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5 August 1982

Japan Report

(FOUO 49/82)

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ECONOMIC

TRADE FRICTION MAY NOW INVOLVE RICE

Tokyo MAINICHI DAILY NEWS in English 8 Jul 82 p 5

[Text] Thailand has requested Japan to refrain from exporting her surplus rice to food-short developing countries and to use Thai rice in Japan's food grant schemes for the needy countries, the Ministry of Agriculture, Forestry and Fisheries disclosed Tuesday.

The Thai request stemmed from the recent plunge in the international rice price which was triggered by the record crop of 276 million tons around the world last year. The historic crop resulted in a global rice glut. The price fall is affecting not only Thailand but also the United States, another key rice exporter.

The benchmark Thai rice price stood at $515 per ton in July 1981 but has come down to as low as $283 at the end of June, hitting hard Thai and American rice growers in particular.

Japan, on the other hand, has been burdened by chronicle rice surpluses. This past April it had a surplus of 3.1 million tons which the government bought from growers at a good price of $1,000 per ton.

Of this surplus, about 400,000 tons have been earmarked for exports at the prevailing international price to work down Japan's surplus for this year. About 50,000-70,000 tons are scheduled to be given away to developing countries in serious food shortage such as Bangladesh. The rest is to be exported to such countries as Poland and Mozambique on easy credit terms.

Thailand holds that the Japanese manner — buying at $1,000 or more per ton and exporting at the prevailing international price — is nothing less than subsidizing its rice exports.

Thailand wants Japan to stop the practice and buy Thai rice for food grants to the needy countries. This Thai request was formally conveyed to Japan through diplomatic channels.

The ministry is growing apprehensive that rice will become another source of friction between Japan and the Association of Southeast Asian Nations (ASEAN) in which Thailand is a key member.

The ministry is to ask a ruling Liberal-Democratic Party mission to try to secure an understanding from the ASEAN members on the Japanese position. The LDP mission is scheduled to leave Japan next Monday for these countries to defuse existing economic friction.

There is also a probability that the United States may request Japan to import rice from America.

Already, there is a voice within the ministry that Japan may have to buy Thai and American rice in granting rice aids to needy developing countries.

CSO: 4120/344

ECONOMIC

TRADE SURPLUS WITH U.S. PREDICTED

Tokyo MAINICHI DAILY NEWS in English 4 Jul 82 p 5

[Text] Japan will have another hefty trade surplus of $13.5 billion with the United States this year following a 1981 surplus of $13.3 billion, according to a private think tank.

The Nomura Research institute said Japanese exports to the United States will rise 1 percent to $39 billion, with imports up 0.8 percent to $25.5 billion.

It attributed the far slower export increase than last year's 23.1 percent rise to sluggish sales of such major items as steel, textiles and chemicals.

A 24.7 percent drop was forecast for steel, which surged 47.5 percent in 1981.

But motor vehicle exports, now in the second year of self-imposed curbs, are expected to climb 6.6 percent following an 11.2 percent gain last year.

The import slowdown from last year's 3.6 percent rise was blamed primarily on reduced purchases of aircraft and foodstuffs.

CSO: 4120/342

ECONOMIC

MITI ORDERS 5 PERCENT CUTBACK IN OIL PRODUCTION

Tokyo MAINICHI DAILY NEWS in English 3 Jul 82 p 5

[Text] The Ministry of International Trade and Industry has instructed oil refineries to cut their oil production by 5 percent in July from a year before, a ranking ministry official disclosed Friday.

The official said the cutback instruction is effective for the month of July. But he added the curtailment period would be extended in view of the plummeting demand.

Oil production has been falling since the recent peak of the December-January period. In the period production stood slightly below 18 million kiloliters. The production in May stood slightly below 14 million kiloliters.

Oil production last July stood roughly at 15 million kiloliters, a near bottom figure in 1981. The precise figure was, however, not available immediately.

The cutdown instruction clearly indicated the ministry's increasing concern over oil demand for immediate future. Oil refineries have been plagued with two problems: overcapacity and sagging demand.

The ministry has been closely monitoring and coordinating, when needed, oil production in Japan for many months by ordering oil companies to submit their quarterly production plans.

CSO: 4120/342

ECONOMIC

TAX INCREASE PLANNED IN FISCAL '83

Tax Increase Planned After Shortfalls

Tokyo THE DAILY YOMIURI in English 8 Jul 82 p 1

[Text] ***Finance Minister Michio Watanabe Tuesday indicated that the Finance Ministry would study plans to introduce new taxes in compiling the government budgets for fiscal 1983 and thereafter.***

Answering a question by Socialist interpellator Kumao Terada in the House of Councilors Budget Committee, Watanabe said that the Finance Ministry would be at a loss if it was not allowed to manipulate the tax system in the least.

This was the first time that the finance minister hinted at the possibility of introducing a new tax.

When the fiscal 1982 government budget was in the making, the Finance Ministry studied the advisability of introducing taxes on advertisement and gambling.

It is believed that Watanabe had such new taxes in mind when he hinted at the possibility of introducing new taxes.

Prime Minister Suzuki told the Budget Committee that the government would make even more drastic expenditure cutbacks and study ways to ensure nontax revenues from various angles.

He added that he did not plan to introduce a large new tax like a general consumption tax.

He also said he was still determined to lift public finances from depending on deficit-financing government bonds in fiscal 1984.

5% Cut In Budget

Top officials of the government and the Liberal-Democratic Party (LDP) are expected to decide Thursday to set an overall framework for requests for appropriations in the fiscal 1983 government budget five percent below the corresponding framework for fiscal 1982.

After such an agreement is reached, the Finance Ministry will immediately start negotiations with the various ministries and agencies for uniform 10 percent cuts in various subsidies.

The cabinet on July 9 will approve the five percent curtailment of the overall framework for appropriations in the fiscal 1983 budget.

Even the growth of such top priority items as defense, energy and foreign aid will be curbed, and public-works projects will cease to be given special treatment.

Accordingly, it is believed certain that the fiscal 1983 government budget will be the most stringent ever since fiscal 1955.

Finance Ministry Plans to Introduce New Taxes

Tokyo THE DAILY YOMIURI in English 30 Jun 82 p 1

[Text] The Finance Ministry is planning to increase taxes by ¥1 trillion in fiscal 1983 following a disclosure that the tax revenue shortfall in fiscal 1981, ending last March 31, totaled ¥2,881.8 billion and the tax revenue shortfall in fiscal 1982 is expected to top this figure by around ¥2 trillion, it was learned Wednesday.

Additional corporation taxes plus introduction of new taxes on gambling and advertising are being considered, sources close to the Finance Ministry said.

Finance Minister Michio Watanabe told the House of Representatives Finance Committee Wednesday that the fiscal 1981 tax revenue shortfall was the first sizable one to be recorded after a budget had been revised. The revised budget totaled ¥31,831.6 billion.

The Finance Ministry estimates final revenue shortfalls at ¥2,501.8 billion for the year, after deducting ¥380 billion for revenues from other than tax and unused amounts for planned expenditures.

The ministry's policy is to make up the loss with the ¥240 billion national tax receipts adjustment fund and the ¥2,261.8 billion national debt consolidation fund.

As a result, tax revenues for fiscal 1982, ending March 31, 1983, are expected to be ¥3,700 billion less than the budget of ¥36,624 billion even if a planned 13.4 percent growth rate was achieved.

Considering the 6.2 percent nominal economic growth rate projected by the government, down from the original estimate of 8.4 percent, officials forecast tax revenue shortfalls of about ¥4,800 billion for fiscal 1982.

The Finance Ministry has decided to transfer sufficient funds from the auxiliary currency recovery reserve to meet the expected revenue shortfalls in fiscal 1982.

The reserve totaled about ¥1.2 trillion as of the end of fiscal 1981 and is expected to reach ¥1.3 trillion at the end of fiscal 1982.

The ministry said that up to ¥1 trillion could be transferred from the reserve for use as revenue.

Policy Switch On Yen

In a major policy switch, the governor of the Bank of Japan suggested Wednesday the central bank was prepared to apply a special interest rate to help shore up the yen's sagging value against foreign currencies.

Haruo Maekawa told a news conference the bank would "take all necessary measures" to stem the yen's depreciation.

Maekawa told the House of Representatives Finance Committee earlier in the day he would carefully discuss which action would have better effect—continuing the present policy of guiding short-term interest rates higher or invoking the special interest system.

His remarks meant that the central bank was determined to support the yen with every means available central bank officials said later.

The special interest system allows the central bank to impose a higher discount rate temporarily without entailing across-the-board interest hikes. The bank previously rejected its application, saying it was a last resort taken in times of emergency.

CSO: 4120/349

ECONOMIC

YEN'S SLIP PARTLY BLAMED ON D-MARK

Tokyo MAINICHI DAILY NEWS in English 3 Jul 82 p 5

[Text] The German mark's depreciation is one of reasons for the yen's further decline in value against the U.S. dollar, Bank of Japan Governor Haruo Maekawa said Wednesday.

Maekawa defended his bank's interest rate policy which he said is understood by monetary policymakers abroad.

He expressed skepticism about the idea of applying a "special Lombard rate" as a means to stem the yen's further depreciation against the U.S. dollar.

"The German mark is declining in value but that is not the sole cause of the yen's depreciation," Maekawa replied when asked about the Japanese currency at a news conference.

The dollar rose further on the Tokyo Foreign Exchange market Wednesday, hitting the 259 yen mark momentarily for the first time in 27 months. The dollar closed out the day at 258.85 yen.

The central bank governor expressed the hope the world economy will pick up later this year despite a rather grim economic outlook forecast by the Organization for Economic Cooperation and Development (OECD).

"There are some reasons for optimism," he explained. "Inflation is gradually subsiding, compared with last year, and that helps to increase income and spending."

Maekawa cautioned against introducing a new stimulative package right now, saying, "I think the government can still wait."

CSO: 4120/343

ECONOMIC

TOYOTA MERGER, STRATEGY CHANGES DISCUSSED

Tokyo MAINICHI DAILY NEWS in English 2 Jul 82 p 5

[Text] NAGOYA—Toyota Motor Co. and its sales arm merged back into a single corporation Thursday.

With the merger, the Toyota companies are aiming to close ranks and deal more promptly with increasingly intense competition both at home and abroad than heretofore.

Shoichiro Toyoda, president of Toyota Motor Sales Co., has assumed the presidency of the new Toyota Motor Corp.

As he put it, the merger will mark a major shift in the Toyota group's marketing strategy.

The world's automotive companies are bracing for heated competition in sales of subcompact cars in the years ahead and Toyota is no exception.

