Asahi Chemical puts faith in Hall sensors

Mohamed Henini, University of Nottingham, UK

Asahi Chemical Industry Co Ltd is one of the largest industrial companies in Japan, with business sectors stretching across a variety of products and end use applications. These activities include an active interest in advanced semiconductors, underlined by the fact that the company supplies 70% of the world market for Hall sensors. The company is committed to creating and expanding markets for its products, as outlined in this article.

The history of Asahi Chemical is one of constantly expanding development and applications for technology and products that meet the needs of society and bring more efficient use of materials and resources. Decades of research, development and operations for this purpose have constantly expanded its base of technology and knowledge in polymeric, fermentation and catalytic chemistry, membrane processes, systems engineering and many other fields. Today its research and development are expanding this base in life sciences, electronics, and high performance materials and processes. Research and development (R&D) in the years ahead will be directed by the so-called 'SP-21', the strategic plan for the 21st century, which is now being formulated. It is intended that this plan will lead the identification and implementation of R&D in electronics, health care, housing and construction materials, and other strategic areas for the development of new core businesses at Asahi Chemical. In these and other fields the pace and the cost of technological advancement are rapidly increasing. A Research on Research ("R on R") initiative is now underway to increase the speed and efficiency as well as the creativity and skill of the R&D effort at Asahi Chemical (Figure 1).

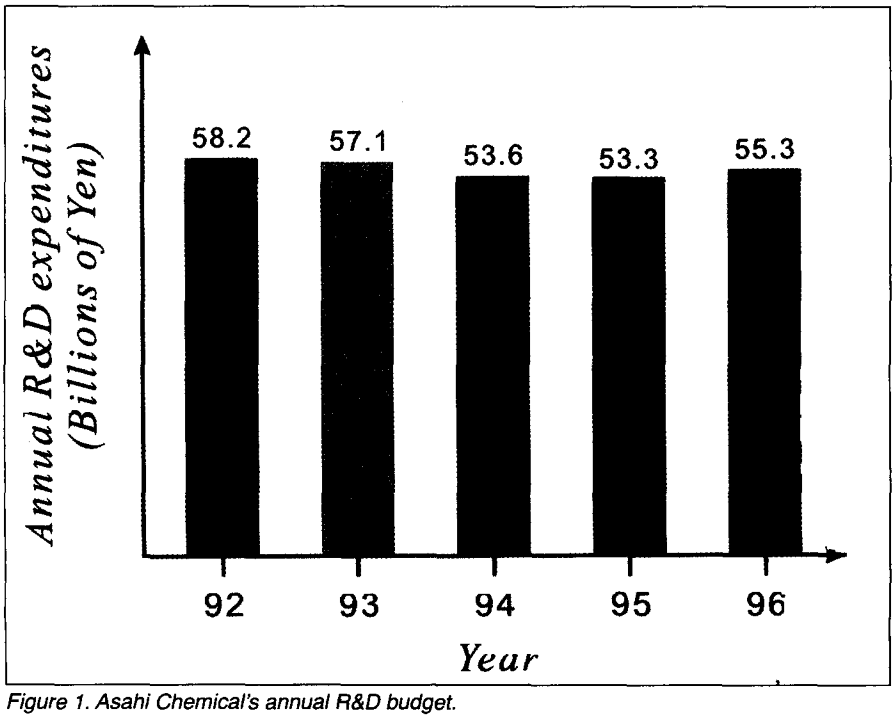

Figure 1. Asahi Chemical's annual R&D budget.

The key sectors and products of Asahi Chemical are (Figure 2): chemicals and plastics; housing and construction materials; fibres and textiles; and special products. Included in the special products sector are both pharmaceuticals and electronics. These are both seen as strategic, future high-growth core businesses, although they currently account for only 6.7% and 4.7% of this sector, respectively.

