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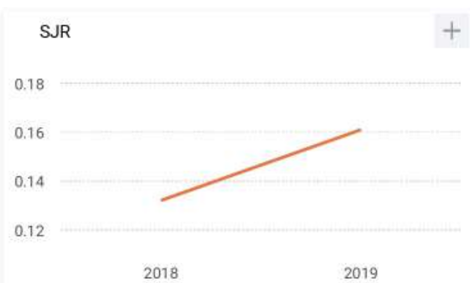

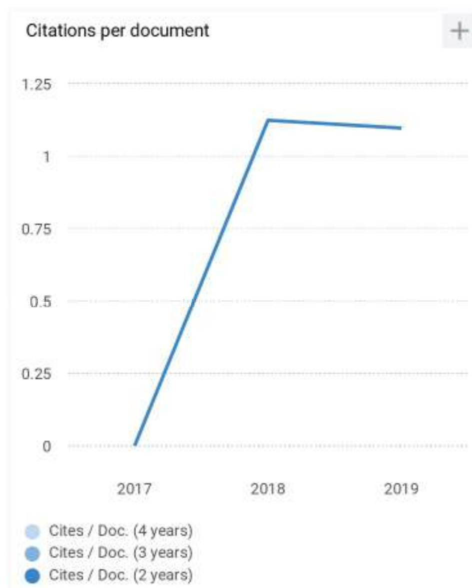

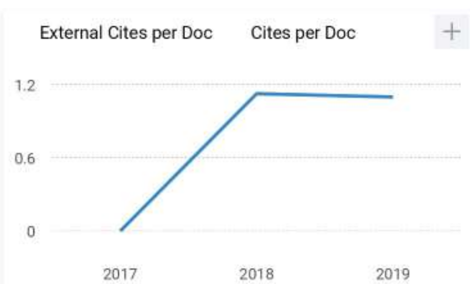

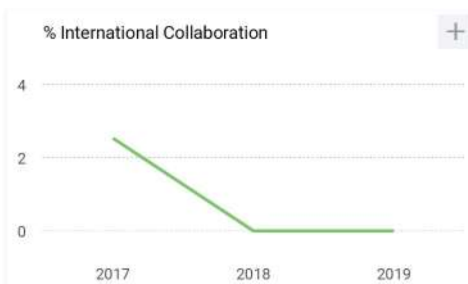

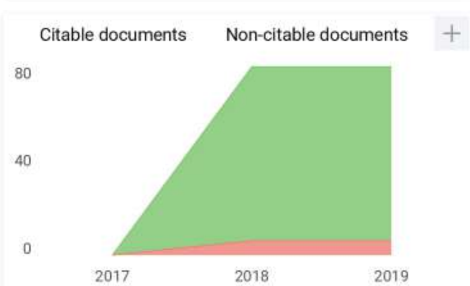

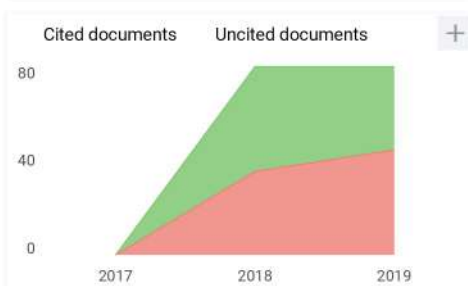

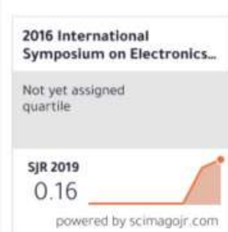

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Welcome messages

Dr. Ir. Patdono Suwigno, M.Eng. Sc.

Directorate General of Institutional Affairs

Ministry of Research, Technology and Higher Education

Dear participants, guests ladies and gentlemen. It is both a great pleasure and honor to welcome you all at the 2016 IEEE International Symposium on Electronics and Smart Devices (ISESD), here in Mercure Bandung Setiabudi, Bandung, Indonesia.