The nation's largest auto producer has chosen to clear a major obstacle in the way to adapting itself to changing world market trends quickly.

The 57-year-old heir in the direct line of the Toyoda family expressed hope that the merger will enable the company to obtain a better picture of consumer demand in developing a new line of vehicles.

Aside from the reason given by the "Prince" of the Toyoda family, it is obvious that the merger has been prompted by a number of other factors.

It has often been said that Toyota is slow in responding to changing marketing situations in general and to international developments in particular, compared with other Japanese auto companies.

There is no secret about the company's slow response to calls from its dealer network for quick introduction of turbo-charged and front-engine, front-drive cars, for example, to woo young drivers away from Nissan Motor Co. and other rivals.

The company often blamed the slow reaction on the "dual management" resulting from the separation of the company's production and marketing divisions 32 years ago.

At the urging of bank loan overseers, Toyota, then in financial difficulties, divested itself of the sales division to set up Toyota Motor Sales in April 1950.

The separation has, however, proved to be a major deterrent to the group's marketing activities.

With the flareup of a global war over subcompact cars anticipated in the mid-1980s, Toyota is putting its world strategy into high gear.

Negotiations have been under way since last March between Toyota and General Motors Corp. on joint production of the fast-selling Toyota Corolla in the United States.

The discussions, on-again, off-again, are now expected to make considerable progress.

The merger will be carried out on a 1-to-0.75 basis, that is to say, Toyota Motor Co. will, in effect, absorb the marketing arm.

The new president is the eldest son of the late Kiichiro Toyoda, who founded Toyota in August 1937, and a grandson of the late Sakichi Toyoda, the founder of Toyoda Automatic Loom Works Ltd.

Although they can hardly compare with earnings of General Motors, the world's largest automaker, the combined total annual sales of the two Toyota companies — an estimated 4.5 trillion yen (127.7 billion) — are the largest ever recorded by a single manufacturer in the nation's industrial history.

In terms of output, Toyota overtook Ford Motor Co. as the world's second largest automaker in 1979.

Last year, Toyota's production totaled 3.22 million units, against 4.63 million produced by GM. The figure does not include output intended for knock-down exports.

Of the total output, 1.49 million units were sold on the domestic market, giving Toyota a 38.3 percent share, compared with 29 percent grabbed by Nissan, the nation's No. 2 automotive company.

The incumbent president, Eiji Toyoda, becomes board chairman of the new Toyota. He is the late Toyoda's cousin.

The new company will have a capital of 120 billion yen ($472 million) and 53,600 workers on its payroll.

CSO: 4120/345

ECONOMIC

AUTOMOBILE EXPORT HIT BY WORLD SLUMP

Tokyo MAINICHI DAILY NEWS in English 3 Jul 82 p 5

[Text] The slow world economy and restrictive auto exports continued to put a brake on Japanese exports in June, according to economic data released Friday by the Finance Ministry and the Bank of Japan.

Export letters of credit (L/C) received by Japanese firms during the month showed a 5.3 percent decline in value from a year ago to $8,302 billion for the sixth straight month of decline, they said.

"Exports are not falling rapidly month by month, but we can't see any signs at all that they will pick up in the foreseeable future," said Bank of Japan officials.

By item, steel exports in June slid 9.0 percent from a year ago and chemical exports fell 17 percent. Also foods were off 14 percent, textiles, down 13 percent, metal products, down 10 percent, and general machines, off 5 percent.

Exports to the United States leveled off, while those to Middle East fell 11 percent. Shipments to Europe declined 7 percent and exports to Asian countries were also down 3 percent.

CSO: 4120/346

ECONOMIC

VTR EXPORTS FALL; COLOR TVS STILL IN DECLINE

Tokyo MAINICHI DAILY NEWS in English 1 Jul 82 p 3

[Text] Production and exports of home-use video tape recorders (VTR) slowed markedly in May while color television output kept its downtrend, according to the Electronic Industries Association of Japan.

May production of VTR stood at 986,000 units, off 2.9 percent from the preceding month, falling below the 1 million level, the association said.

The figure represents a 58.5 percent growth from the same month of last year but at a very slow pace, compared with previous years. VTR production doubled each year until 1981.

Exports of VTR also declined 14.5 percent from April to 718,000, although they increased 44.1 percent on a year-to-year basis.

This is the first time the year-to-year growth rate fell below the 50 percent level since February, 1977, the association said.

Production of VTR from January through May stood at 4,868,878 units, up 68.6 percent from the same period of the preceding year. VTR exports in the first five months increased 74.1 percent to 3,852,416.

Meanwhile, color television production in May declined 6.8 percent from a year ago to 902,000 units for the sixth straight month of decline since last December.

Domestic shipments of color television sets in May rose 2.9 percent from a year ago to 538,000 while exports fell 20.3 percent to 338,780.

From January through May output of color television sets declined 8.5 percent from the same period of last year to 4,306,237, and exports were off 13.5 percent to 1,770,167.

CSO: 4120/342

ECONOMIC

STEELMAKERS' PRICE RISE REPORTED

Tokyo MAINICHI DAILY NEWS in English 1 Jul 82 p 3

[Text] In reflection of stagnant economic activities, demands for steel products are not brisk, but the nation's mammoth steelmakers will be able to force price increases of about 5 percent by mid-July on their major customers, including automakers and shipbuilders, a leader of the steel industry disclosed Wednesday.

The customer industries have come to understand the difficult situation facing the steel industry, the executive explained.

From late April to early May, the big steelmaking companies headed by Nippon Steel Corporation began asking their users to accept markups ranging from 5.2 to 5.5 percent, or 4,600 to 4,900 yen, in prices of their products.

Increases in prices of iron ores and coal were among the major reasons cited by the steel industry in seeking higher prices for steel products.

At first, the user industries were very angry with the steelmakers' proposal. While prospects of their businesses appeared quite dark, some of the steel companies, especially Sumitomo Metal Industries and Nippon Kokan Kaisha, were reporting the best business records ever for their settlement account term ended last March.

With the progress of weeks, however, the situation surrounding the steel industry turned worse and worse.

Orders for steel pipes declined sharply and exports dropped noticeably. Coupled with stagnant demands on the domestic front, production of crude steel for the current fiscal year became certain to drop below the 100 million-ton level for the first time in 11 years.

Under these circumstances, the user side came to conclude that they would have to accept price raises of 5 percent or so, the steel leader reported.

He added that most of major customer companies have already expressed their approval of the proposed price increases. Details, including discounts, will be ironed out between the steel companies and their customers by early July, he said.

In past years, it was Toyota Motor Co. that was the "pace-setter" among user industries in negotiations with the steel industry, but this year the company has avoided assuming that position, steel industry sources also reported, adding that as this year's negotiations coincided with Thursday's merger between Toyota and its sales arm, the new automaker will finalize its negotiations with steel prices only by mid-July this year.

CSO: 4120/347

ECONOMIC

BRIEFS

AUTO EXPORTS--Japan auto exports in May were down 6.9 percent from the previous year at 489,327 units, marking the 10th consecutive monthly year-to-year decline, it was disclosed Tuesday. The Japan Automobile Manufacturers Association said that passenger cars accounted for 333,114 units, off 4.7 percent, trucks 152,385 units, down 8.3 percent, and buses 3,828 units, off 61.1 percent. Exports to South Africa were down 58.3 percent, Africa 45.9 percent, Europe 28.9 percent, Southeast Asia 11.9 percent and the United States 0.4 percent. On the other hand, exports to the Mideast and the Oceania were up 61 percent and 46.3 percent, respectively. The announcement also said that Japan's motorcycle exports declined 30.8 percent to 211,681 units. Exports to Europe and Southeast Asia were down 34 percent and 28.5 percent, the announcement added. [Text] [Tokyo Mainichi DAILY NEWS in English 1 Jul 82 p 3]

CSO: 4120/342

SCIENCE AND TECHNOLOGY

JAPAN RESTRICTS EXPORT OF JNL'S TECHNOLOGY TO USSR

Tokyo NIHON KEIZAI SHIMBUN in Japanese 30 Jun 82 p 1

[Text] It was recently disclosed that the Japanese Government is stringently restricting the Japanese National Railways (JNL) from cooperating with the Soviet Union on railway transportation technology and construction technology. According to informed sources, the Japanese Government says that "all technologies that can be used for military purposes cannot be exported to the Soviet Union." It is said that the government totally banned export of technology related to underwater tunnel construction in which the Soviets have been greatly interested for some time in connection with the Sakhalin oil development project. In addition, exchanges of publicly released material which contains information on this technology must undergo prior scrutiny by the Ministry of Foreign Affairs. Also, it is reported that a short-term inspection tour by Soviet railroad engineers, which the Soviet Union had been hoping for in relationship with its plans to electrify its railroad system, was rejected.

Turned Down Soviet Engineers' Inspection Tour

The criterion and content of the Japanese Government's sanctions against the Soviet Union related to the railroad technology have not been disclosed. However, according to related sources, the Ministry of Foreign Affairs regards JNL as "semi-governmental" and has presented to it detailed guidelines for technological cooperation with the Soviet Union. According to the same sources, the technology banned from exporting includes 1) tunnel excavation and construction technology and 2) computer-related technology. As to electronics technology, a prior consultation within the government is an indispensable condition even before negotiations with the Soviets start. It is said that exchanges of document (open-source material) which contains technical information will be restricted, and that such documents are subject to prior inspection by the Ministry of Foreign Affairs.

JNL's technology had been until now regarded as "civilian technology." It seems, however, that the Jpaanese Government strictly restricts technological cooperation with the Soviet Union on this technology because of the possibility that the Soviet Union could use tunnel construction technology to build underground silos for intercontinental ballistic missiles and could use computer technology to create efficient mass transportation systems for military equipment.

JNL's technology is said to be the first-class in the world in every field, including control, rolling stock, construction, etc. Tunnel excavation technology especially, as the tunnel construction project between Aomori and Hakodate has shown, can excavate even soft earth and is unequaled in the world. For this reason, the Soviet Union has asked for Japanese cooperation to establish new excavation technology for the Sakhalin oil project because the weather off Sakhalin is fierce in winter. It is believed that Japan's cooperation with the Soviet Union on tunnel technology has become impossible for the time being now that strict controls have been imposed on JNL's technology. JNL also turned down a request for a visit to Japan by three railroad engineers from the Soviet Railway Transportation Central Science and Technology Committee. Also, it is reported that JNL declined in invitation from the Soviet Union for an inspection tour of Soviet railway technology by Japanese engineers.