Asahi's electronics division

In electronics, 1996 sales increased by ¥10.9 billion on the previous year to ¥56.8 billion, led by market growth in large scale integrators (LSIs) and Hall sensors. Two important subsidiary companies of Asahi Chemical are Asahi Kasei Electronics Co Ltd, which holds a 70% share of the world market for Hall sensors, and Asahi Kasei Microsys-tems Co Ltd, which specializes in mobile communications and multimedia systems.

Asahi Kasei Electronics, which was founded about 15 years ago, is concentrating on the development

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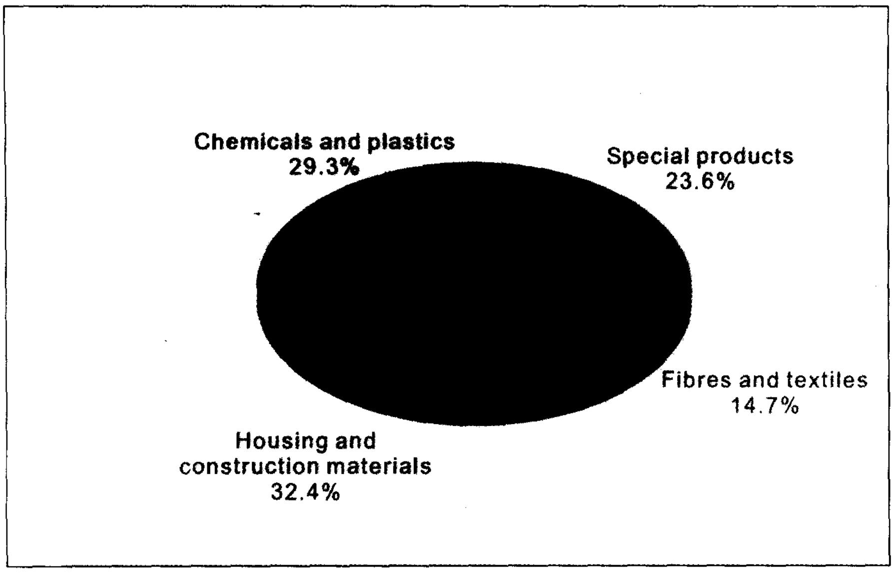

Figure 2. Key sectors of Asahi Chemical in terms of sales.

and growth of magnetic sensors. The use of magnetic sensors has grown rapidly year by year and is expected to continue to grow well into the 21st century, with rapid expansion into new fields and applications. This growth is led by the need for high performance motors in video cassette recorders, floppy disk drives, CD-ROM drives, fans, printers, current sensors and other office automation systems.

InSb and InAs Hall sensors produced by Asahi Chemicals were described by Dr N. Kuze and Dr I. Shibasaki (*III-Vs Review*, Vol. 10, No. 1, pp. 28-32). This article will report on some new advances in this field.

Hall sensors

M. Yamamoto *et al.* have recently studied the dependence of the surface morphology and the sheet carrier density of InAs thin film epitaxially grown on (100) GaAs substrates with various misorientations of tilt directions and angles of tilt. The properties of Hall elements fabricated on these substrates were also studied.

Figure 3 shows Nomarski interference microscope photographs of the surface morphology of Si-doped InAs thin films grown on 2° off the (100) GaAs surface with various directions of tilt towards: (a) [0$\bar{1}$0], (b) [0$\bar{1}\bar{1}$], (c) [00$\bar{1}$], (d) [0$\bar{1}$1] and (e) to misorientation. Arrows indicate directions of tilt. As can be seen, the structure of the surface morphology depends on the directions of tilt. The sheet carrier density was found to be independent of the directions of tilt. Figure 4 shows Nomarski interference microscope photographs of Si-doped InAs thin films grown on (100) GaAs substrate tilted towards [00$\bar{1}$] with various misorientation angles: (a) 1°, (b) 2°, (c) 3°, and (d) 4°. The arrow indicates the direction of tilt. It is clear that the more tilted the angle of the misorientation is, the rougher is the surface morphology. It was also found that the more tilted the angle of misorientation is, the less dense is the sheet carrier density.