The Directorate General of Institutional Affairs currently puts a lot of efforts to increase the level of universities in Indonesia to a World Class University level. In correspond to these efforts, we hold a national center of excellence program. This program covers topics that are essential to the development of Indonesia. As a part of the National Center of Excellence (CoE), Microelectronics Center is one research center that is supported by us to be the leader in microelectronics area. In the national level, besides microelectronics center, we have other 19 CoEs. This is a prestigious and very competitive program for all univesities in Indonesia.

As a national research center, we also give them a mandate to hold an international conference. We hope that by holding such an event, they can expose their research result, can communicate with many experts from all around the world, and can contribute to the society. We also hope that this conference will be a periodical conference that involves many experts and can be held in different places in Indonesia.

Finally, we would like to express our sincere gratitude to the Insitut Teknologi Bandung (ITB) and Microelectronics Centers ITB and all the technical sponsors for their excellent supports in this conference. We hope that the gathering of ISESD 2016 participants from various countries and cultures will bring a better understanding from each other and all of you will have enjoyable time here in Bandung, Indonesia.

Welcome messages

Dr. Ir. Kadarsah Suryadi, DEA
Rector
Institut Teknologi Bandung,
Indonesia

Dear participants, guests ladies and gentlemen. It is both a great pleasure and honor to welcome you all at the 2016 IEEE International Symposium on Electronics and Smart Devices (ISESD), here in Mercure Setiabudi Bandung, Bandung, Indonesia.

Institut Teknologi Bandung (ITB) has been known as a leading university in the field of science and technology in Indonesia. There are many works from the alumnee that give a significant contribution to the development of Indonesia through the use of technology. ITB as a university, should always follows the philosophy of tri dharma of higher education which are education, research, and contribution to the society. We have been always putting all of our efforts to implement this philosophy through our academic and social activities.

As we all know that the pace of development and advancement of technology, especially in electronics, is very fast. Therefore, Microelectronics Center ITB, being as a national research center in the topic of electronics, plays an important role to lead and to pioneering the development of electronics in Indonesia. Furthermore, as an effort to deepen the knowledge, to keep up to date with the latest development and advancement of technology, as well as to explore and to discover a new understanding in the field of science and technology, such a conference is held. I hope that by holding this conference and gathering all the academia from various countries, Microelectronics Center can always be the frontier in electronics technology and can give even bigger contribution to the development of Indonesia now and in the future.

Finally, we would like to express our sincere gratitude to the School of Electrical Engineering and Informatics (STEI) and Microelectronics Centers ITB and all the technical sponsors for their excellent supports in this conference.

We hope that the gathering of 2016 ISESD participants and experts from various countries can be as a media to exchange ideas and cultures can exchange many ideas and from each other and all of you will have a wonderful experience here in Bandung, Indonesia.

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Welcome messages

Dr. Ir. Jaka Sembiring, M.Eng.

Dean of School of Electrical Engineering and Informatics

Institut Teknologi Bandung, Indonesia

Dear participants, guests ladies and gentlemen. Welcome to Indonesia, welcome to Bandung and welcome to the 2016 IEEE International Symposium on Electronics and Smart Devices (ISESD).

As the Dean of the School of Electrical Engineering and Informatics, Institut Teknologi Bandung (STEI ITB), it is my great honor to be able to welcome you to this conference.

This international conference is one of several international conferences organized by the School of Electrical Engineering and Informatics in 2016. These various conferences are related to our research groups in the school. The ISESD 2016 is closely related to the Electronics Engineering research group.

The topics discussed in this conference covers some very important subjects such as Devices, Circuits, and Systems, VLSI, Communication Systems, Multimedia and Systems, Signal Processing, Internet of Things, and Smart Devices. The research and development in these fields are of great importance for now and in the future.

I appreciate the participation of attendees coming from many countries such as Japan, Taiwan, Malaysia, Turkey, Vietnam, India, as well as participants from other countries including Indonesia.

In this occasion I would like to give my sincerely gratitude to my colleague, Muhammad Amin Sulthoni, as the General Chair of ISESD 2016 and his team for all their efforts in organizing this conference.