The Soviet Union is planning a large-scale modernization program for its railroad system, including the construction of 2 second [?trans.] Siberian Railroad and electrification of 6,000 km-long railroad centered on the Second Siberian Railroad. In this project, the Soviet Union is said to expect considerable technological cooperation from Japan. Thus, some JNL officials have expressed regret about the strict restrictions placed on railroad technology cooperation with the Soviet Union.

CSO: 4106/138

SCIENCE AND TECHNOLOGY

LARGEST FUEL CELL PLANT TO START IN FALL

Tokyo MAINICHI DAILY NEWS in English 3 Jul 82 p 5

[Text] Tokyo Electric Power Co. said Friday that it would start operation of the world's largest fuel cell plant this fall at its thermal power plant in Goi, Chiba Prefecture, east of Tokyo.

A spokesman said that the company had invested 5 billion yen ($19.6 million) in construction of the plant jointly developed with America's United Technology (UT) that developed similar cells for the Apollo space program.

The plant consists of 20 cells each with 240 kilowatt capacity for total output capacity of 4,800 kilowatts. It requires some 1,000 square meters of land for this type of capacity.

The fuel cell uses chemical reaction of hydrogen having energy density three times more than oil.

Since hydrogen is an unlimited source of energy and free from pollution, it has attracted attention as an electric power source for private sectors.

The Ministry of International Trade and Industry is also developing a pilot plant under its "moonlight" energy saving program. Its output capacity is about 1,000 kilowatts.

A Japanese gas firm and a heavy electrical machinery maker are also jointly developing a similar plant but its capacity is only 40 kilowatts.

The only demerit is high construction cost and the battery's short lifespan.

The construction cost of the plant is about 1 million yen ($3,921) per kilowatt, three times more than that of a nuclear power plant.

The battery's lifespan is only 40,000 hours (four years and a half).

But the spokesman expressed the hope that the construction cost would drop to one-fifth

CSO: 4120/348

SCIENCE AND TECHNOLOGY

UDC 537.611.3:621.377.6

DESIGN, FABRICATION OF 1 MEGABIT BUBBLE MEMORY

Tokyo FUJITSU SCIENTIFIC & TECHNICAL JOURNAL in English Vol 18, No 2, 82 pp 307-342

[Article by Takeyasu Yanase, Hiroshi Inoue and Teiji Majima: "Design and Fabrication of a 1 Megabit Bubble Memory Device"]

[Text]

A low drive field 1 megabit bubble memory device has been developed. This device features relaxed function designs and a planar process using a new type of heat resistant resin named PLOS. The 1 megabit device uses a block replicate/swap organization based upon 1.9 μm diameter bubbles. A basic cell size is 7 μm × 8 μm while the minimum feature size has a value of 1 μm. A chip size is 9.1 mm × 9.9 mm. Fabricated 1 megabit chips have been characterized over a drive field range of 3581 A/m to 5173 A/m (45 Oe to 65 Oe) (peak fields of 100 kHz triangular wave drive), and over a temperature range of 0 °C to 90 °C.

Results obtained in the characterization for the 1 megabit chips are good enough to guarantee the same drive field and sense requirements for packaged 1 megabit devices as those for 3 μm bubble 256 kbit devices.

1. Introduction

Gap-tolerant propagation elements reported by Bonyhard and Smith in 1976[1] led us to realizing 8 μm period bubble memory devices. The first 1 megabit chip, whose design was based on half scale from 16 μm period devices, was reported by Archer in 1977[2]. Since then considerable effort in bubble materials and device designs optimization for the 8 μm period devices has been directed towards realizing 1 megabit devices as commercial products. Several fabrication results of 256K-1 megabit devices with 1.5-2.0 μm diameter bubbles have been reported[3)-6)]. Unlike the well-established 16 μm period devices, some remaining problems still must be solved. Almost all the device designs reported so far are based on scaling from those for the 16 μm period 3 μm bubble devices.

In such designs, the minimum feature size of permalloy patterns and the minimum conductor pattern width should be about 1 μm and 2 μm, respectively. This narrow conductor might cause migration problems and a considerable increase in function drive voltages.

The most serious problem is the increase of the minimum rotating drive fields. In small bubble devices such as those with bubble diameter below 2 μm, high drive fields are required because of the increase in the magnetization of the garnet materials[7)-9)]. When the conventional scaling rule is applied to the 8 μm period devices a significant difference was observed. The required drive fields were found to be determined by those of function operations, such as replicate gates, swap gates and stretcher-detector, rather than those of the 8 μm period propagation. If the function drive fields can be made comparable with the propagation drive field, the required drive fields for the 8 μm period devices are expected to be almost the same as those for the 16 μm period devices. The required drive fields for function operations could be remarkably improved by employing a new design concept of relaxed function designs[10)]. In this concept pattern periods and sizes in function designs are increased up to twice those of the conventional designs. Steps of permalloy patterns at the conductor edges are another causes of increases in the required drive fields. In the 8 μm period devices fabricated by the SiO lift-off planar process[11)], which has also been applied to the 16 μm period 256 kbit-device, small but sharp steps of the permalloy patterns at the conductor crossings sometimes prevented the bubbles from

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The C.G.S. unit to M.K.S. unit conversion table:

$$1\ \text{Oe} = \frac{10^3}{4\pi}\ \text{A/m} \qquad 1\ \text{Gauss} = \frac{4\pi}{10^4}\ \text{Wb/m}^2 \qquad 1\ \text{Å} = 0.1\ \text{nm}$$

propagating with lower drive fields. A new type of resin named PLOS which has been newly developed in FUJITSU LABORATORIES LTD.[12)] has been studied for the 1 megabit bubble memory device. A TaMo alloy-Au system is also introduced for the conductor to overcome migration problems.

It is expected that the required drive fields for the 1 megabit device can be effectively reduced by employing both the relaxed function designs and the PLOS process.

This paper details the design, fabrication and characteristics of the 1 megabit bubble memory device. It also includes a demonstration of a packaged 1 megabit device.

2. Relaxed function designs

2.1 Stretcher

Bubble stretching generally requires high drive fields and limits overall device operations.

In a primary development stage for the 8 μm period devices, an attempt to improve bubble stretching characteristics includes increasing the stretcher column periods and modifying the chevron patterns[13)]. The stretcher design improvement in our experiments is summarized in Fig. 1. A 10.5 μm column period asymmetric chevron stretcher, a half scale of the 16 μm period device, has a strong margin dependence on the drive field and poor bias margins at low drive fields. The stretching margins are expected to improve by increasing the column period. This should intensify the magnetic poles at both ends of the chevron pattern. The asymmetric chevron stretchers with large column periods actually improved the stretching margin, particularly at the low drive fields. However excessively large periods, such as the 15 μm period, deteriorated both the upper and lower thresholds of the stretching margin. This was due to the distribution of the permalloy patterns field gradient, which is a basic requirement for bubble propagation. Although a deep potential well, a dominant factor for bubble stretching, appeared at both ends of the large-period chevron patterns, the fields gradient would be discontinuously distributed along the large-period chevron pattern. These results produced a modified chevron stretcher called the Mt. Fuji

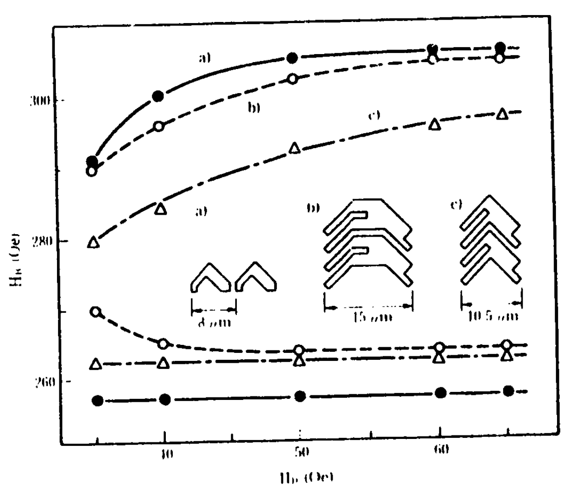


Fig. 1 Stretch margins of long-period modified chevron patterns compared with an asymmetric chevron straight propagation margin at 100 kHz.

stretcher. This stretcher has excellent stretching margins, comparable to the 8 μm period propagation margins shown in the figure. The long-period Mt. Fuji stretcher can realize both the smooth field gradient along the patterns and the deep potential wells at the ends of the patterns simultaneously. Margin losses of the stretcher at the low bias fields shown in the figure are mainly caused by the bubble strip-out along the poorly designed detector leads. The drive field is measured by the peak field of triangular wave drive throughout this work.

2.2 Replicate gate

The successful result obtained with the long-period Mt. Fuji stretcher caused us to investigate the block replicate gate improvement by increasing the pattern size. Stretching the bubble at the head of the pickax patterns[1] and then cutting the bubble strip with a current pulse in a hairpin conductor accomplishes the

Design and Fabrication of a 1 Megabit Bubble Memory Device

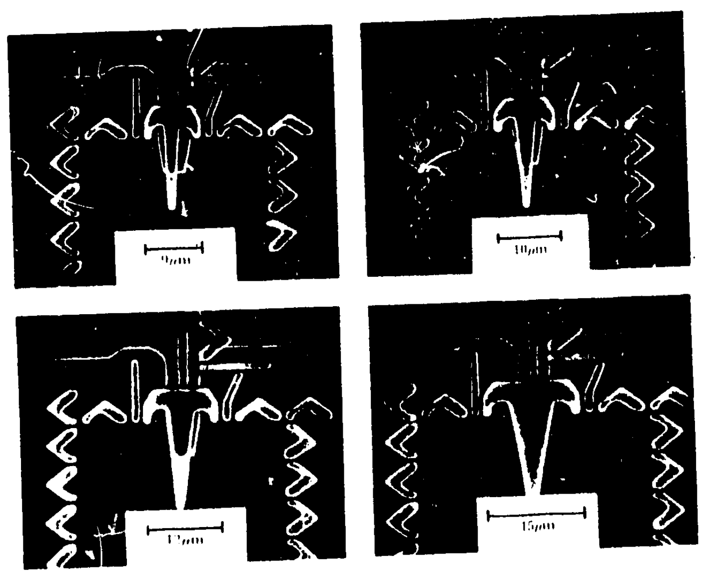


Fig. 2 SEM photographs of experimental replicate gate designs. Widths of the pickax pattern are 9 μm, 10 μm, 12 μm and 15 μm, respectively.

replication. The replication bias margins at high bias fields and low drive fields are expected to be improved by enlarging the pickax pattern and making the magnetic pole stronger at the head. Figure 2 shows experimental designs of replicate gates where the size of the pickax pattern is varied from 9 μm to 15 μm in width. The 9 μm pickax is a half scale of the 16 μm period device. In Fig. 3, bias field margins of these replicate gates are shown as a function of the replicate pulse phase at a drive field of 45 Oe. The LPE film is $(YSmLuCa)_3(GeFe)_5O_{12}$ and its bubble diameter is 1.5 μm. As expected, a significant improvement in the bias field margin at this low drive field is obtained as well as some improvement in the phase margin as the pickax pattern is increased.