The molecular beam epitaxy (MBE) Si-doped InAs layers were then processed into Hall elements by using their standard symmetrical cross pattern production process. The offset voltage, which is important for Hall elements, was found to depend largely on the direction of tilt. The smallest offset voltage suitable for commercial production of Hall elements was observed for devices made on substrates tilted towards [0$\bar{1}\bar{1}$] direction. The difference of offset voltages was attributed to the crystalline properties of the InAs thin films.

These novel results have been applied to mass produce MBE grown InAs Hall elements. It is believed that InAs Hall elements will be a promising device, opening up new areas for magnetic field sensor applications.

Applications for Hall elements

In recent years there have been strong demands for Hall elements for electronic equipment such as video cassette recorders, floppy

Table 1. Comparison of Hall element characteristics of InSb, InAs and InAs-DQW.

Hall Element	Output drive voltage, V_H (mV)	Temperature coefficient of V_H	Temperature coefficient of input resistance	Condition
InSb	196-274	-	-2%/degree	1 V
InAs	100	-0.21%/degree	0.05%/degree	6 V
InAs-DQW	260-300	-0.25%/degree	0.2%/degree	6 V

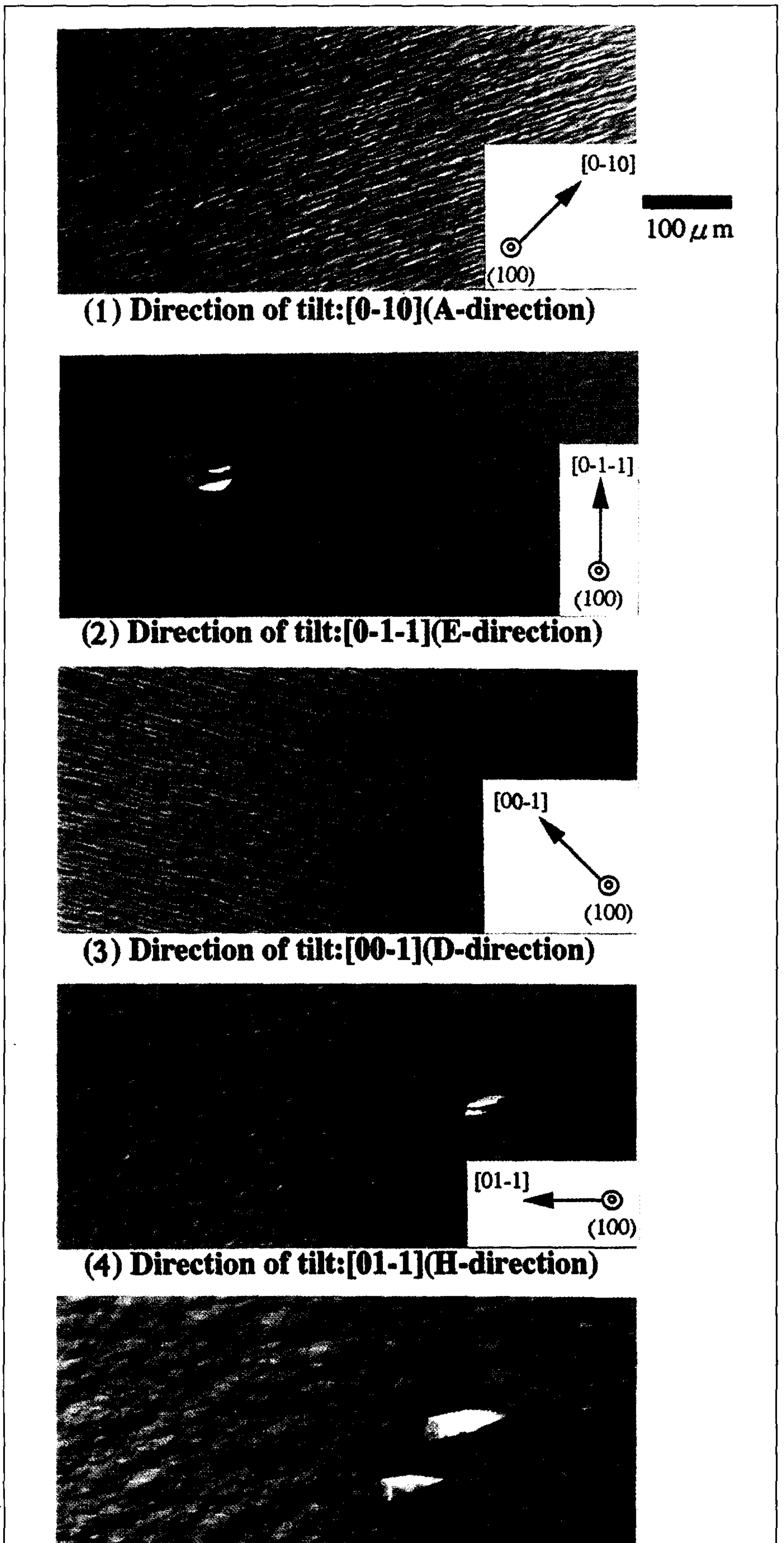

Figure 3. Nomarski microscope photographs of Si-doped InAs thin films grown by MBE on 2° off the (100) GaAs surface with various directions of tilt.

