. With this evolving style of manufacturing, the manufacturers should emphasize the relationships they have with their component suppliers. In other words, the manufacturers should ask their suppliers to list the substances contained in their components and provide data about the harmful effects that any of them may have (**Figure 5**). Green Process activities can grow only if they are linked with corresponding

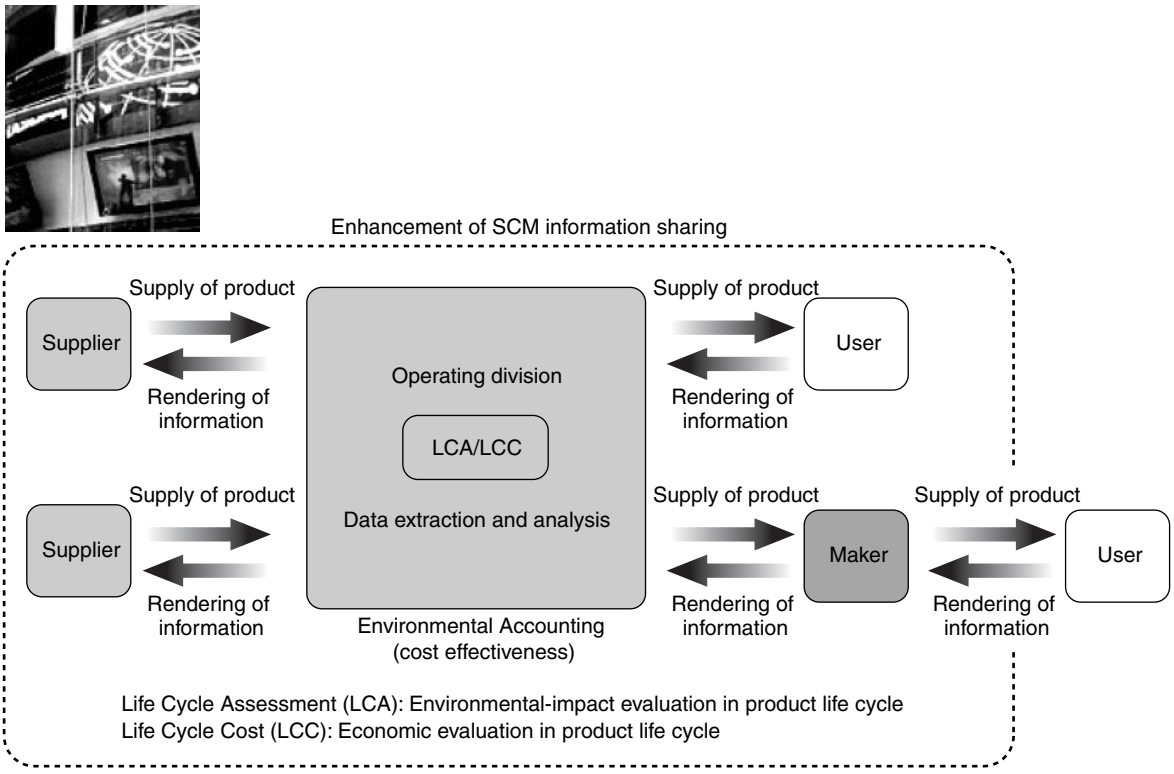

Figure 5
Supply chain management (SCM).

activities at the sources of manufacturing materials; that is, they require supply chain management (SCM) to grow. A manufacturer cannot implement SCM alone, but must build an SCM system in connection with every supplier related to its manufacturing processes. By standardizing Green Process activities and deploying them at other enterprises, we will be able to build an SCM system that extends over many enterprises.

8. Conclusion

Environment-conscious operations such as Green Factory and Green Process activities will become much more important for the manufacturing systems and processes at semiconductor factories. The Fujitsu Group has formulated the fourth stage of its Environmental Protection Program (2004 to 2006) and aims to establish sustainable management based on environment-conscious operations and help protect the environment for its customers and society in general. We will further promote Green Process activities under these concepts and link the activities with cost reduction efforts so that enterprises can function in harmony with the global environment.

Reference

1) T. Kudo, S. Kawauchi, S. Okuda: Green Process Technology Oriented for Environmental Burden Reduction. (in Japanese), *Clean Technology*, **14**, 12, p.11-14 (2004).

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