This improvement for the replicate gates shows possibilities of reducing the

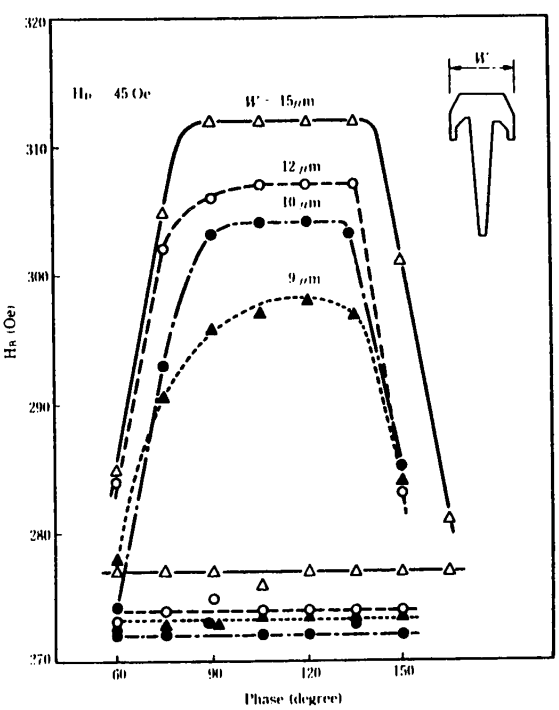


Fig. 3 Bias margin vs. replicate phase characteristics of the replicate gates shown in Fig. 2 at 100 kHz triangular drive field of 45 Oe.

required drive fields for the 8 μm period devices to the level of the 16 μm period devices with the long-period Mt. Fuji stretcher. This is possible if spatial restrictions at the gates are relaxed and their pattern sizes are enlarged up to approximately twice those of storage loops maintained at 8 μm.

The drawback of the long-period pattern design might be the lower frequency limit. Figure 4 shows a frequency dependence of the bias field margins in a 16 μm period propagation path and a 13.5 μm period Mt. Fuji stretcher. The strip

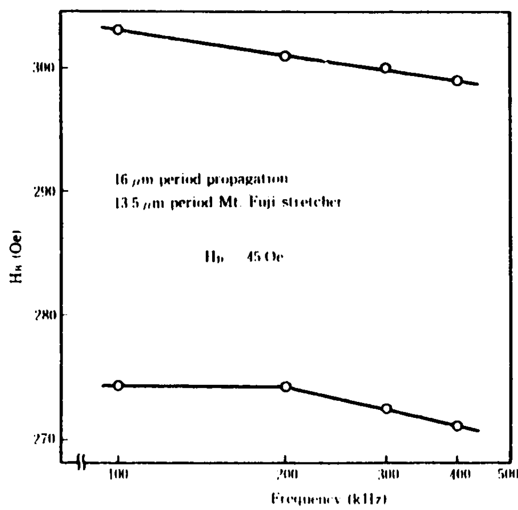


Fig. 4 Frequency dependence of a long-period propagation path.

width and mobility of the LPE film are 1.5 μm and 360 cm/s/Oe, respectively. Margin degradation is not observed up to 400 kHz, which is sufficiently high compared with the drive field frequencies of 100-200 kHz used in the commercial 16 μm period devices.

2.3 Swap gate

Relaxing the special restrictions would also be useful in swap gate designs. An important consideration for the swap gate design is how to obtain enough current margin[11),14)].

At high swap currents the bias margin is lost at the low bias field. This is caused by the failure that occurs when the bubble is trapped at the permalloy pattern, which is magnetized by the conductor current rather than by the drive fields. This tendency could be minimized by making its permalloy pattern as large as possible. Figure 5 shows a primary design of the swap gate and its cur-

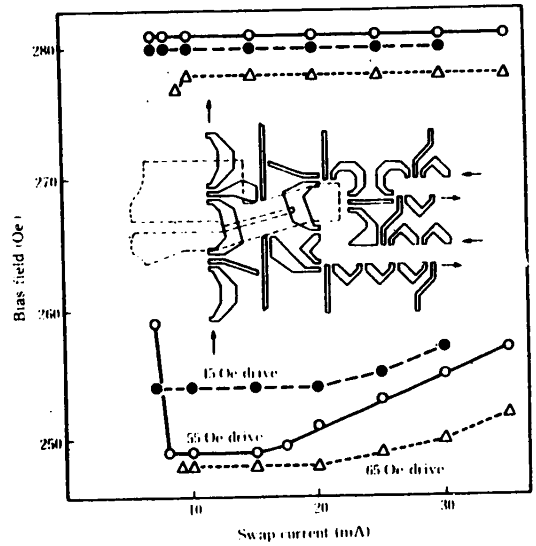


Fig. 5 Double-period swap gate and its performance.

rent margins. As shown in the figure, adequate current margins can be obtained by using enlarged gate patterns. Enlarged gate pattern designs also permit a wide conductor pattern improve the registration tolerance.

In the replicate and swap gate designs described above, the minimum conductor width can be maintained at the same value of 4 µm as in the 16 µm period devices.

3. Optimization of minor loop propagation

As described in the previous section, the required drive fields for the 8 µm period devices could be improved by employing the relaxed function designs. This demonstrates the importance of drive field reduction in minor loop propagation[15]. Under the worst conditions, the overall bias margins are limited by the minor loop propagation at low drive fields. These include the full loading of

bubbles, start-stop operations, or the application of a DC in-plane field for the start-stop operation. Figure 6 shows the propagation margin curves in the minor loops under those conditions. Each margin curve represents a 1.6 µm diameter bubble propagation along the forward and return tracks of asymmetric chevron minor loops. There is a significantly large difference in the bias margin between the tracks. The bias margin of track B is so poor that it determines the overall margin, increasing the drive field of the chip. Two approaches have been made to compensate for this difference and to improve the propagation margin. One is to improve the propagation margin of 8 µm period tracks by optimizing the pattern

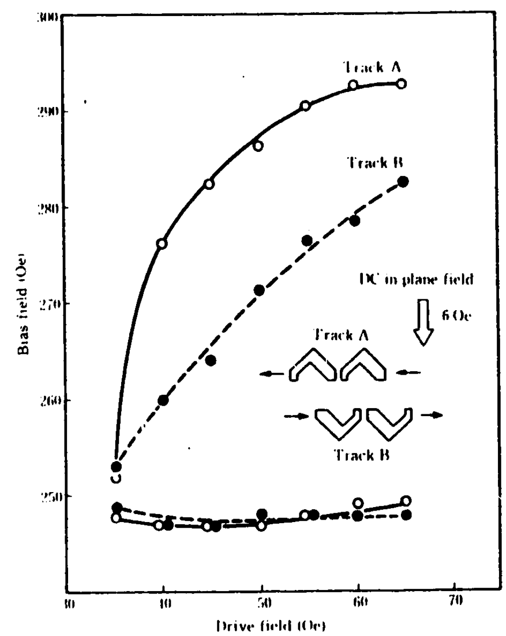


Fig. 6 The propagation margins of the 8 μm period asymmetric chevron tracks for the 1.6 μm bubble with the DC in-plane field of 6 Oe.

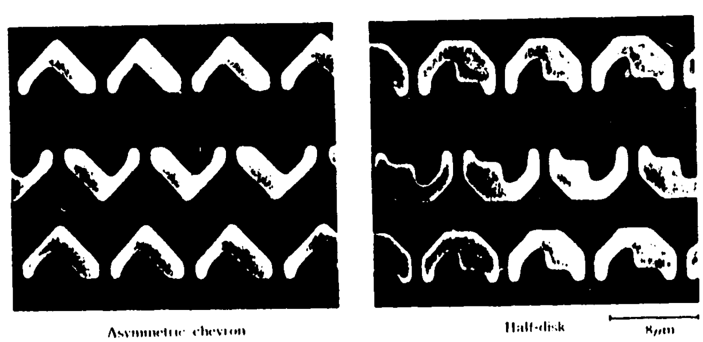


Fig. 7 SEM photographs of the 8 μm period asymmetric chevron and half-disk patterns.

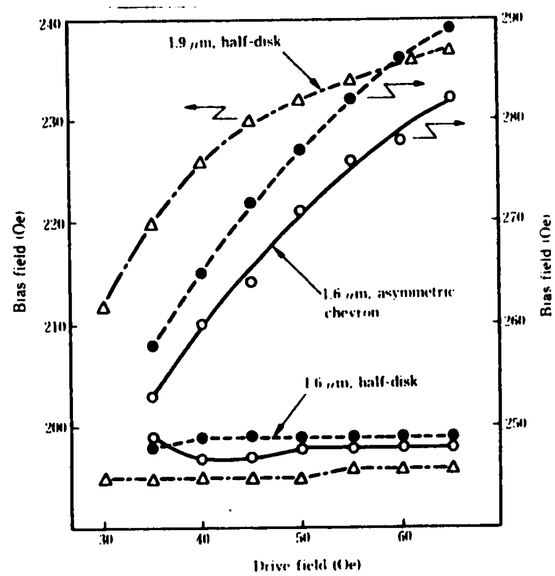


Fig. 8--Comparison between the propagation margins for the poor tracks of the asymmetric chevron and half-disk shown in Fig. 7 using 1.6 μm and 1.9 μm diameter bubbles.

design and the bubble diameter. The other is to investigate the margin difference between tracks and optimize the direction of the DC in-plane field against the crystal axes of garnet films.

3.1 Pattern design and bubble diameter

Designs of the asymmetric chevron and half-disk patterns used in the optimization are shown in Fig. 7. The pattern periods are 8 μm while the gaps have a value of 1 μm. The cell size is 8 μm x 8 μm. The composition of the LPE films is $(YSmLuCa)_3(GeFe)_5O_{12}$. The parameters of the garnet films are: strip width of 1.6 μm and 1.9 μm, thickness of 1.7 μm and 1.9 μm, and saturation magnetization $4\pi Ms = 510$ and 430 Gauss, respectively. The permalloy thickness is 3700 Å and the garnet-to-permalloy spacing is 4800 Å.