disk drives, CD-ROMs, non-contact switches, current sensors, position sensors and ferrous material detectors. In these applications, the Hall elements employ the Hall effect to detect magnetic fields. InSb thin film Hall elements and GaAs Hall elements are well-known and are produced in high volume as magnetic field sensors. InSb Hall elements have high sensitivity to the magnetic field, but are not suitable for high temperature operation. On the other hand, GaAs Hall elements have a good temperature stability but their sensitivity is not so high. Thin film InAs Hall elements were predicted to have both high sensitivity and stability at high temperature operation. However, it is difficult to obtain InAs thin films with the submicron thickness, high electron mobility and high sheet resistance required for high sensitivity Hall elements.

Asahi Chemical solved these problems by employing MBE to grow InAs thin film on GaAs substrates with 0.5 μm thickness and higher electron mobility of more than 10 000 $cm^2.V^{-1}s^{-1}$ at room temperature. The company is able to produce more than 8 million devices per year for use in the various electronic applications mentioned earlier.

Deep quantum well structures

Recently, Kuze and his colleagues have investigated InAs deep quantum well (InAs-DQW) structures made from InAs/AlGaAsSb materials on GaAs substrates by MBE. This material is of interest because of the large conduction band offset of ≈1.3 eV and the high electron mobility of InAs. They have quantitatively measured the speed of lattice relaxation of AlGaAsSb on GaAs surfaces using reflection high electron energy diffraction (RHEED) linescan image analysis. They found that the lattice relaxations were complete within three monolayers for GaAsSb and seven monolayers for AlGaAsSb on GaAs