I hope that all of you will have a fruitful conference not only during presentation, discussion and technical sessions, but also during social and interpersonal communication from each other at the breaks, lunch, dinner and so on. I hope that the gathering of ISESD 2016 participants from various countries and cultures will bring a better understanding from each other and all of you will have enjoyable time here in Bandung, Indonesia.

Welcome messages

Trio Adiono, ST., MT., Ph. D.

International Steering Committee Chair

Institut Teknologi Bandung, Indonesia

On behalf of steering committee we would like to welcome all delegates travelling from various countries to the first 2016 IEEE International Symposium on Electronics and Smart Devices (ISESD) which is held in Bandung, known internationally as Paris van Java.

ISESD is held in order to accomodate all innovations and to anticipate the advancement of current state of the art of technology towards electronics and smart devices. As you may know that smart devices now become an integral part of our daily life. Many consumer apliances are now become a smart home appliances. In bigger ecosystems, we can also find the implementation of smart devices such as smart city, smart card, smart home, etc. Such smart devices are now become a trend that many companies as well as academia are pursuing towards it. Therefore, we hold this conference to facilitate many experts all around the world to discuss and to present their latest innovation in the area of smart devices technology.

Moreover, this conference is not limited to only certain areas, but we also open for multidiciplinary topics starting from devices, circuit & system, VLSI, communication systems, multimedia and systems, signal processing, and Internet of Things. It is because we believe that we can not get the best product of application without interacting with various areas of expertise.

We hope that in the future ISESD can cope with future challenges of smart devices technology, so that it can fullfill the society needs and even pushing a new technology that people may not think about yet. We also plan ISESD is not held in Bandung only, but spread out in other cities in Indonesia or even in the world.

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Welcome messages

Dr. Eng. Muhammad Amin Sulthoni ST., MT

General Chair

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It is both a great pleasure and honor to welcome you all at the "2016 IEEE International Symposium on Electronics and Smart Devices (ISESD)", here in Mercure Bandung Setiabudi, Bandung, Indonesia.

ISESD is our first international conference which is organized by the National Center of Excellence of Broadband Wireless Access. This is a venue for exchange of information for researchers, academicians, and professionals through presentation of their new research ideas, innovations and development results as well as discussion of possible cooperation among the conference participants. We also hope the fruitful discussion in this conference can fullfil the gap among academia, researchers, professionals and industries that may enhance the benefit of technology for human life.

We are very pleased to have scholars and participants coming across several countries over the world with different interests and expertises. The conference is divided into 7 regular session topics with additional 2 special sessions. A series of the state of the art plenary sessions will be presented by 3 international renowned experts. It has been a real honor and privilege for us to serve as the General Chairs of the Conference. It is really our hope that you can find the conference inspiring, satisfying and enjoyable. We would like to thank to all keynote speakers, authors, and participants, and wish you have pleasant experience in Bandung, Indonesia.

On behalf of the organizing committee, we would like to thank to ISESD International Advisory/Steering Committee members, and all the organizing committee members for their valuable time and contribution to the excellent arrangement of this conference. This conference will not possible without the hard work of authors, reviewers, invited speakers, session chairs to make excellent technical program of this conference.

Finally, we would like to express our sincere gratitude to the School of Electrical Engineering and Informatics, Insitut Teknologi Bandung (ITB), Microelectronics Centers ITB, and all technical sponsors for their excellent supports.

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Silica-on-Silicon waveguides with MgF_2 cladding layers

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***Abstract*—we report on the choice of MgF_2 as cladding layers on silica-on-silicon optical waveguides fabricated by electron beam irradiation. The deposition methods need to be chosen carefully with low temperature as not to damage the low refractive index change during fabrication process. The main consideration is that the refractive index of the cladding layer should be very close to that of silica and it have good transparency, as well as be capable of being deposited at low temperature. The thickness profile then examined using DEKTAK II surface profiler.**