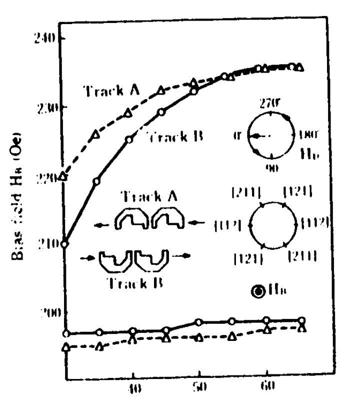
The straight propagation margins of these two patterns with start-stop operation are compared by using these two garnet films. The DC in-plane field of 6 Oe is applied in the direction at right angles to the propagation direction. The propagation margins for the poor tracks of the minor loops are compared in Fig. 8. For 1.6 μm bubbles, the asymmetric chevron tracks have poor bias margins at low drive fields while the half disk tracks improve the upper thresholds of propagation margins. The half disk tracks using the 1.9 μm bubbles have wider propagation margins and require lower drive fields compared to those using the 1.6 μm bubbles.

These results demonstrate a number of effective methods to reduce the required drive fields for 8 μm period propagation. A propagation element whose permalloy volume is as large as possible should be used. The half-disk pattern is superior to the asymmetric chevron pattern. 1.9 μm bubbles should be used rather than the 1.6 μm bubbles which agree to conventional scaling rules.

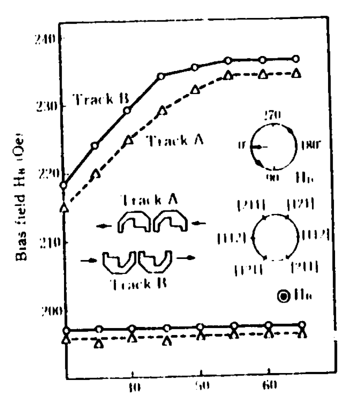
3.2 Crystal orientation

Figures 9-a) and -b) show the propagation margins of the half-disk propagation tracks for the 1.9 μm bubbles without the DC in-plane field. In Fig. 9-a) the propagation margin of track A aligned along the crystal direction $[\bar{1}\bar{1}2]$ is superior to that of track B aligned along the crystal direction $[11\bar{2}]$. This alignment was defined as "0 °" orientation where $[\bar{1}\bar{1}2]$ is aligned to the 0 ° direction of the drive field. In "180 °" orientation, where $[\bar{1}\bar{1}2]$ is aligned to the 180 ° direction of the drive field, the propagation margin of track B is superior to that of track A as shown in Fig. 9-b).

When the DC in-plane field is applied in the 90 ° direction of the drive field, the bias margin difference in Fig. 9-a) is enlarged as in Fig. 10-a). The upper thresholds of the bias margins for track A are improved w... those for track B are degraded. The same behavior with respect to the DC ...lane field is observed in "180 °" orientation, as shown in Figs. 9-b) and 10-b). In this case the bias margin difference is reduced. Therefore, this tendency of the DC in-plane field threshold does not depend on the crystal orientation.



a) 0° orientation



b) 180° orientation

Fig. 9 - The propagation margins of half-disk tracks for the 1.9 μm bubbles without the DC in-plane field.

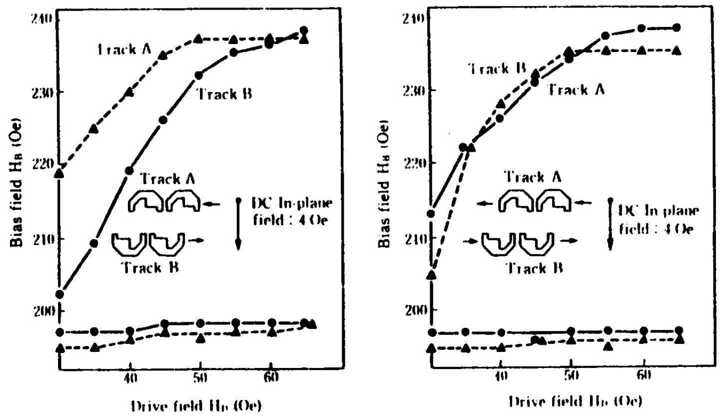


Fig. 10 - The propagation margins of half-disk tracks for the 1.9 μm bubbles with the DC in-plane field of 4 Oe.

In Fig. 10-b) the bias margin difference can fortunately be compensated for by aligning the crystal orientation $[\bar{1}\bar{1}2]$ to the 180° direction of the drive field, the propagation direction for track B, and applying the DC in-plane field along the 90° direction of the drive field. Similarly in "0°" orientation, the bias margin difference can be compensated for by applying the DC in-plane field along the 270° direction of the drive field. Compared with the results in Fig. 6, the 8 μm period minor loop propagation margins are greatly improved.

In Figs. 9-a) and 9-b), difference in the propagation margins between track A and B is reversed by changing the crystal orientation 180°. This demonstrates that the difference is caused by the in-plane anisotropy of the garnet film. This appears to be the same as the case in contiguous disk devices where anisotropic propagation margins are caused by threefold symmetric charged walls[16]. In this case the difference in the bias margins between the propagation directions is supposed to be related to the threefold symmetry of bubble collapse fields. This symmetry is caused by the threefold symmetric response of the closure domains associated with bubble-to-in-plane fields[17].

In Figs. 10-a) and -b), the upper thresholds of the bias margins for track A are improved, while those for track B are degraded by the application of the DC in-plane field. Apparently the in-plane field directly increases the drive fields at the pattern gaps, where the margin thresholds are determined in track A, while reducing them in track B. This improves the upper thresholds of the bias margins for track A and degrades those for track B. The direction of the in-plane field can be chosen independently from the garnet film orientation. The margin

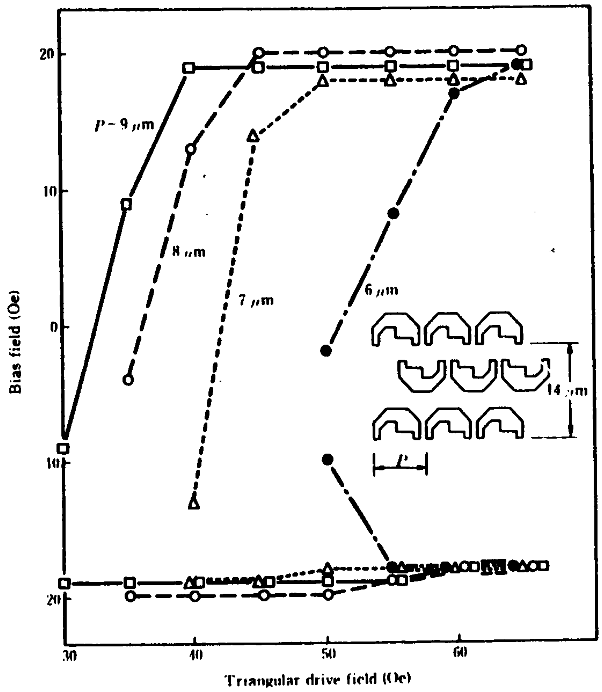


Fig. 11—Bias margins of the minor loop propagation with the basic cell sizes varied from 6 μm × 7 μm to 9 μm × 7 μm.

threshold difference caused by the in-plane anisotropy of the film can be cancelled by the difference caused by the DC in-plane field, as shown in Fig. 10-b).

3.3 Cell size

Figure 11 shows the minor loop designs used in the design optimization, where the propagation period is varied from 6 μm to 9 μm and a loop-to-loop distance of the minor loops is kept at 14 μm. Figure 11 also shows the bias margins of these minor loop propagations with heavily loaded 1.9 μm bubbles and the DC in-plane field of 5 Oe. The 9 μm period propagation shows a sufficient bias margin even at low drive fields and the required drive fields are increased by decreasing the propagation period. Both required drive fields and bias margins for the 8 μm and 7 μm period propagation are found to be acceptable for practical use, while those for the 6 μm period propagation are drastically degraded. These characteristics and the possessed area restriction led us to choose the basic cell size of 8 μm × 7 μm for the 1 megabit device.

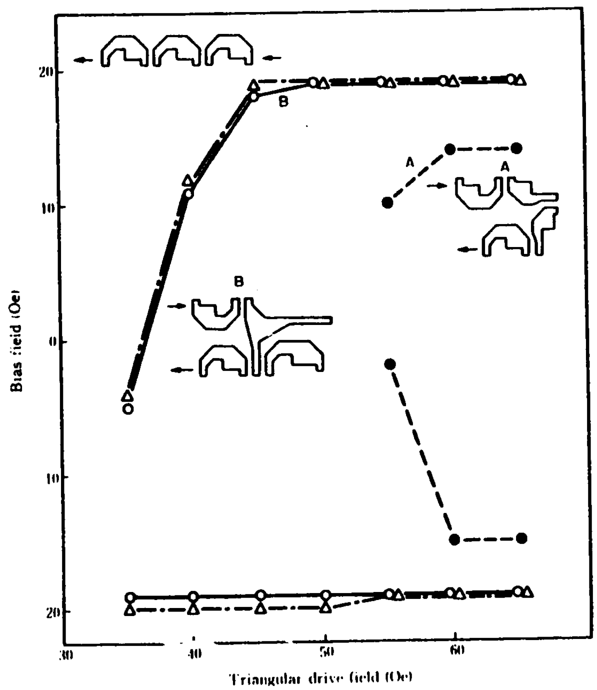


Fig. 12—Designs and bias margins of 180° inside turns compared with the half disk straight propagation margin at 100 kHz.

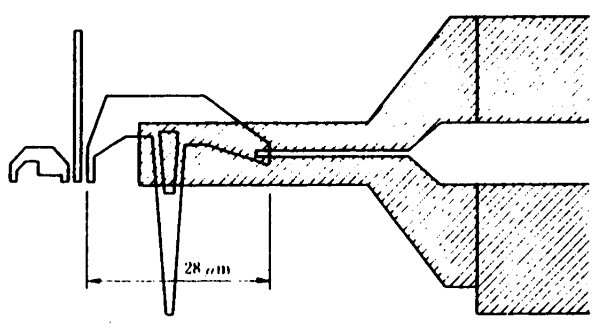


Fig. 13 Design of the hammer type nucleation generator.

To preserve enough spaces at the replicate and swap gates, the minor loops are folded. Many designs of 180° inside turns, which are essential for the folded minor loops, are tested by using the cell size of 8 μm x 7 μm. In Fig. 12, design A (a half scale of the 16 μm period device) requires significantly high drive fields with heavily loaded bubbles. Design B does not limit the minor loop propagation margins and can improve the required drive fields.