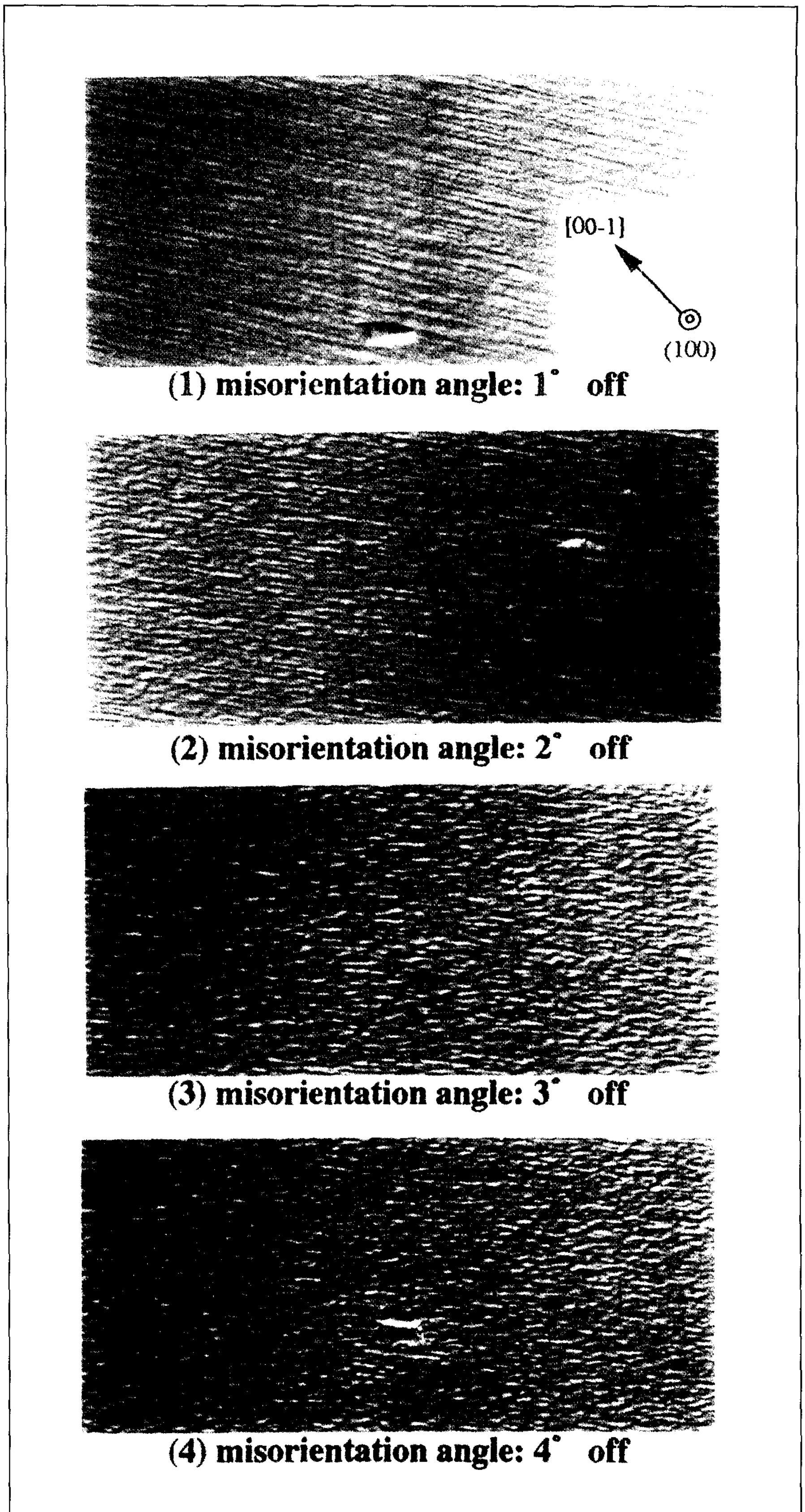

Figure 4. Nomarski microscope photographs of Si-doped InAs thin films grown by MBE on (100) GaAs substrate tilted towards [00$\bar{1}$] with various misorientation angles.

surfaces. They have also observed that two-dimensional growth occurs after deposition of 20 monolayers of GaAsSb on GaAs surfaces. Furthermore, it was confirmed by atomic force microscopy (AFM) that the InAs grows on AlGaAsSb two-dimensionally because it is lattice matched to InAs. High electron mobilities of more than 32 000 $cm^2.V^{-1}.s^{-1}$ and high sheet carrier concentrations of 1.0 x 10^{12} cm^{-2} at room temperature were achieved in the AlGaAsSb/InAs/AlGaAsSb DQWs.

To demonstrate the potential of AlGaAsSb, S. Miya *et al.* fabricated two types of InAs channel devices, namely Hall elements and FETs, using $Al_{0.65}Ga_{0.35}AsSb$ as the buffer/barrier material. It was found that InAs-DQW Hall elements have a high output voltage and little more temperature dependence than commercially available InAs and InSb Hall elements (Table 1).

InAs-DQW FETs were also fabricated. DC measurements showed good pinch-off characteristics and the gate leakage current was several tens of μA. The FET of 1 μm gate had a f_T value of 33 GHz. The effective electron velocity of 2.2 x 10^7 $cm.s^{-1}$ in their FETs is a high value and comparable to that of a typical InGaAs/InAlAs HEMT on an InP substrate.

Magnetic sensors

Asahi Kasei Electronics has also developed high-performance hybrid Hall Effect ICs as magnetic sensors. Applications include: a voltage regulator; Hall voltage generator (InSb Hall element); signal amplifier; Schmidt trigger; and open collector output. These ICs can be used directly with bipolar or metal oxide semiconductors (MOS) logic circuits.

More than 70% of the world's Hall sensors, mainly high sensitivity InSb thin film Hall sensors, are produced by Asahi Kasei Electronics, the recognized leader in this field. To meet the sharply rising demand for these devices in CD-ROM drives and other applications, it is expanding production capacity for InSb and preparing for commercial

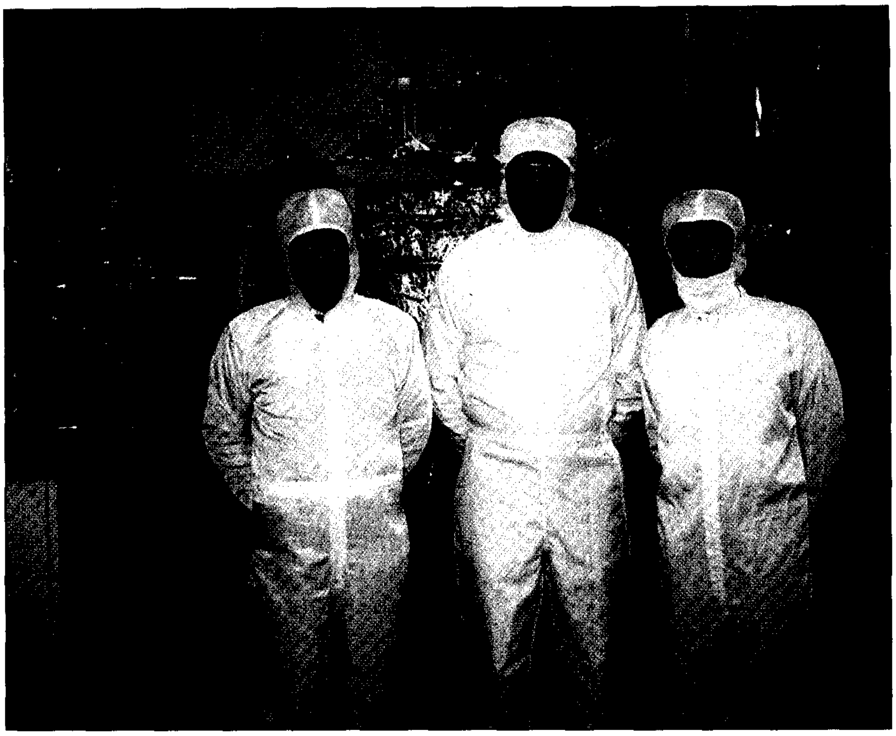

Figure 5. In Asahi Chemical's MBE laboratory are Dr I. Shibasaki, Dr M. Henini and Dr N. Kuze.

production of new InAs Hall sensors. Both came on stream in August 1996.

It is clear that Japan is working hard to revitalize its R&D activities and foster the dynamism of technological creativity in order to become the world leader in the development of new technologies. Asahi Chemical is a typical example of Japanese companies in the private sector that carries out research and development to maintain and expand its corporate activities.

Contact:
Dr M. Henini
Physics Department
University of Nottingham, UK.
Tel: +44 115 951 5195;
Fax: +44 115 9515180;
e-mail: mohamed.henini@nottingham.ac.uk