4. Designs of generator and detector

4.1 Generator

Spurious bubble generation at high temperatures in a pickax type nucleation generator[18] has been reported. The spurious generation, whose error rate is very small, occurs in the conditions of high temperatures, low bias fields, and in high generation currents with a wide pulse width and sparse data patterns. Unfortunately, a temperature range for overall device operation is limited by the nucleation generator. To avoid this problem, a replicate generator was employed for the first 1 megabit device[19], whose characteristics were the same as those of the block replicate gates even at high temperatures. The replicate generator should keep seed bubbles stable in its small loop, and is more complicated to operate than the simple nucleation generator. Scores of different nucleation generator designs were tested to improve its characteristics at high temperature.

The design concept used magnetic poles localized at one point of the permalloy pattern. A new design named a "Hammer" type nucleation generator[20] has been successfully developed. Figure 13 shows a design of the hammer type nucleation generator with an enlarged pattern size. The nucleation point is kept away from the head of the hammer pattern by a horizontal arrangement of the hairpin conductor. Figure 14 shows its error rate curves for the minimum and maximum generation currents with a pulse width of 200 ns at a chip temperature of 70 °C and low bias fields, compared to those of the pickax type nucleation generator. The data pattern is repeated with $(10000000)^n$. The error rate is defined as the number of errors divided by the number of read-out bits including "0"s. In short term testing which can detect only a high error rate such as 10^{-3}, the pickax type generator appears to work stably with a sufficient current margin. The real maximum current is actually lower than this, and in order to determine it the generator must be tested at low error rate over a long term. For example, it takes more than ten seconds to detect errors with error rates lower than 10^{-6} where the error rate curve seems to be saturated. A very wide current margin is obtained by using the hammer type nucleation generator as shown in the figure. The generator can also be tested in a short period of time to determine the actual threshold.

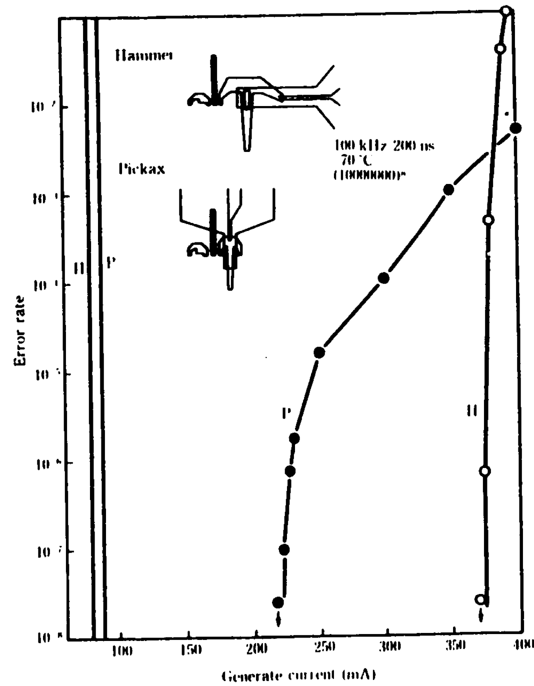


Fig. 14–Error rate curves of the generation currents for the hammer type nucleation generator, compared with those for the pickax type nucleation generator.

4.2 Detector

Output signal and noise properties of the serpentine detectors for the 8 μm period devices exhibited extreme dependence on design details[13]. Many sorts of serpentine detectors have been tested to obtain sufficient performance for practical use. Some of our results are summarized in Fig. 15 where their normalized output signals are plotted as a function of the drive fields at a midpoint of the bias field. Active and dummy detectors with side-by-side arrangement are used in this test. By decreasing the drive fields, the output signal voltages are abruptly increased as shown in the figure. Those abrupt changes are caused by ω-2ω transition of the output wave form[13]. A 9 μm period serpentine detector, (a half scale from the 16 μm period device) has poor output signal voltages and requires high drive fields. Some improvements are observed in the designs of "Nelson" types[13),21)], but those are still insufficient for practical use. A 10.5 μm period asymmetric chevron type detector has sufficient output signal voltages in the wider drive field regions so that the required drive fields for this detector can match those for other parts of the device.

These results demonstrate that a combination of the 10.5 μm period asymmetric chevron type detector and the 13.5 μm period Mt. Fuji stretcher provides satisfactory performance for small bubble detection.

5. 1 Megabit chip

As described in the previous sections, the function designs have been

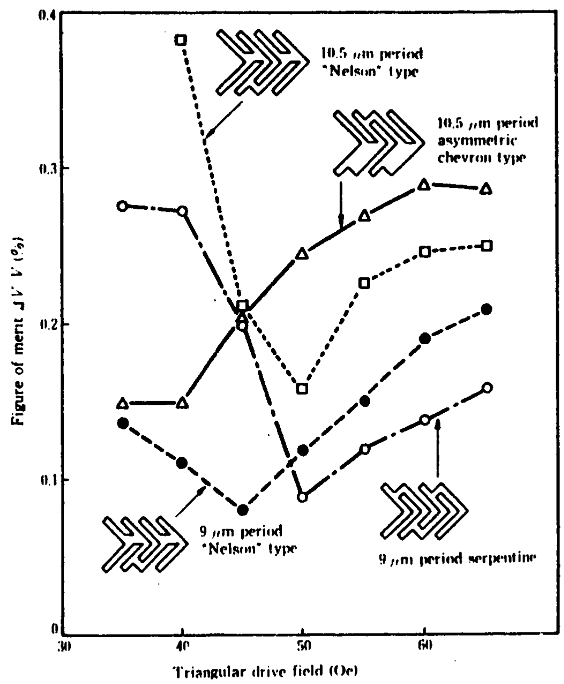
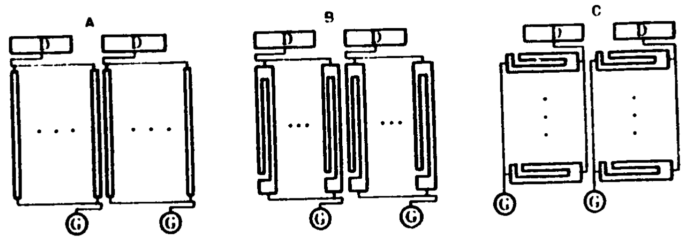


Fig. 15—Normalized output signal voltages vs. drive field for various designs of serpentine detectors.

successfully improved by using the relaxed function designs. Satisfactory minor loop propagation characteristics have also been obtained by employing the half-disk patterns and the 1.9 μm diameter bubbles. An 8 μm period 1 megabit bubble memory device has been designed using these technologies.

5.1 Architecture

Chip organization has been studied to relax the function designs. Type A in



Loop organization	A	B	C
Number of minor loop	$\sqrt{N}/2$	$\sqrt{N}/4$	$\sqrt{N}/2$
Minor loop length	$2\sqrt{N}$	$4\sqrt{N}$	$2\sqrt{N}$
Average access time	$1.25\sqrt{N}t$	$2.25\sqrt{N}t$	$1.25\sqrt{N}t$*

N : Chip capacity
t : Rotating field cycle
* : Double-period propagation at the gates

Fig. 16—Schematic representation of various chip organizations. Organization (C) employs double-period propagation at the gates.

Fig. 16 shows a block replicate organization used in commercial 16 μm period devices, and Type B is organized by connecting neighboring loops and making the gate period twice that of design A. This organization permits an adequate number of spaces at the gates to be saved. The folded minor loop length of design B is twice that of design A, and the access time degrades. The number of minor loops, the lengths and average access times are listed against the capacity and rotating field cycle. The average access times shown do not include latency time from the first loop to the detector. The drawback of design B can be removed by modifying the loop layout as shown in Type C of Fig. 16. By using double-period propagation patterns in write and read lines, the access time can be made the same as in design A[10].

Figure 17 shows the 1 megabit chip architecture with the relaxed function designs and the folded minor loops. It is composed of two 512 kbit-blocks organized with block replicate gates and true swap gates. Each block has two generators and two detectors which are respectively shifted one bit position from each other. The chip is divided into even and odd blocks by selecting bonding pads of generators and detectors. As a result the 1 megabit chip can be obtained from only one set of photo masks for the 512 kbit-block. There are 600 minor loops in total, 512 data loops, 2 boot loops and the surplus loops for ECC and redundancy. The minor loop length is 2053 bits. The data rate is 100

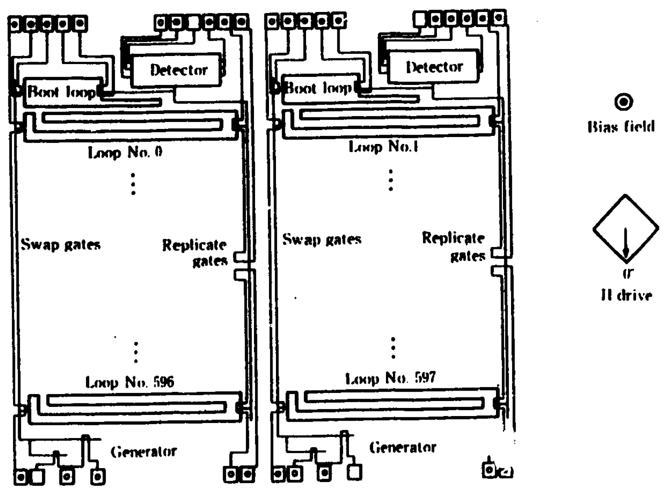


Fig. 17 – 1 megabit chip architecture.

kbits/s and the average access time is about 11.2 ms at a drive frequency of 100 kHz. The chip size is 9.1 mm x 9.9 mm.

5.2 Function designs

Figure 18 shows designs of the block replicate gate and the true swap gate[19]. The half-disk patterns have been employed for the folded minor loops and major lines. Pattern periods in the minor loops are 8 μm in x direction and 7 μm in y direction as described in Sec. 3-3.

Consequently, the pattern periods in the write and read major lines are 14 μm. The width of the pickax pattern head is 13.6 μm. The minimum conductor widths and gaps are 4 μm and 1 μm, respectively. The minimum feature size of the permalloy patterns is 1 μm. The nucleation generator design shown in Fig. 13 is employed instead of the replicate generator[19]. The 13.5 μm period Mt. Fuji stretcher shown in Fig. 1 and the 10.5 μm period asymmetric chevron detector shown in Fig. 15 are employed as mentioned before.

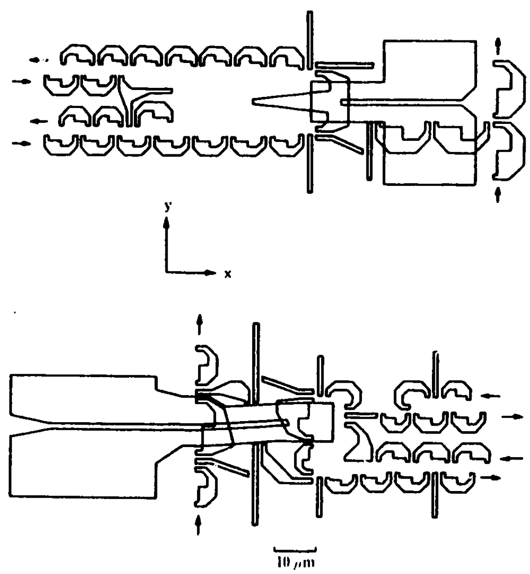


Fig. 18--Design of block replicate gates and true swap gates.

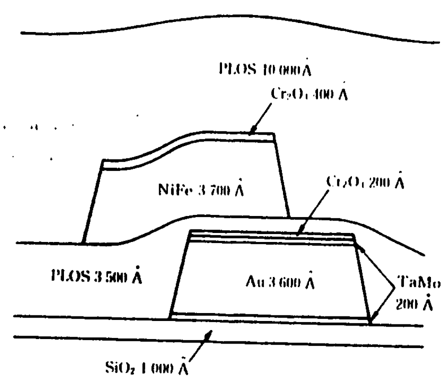


Fig. 19--Schematic structure of the chip fabricated by PLOS.

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Fig. 20–SEM photographs of the permalloy patterns at the conductor crossing of the PLOS and the SiO lift-off process chips. The isolation layers all removed by CF_4 and O_2 plasma.

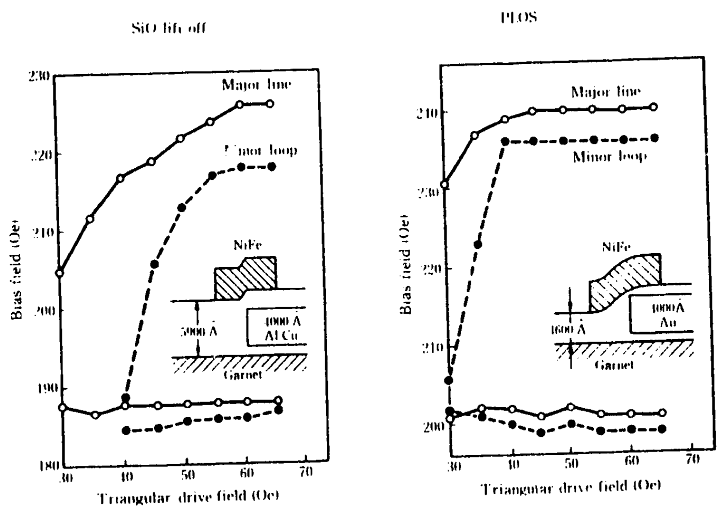

Fig. 21 · Propagation margins of the minor loops and the write major line of both the PLOS and the SiO lift-off process chips.

6. Fabrication

6.1 Planar process

For bubble memory devices, the planar process is very important because good step coverage of the permalloy patterns at conductor pattern edges is essential for stable bubble propagation. Steps of permalloy patterns in non-planarized chips sometimes cause increases in the required drive fields and degradation of bias margins. The SiO lift-off planar process[11] was already established for the 16 μm period devices.

When the SiO lift-off planar process is applied to the 8 μm period devices, degradation of the propagation margins at the conductor crossings is observed in some cases. This degradation is supposed to be caused by small but sharp steps of the permalloy patterns at the conductor edges, which does not affect the bubble propagation margins in the 16 μm period devices. To solve this problem in bubble memory devices the use of resin has been proposed[22].

A new type of resin recently developed in FUJITSU LABORATORIES LTD. has been studied for the 8 μm period 1 megabit device[12]. This resin is a ladder type organosiloxane polymer named PLOS. Compared to the polyimide, PLOS has a better leveling effect and a higher decomposition temperature of more than 520 °C.

A new process developed to apply PLOS for the 1 megabit bubble memory device is shown in Fig. 19. Initially, 1000 Å SiO_2 is sputtered on the wafer. A 3600 Å gold film layered with 200 Å TaMo alloy and 200 Å Cr_2O_3 is then introduced. The layers are then evaporated successively in the same vacuum by an electron gun. A Cr_2O_3 film is used for the anti-reflection layer to reduce the standing waves in the photo resist during exposure. Conductor patterns are delineated by a 10-to-1 projection aligner and ion etching. A 3500 Å PLOS layer is spun for a planarizing layer. The coated PLOS is pre-cured at 120 °C for 1 h and cured at 450 °C for 1 h. A 3700 Å permalloy is evaporated on the PLOS by an electron gun at a substrate temperature of 320 °C. Permalloy patterns are delineated in the same way as the conductor patterns. The photo-resist is then removed by acetone. In this case plasma dry ashers can not be used because O_2 plasma etches PLOS as well as the photo resist. One μm PLOS passivation is spin-coated and cured at 325 °C. To open via-holes for bonding pads, PLOS is etched by CF_4 and O_2 gas plasma.

Figure 20 shows SEM photographs of the permalloy pattern at the conductor crossing of the PLOS and SiO lift-off process chips. A smoothly leveled step is clearly visible in the PLOS process chip, while there is a sharp step at the conductor crossing in the SiO lift-off process chip. As shown in Fig. 21, sufficient bias margins and low required drive fields for both 14 μm period major lines and 8 μm period minor loops are obtained by using the PLOS process. The PLOS process also has a better leveling effect and greater spacing thickness reduction, compared to the SiO lift-off process.

6.2 TaMo alloy-Au conductor

Some conductor systems have been studied for the 1 megabit device[23]. In the 16 μm period devices, AlCu has been in use. This AlCu alloy could have a problem in electromigration when reducing the conductor width from 4 μm. Bubble memory devices carry higher current densities of nucleation generators are more than 10^7 A/cm^2.

It is well known that gold is potentially better than AlCu from the standpoint of electromigration. However, adhesion to other matierals is generally very poor, and the gold conductor usually takes a sandwich structure with refractory metals which adhere strongly to insulation layers. TaMo alloy interdiffusion and reliability have been studied, and compared with conventional refractory metals such as Ta, Mo, and W. Interdiffusion kinetics were studied

	Electromigration	Interdiffusion	Corrosion resistance
TaMo/Au/TaMo	Excellent	Excellent	Excellent
Ta/Au/Ta		Poor	
Mo/Au/Mo		Excellent	Poor
W/Au/W			
Al-Cu	Fair	—	Fair

Fig. 22–Results obtained from reliability tests on Au conductor systems and AlCu conductor.

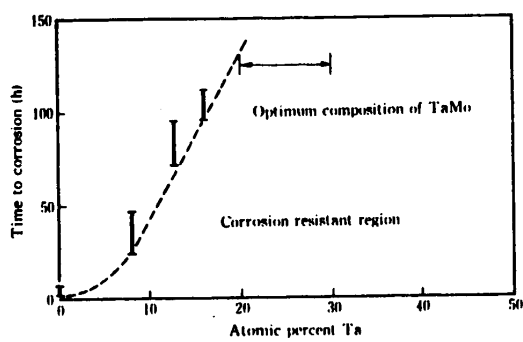

Fig. 23–Corrosion resistance of TaMo binary alloy in water vapor of 2 atm at 120 °C.

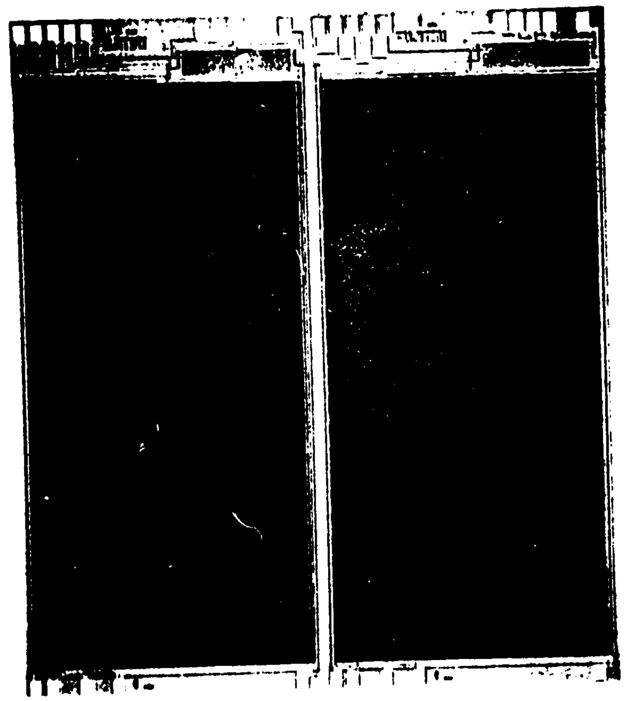

Fig. 24—1 megabit chip fabricated with PLOS and TaMo alloy-Au conductor.

using resistance measurements. The lifetime due to electromigration was measured by the lifetime method. Corrosion resistance was measured by pressure-cooker tests performed in water vapor of 2 atm at 120 °C.

Results obtained in our study are summarized in Fig. 22. All Au conductor systems show excellent electromigration resistance compared to the AlCu conductor. Ta/Au/Ta conductors have a large diffusion coefficient but excellent corrosion resistance, while Mo/Au/Mo and W/Au/W conductors have a small diffusion coefficient but poor corrosion resistance. In contrast, the TaMo/Au/TaMo conductors have a small diffusion coefficient as well as excellent corrosion resistance.

Figure 23 shows the results of a pressure-cooker test conducted to determine an appropriate TaMo alloy film composition. The figure shows the rate of degradation by corrosion as a function of the Ta content in the TaMo alloy film. The rate of degradation is sharply reduced by increasing the Ta content. It was also observed that the inter-diffusion coefficient gradually increases from 40% Ta so that the optimum composition of TaMo alloy can be chosen within 20% to 30% Ta.

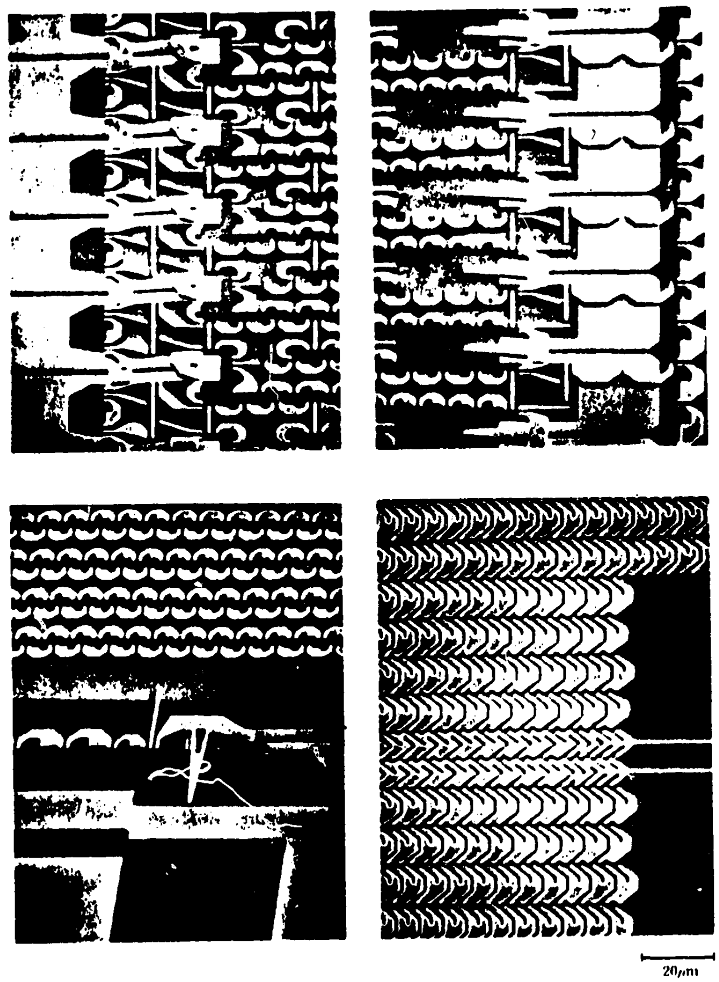

Fig. 25—SEM photographs of the true swap gates, replicate gates, hammer type nucleation generator and novel stretcher-detector.

The AlCu conductor is still thought to be reliable for the 1 megabit device with the relaxed function designs. These designs require a minimum conductor width which can be maintained at 4 μm, or the same as that of the commercial 16 μm period 256 kbit-devices. More reliable megabit devices can be realized by using a TaMo alloy-Au conductor.

Figure 24 shows a photograph of the 1 megabit chip fabricated with PLOS and TaMo alloy-Au conductor. Figure 25 shows SEM photographs of the true swap gates, replicate gates, hammer type nucleation generator and novel stretcher-detector.

The composition of the garnet film used for the 1 megabit devices is $(YSmLuCa)_3(GeFe)_5O_{12}$. Typical parameters are $4\pi M_s$ 452 Gauss, thickness 1.85 μm, and strip width 1.9 μm.

7. Characteristics

The fabricated 1 megabit chips have been characterized over the drive field range from 45 Oe to 65 Oe peak fields of 100 kHz triangular wave drive, and over a temperature range from 0 °C to 90 °C. Figure 26 shows the temperature dependance of overall margins as a function of swap current at the drive field of 55 Oe. Although the low bias field margins at high currents are limited by strip-out errors of the bubbles to be transfered in, swap current margins of 20 mA are obtained over the temperature range from 0 °C to 90 °C. These characteristics are confirmed to be almost the same as those at the drive fields of 45 Oe and 65 Oe.

Figure 27 shows the temperature dependence of the overall bias margins as a

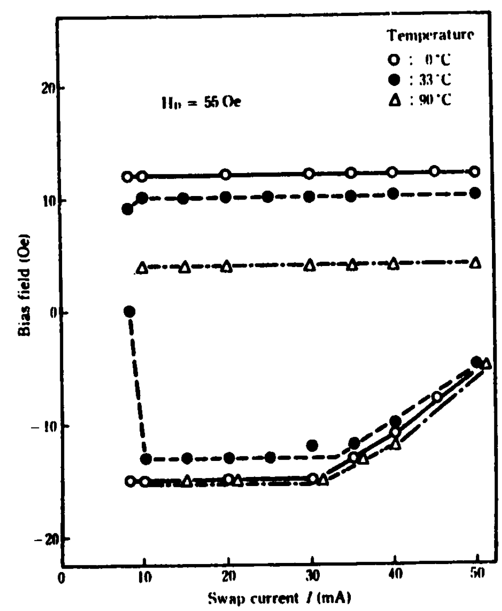

Fig. 26—Temperature dependence of overall bias margin as a function of swap current.

function of the replicate pulse phase at the drive field of 55 Oe. The phase margins of 30 degree are obtained over the temperature range from 0°C to 90°C. These characteristics are also confirmed to be same as those at the drive fields of 45 Oe and 65 Oe. In these measurements, the replicate pulse phase margins are measured with modulation[24] of both pulse amplitudes and widths from nominal values as shown in the figure. The upper thresholds of the bias margins are limited by propagation failures in the minor loops. The lower thresholds of the bias margins are limited by propagation at the swap turns in the minor loops. Therefore the overall bias margins are not determined by the replicate gates themselves. These enlarged gate pattern designs which use relaxed function designs, enable wider conductor patterns to be made and improve the registration tolerance to the same level as in the 3 μm bubble devices. Judging from the variously aligned samples, a registration tolerance of about ±0.5 μm is expected to be retained for all functions such as the swap gates, replicate gates and generator.

Figure 28 shows the output signal and noise voltages at a 3 mA detector current as a function of the drive field amplitude over the temperature range from 0 °C to 90 °C. The resistance of the detector with 250 asymmetric chevrons is

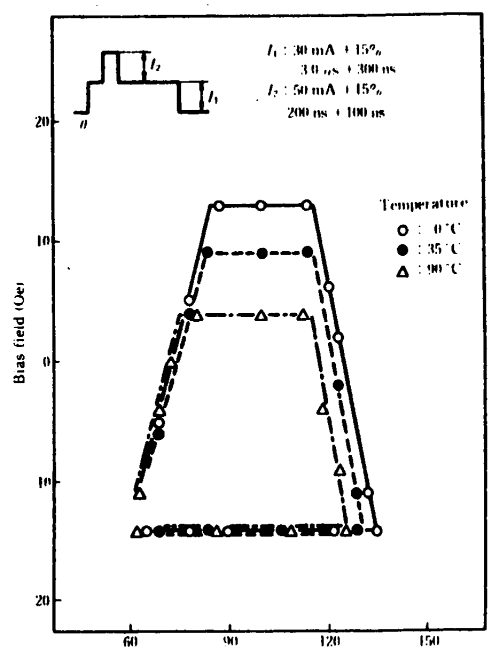

Fig. 27–Temperature dependence of overall bias margin as a function of replicate pulse phase.

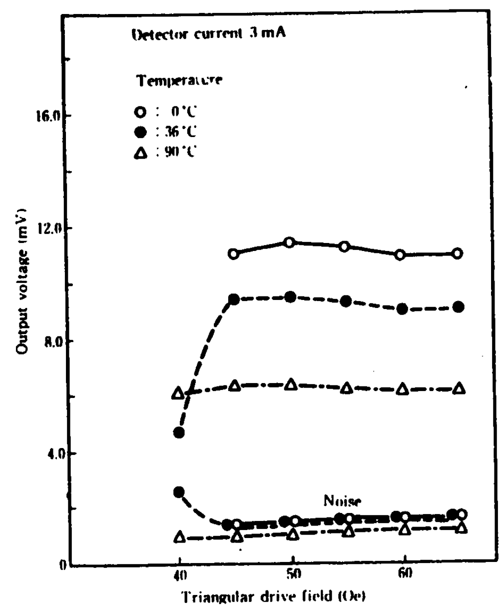

Fig. 28—Output signal and noise voltages vs. drive field at chip temperatures 0 °C, 36 °C and 90 °C.

about 1 kilo-ohms. Sufficient signal-to-noise ratios and output signal voltages of more than 6 mV are obtained, even at the drive field of 45 Oe over the temperature range. The superior characteristics of this detector also indicate that by selecting optimum timings of the sense amplifier clamping and strobing, the output signal and noise voltages can be independent of the drive field amplitude in the range from 45 Oe to 65 Oe.

Results obtained in the characterization of the 1 megabit device are good enough to guarantee the same drive field and sense requirements for a packaged 1 megabit device as those of the well-established 3 μm bubble 256 kbit-devices. The 1 megabit device can also be realized with device interface characteristics almost the same as those of the 3 μm bubble 256 kbit-devices. These include a chip size within 1 cm^2, a package size, a nominal drive coil current of 500 mA and function pulse margins such as amplitudes, phases and widths. The packaged 1 megabit device can be realized by merely replacing the chip with the 256 kbit-device package.

Figure 29 shows the temperature dependence of overall bias margins for the packaged 1 megabit device. The overall bias margins have been measured at two different drive field amplitudes of 50 Oe and 65 Oe peak fields of 100 kHz triangular wave drive under the worst-case conditions. These conditions include full loading for the upper thresholds and sparse loading for the lower thresholds,

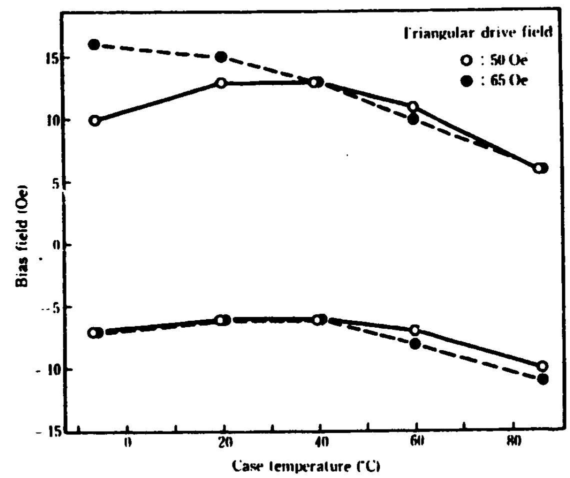

Fig. 29—Temperature dependence of overall bias margins for a packaged 1 megabit device.

with start-stop operation where bubbles are stopped more than 6000 times at each pattern in the minor loops. The characteristics of the packaged 1 megabit device shown in Fig. 29 can guarantee the overall bias field margins of ±3 Oe over the drive field range from 50 Oe to 65 Oe and over a case temperature range from 0 °C to 86 °C.

A low power operation has been realized for the packaged 1 megabit device. This consists of a 500 mA coil current which provides a 57 Oe drive field, a 670 mW package power dissipation and the wider ambient temperature range from 0 °C to 70 °C.

8. Conclusions

A low drive field 1 megabit device using 1.9 μm diameter bubbles has been realized by employing the relaxed function designs and the planar process using a new type of resin, PLOS.

TaMo alloy-Au system can realize a highly reliable conductor for the megabit bubble memory devices.

The same drive field and sense requirements as those of 3 μm bubble 256 kbit-devices, and a wider ambient temperature range of 0 °C to 70 °C can be realized for the packaged 1 megabit device.

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