***Keywords*—MgF_2 cladding, silica-on-silicon, optical waveguide**

I. Introduction

An important requirement of all integrated optic systems is the availability of low loss waveguides. Of all the technologies described earlier, silica-on-silicon integrated optics is now the most advanced. It's simple fabrication also offers cheap processing and compatibility with established silicon-based microelectronics. It has the particular advantage that a wide range of low-loss components can be produced on large substrates. Furthermore, silica-on-silicon guides have similar parameters to those of optical fibres, allowing low coupling loss. The devices, however, are currently mainly of passive optical function [1]. The initial point of silica waveguide formation is a silicon wafer, typically 10 cm in diameter, ≈500μm thick, and of (100) orientation. It has the advantage of a high degree of planarity, ready adhesion of the deposited silica and excellent heat dissipation [2]. It has the potential to allow hybridisation of optical and electronic components onto a common substrate, and substrate crystallinity can be exploited to fabricate V-groove structures for passive alignment of optical fibres with the integrated waveguide [3].

To fabricate waveguides in silica-on-silicon, a number of different glassy layers must be deposited on the Si substrate. A uniform buffer layer of silica is first deposited to a thickness of 10-20 μm. The buffer thickness should be large enough to prevent the light from the core layer leaking into the substrate, which has a much higher index than silica. The required thickness increases as the difference in refractive index between core and cladding is reduced.

A second layer of glass (from which the core will eventually be formed) then is deposited on top of the buffer layer. The refractive index of this layer must be slightly higher than that of the buffer in order to allow light guidance. The required index difference can be achieved by doping with suitable compounds. Dopants that increase the refractive index of silica include Al_2O_3, As_2O_3, GeO_2, N_2, P_2O_5, TiO_2 and ZrO_2. Amongst these GeO_2 has attracted considerable interest because it can be used to create a relatively high index core [4]. The thickness of the core is determined by two requirements: (1) the waveguide should be single mode, and (2) coupling loss to a single mode optical fibre should be minimised. A final layer of silica is deposited above the core to produce a buried channel waveguide. It is important to ensure that the refractive index of the top cladding matches as closely as possible to the buffer layer in order to symmetrise the optical mode propagating in the core.

Electron beam irradiation can be used to fabricate low-loss channel waveguide components operating at near infrared wavelengths. Substrate absorption and OH^- contamination have been minimized, and low (≈ 0.1 dB/cm) and spectrally flat propagation losses have been obtained in material deposited by plasma enhanced chemical vapor deposition (PECVD) [8]. A number of device configurations has also been demonstrated, using a simple process based on irradiation through an electroplated Au surface mask. However, despite its ability to produce a low loss waveguide, the irradiation process is currently unproved. For example, the effect of irradiation itself has been found to be highly material-dependent. The achievable index change is also weak, the stability of the induced change is limited, and further processing after irradiation remains an issue to be solved.

In this paper we report the use of MgF_2 as cladding layers in electron beam irradiation fabricated silica on silicon waveguides.

II. CHOICES OF CLADDING LAYER ON ELECTRON BEAM FABRICATED WAVEGUIDES.

To form a practical device from an irradiated waveguide, a permanent cladding layer must be deposited over the core. The main consideration is that the refractive index of the cladding layer should be very close to that of silica. It should also have good transparency, and be capable of being deposited at low temperature. Good chemical stability and low water absorption are also necessary. In a low Δn silica-on-silicon waveguide (especially for waveguide formed by electron beam irradiation process), a thick silicate glass is used to isolate the core. The required thickness can be reduced by lowering the cladding refractive index, which at the same time increases the range of possible materials and deposition processes. However, it increases the asymmetry of the guide, and any polarization-dependence of modal properties.

Several deposition methods can be used to form the cladding layer, for example sputtering, and PECVD. However, deposition by sputtering usually is too slow. PECVD is much faster, but would require the waveguide to be subjected to a temperature of (350 ^{0}C for several hours). High temperature thermal annealing might then also be required to eliminate OH^- contamination and obtain low propagation loss. An alternative is a spin-coated, UV-cured polymer. A number of polymers with low refractive indices is available [5]. Spin-coated layers of one particular polymer, EPO-TEK 06125, were investigated, but difficulties were found with the adhesion of the layer when it had reached a thickness suitable for a cladding (10 μm). The dimensional stability of the layer was also found to be questionable. Alternatively, a number of inorganic materials is also available, Table 1 shows a list of inorganic materials with low refractive indices.

Material	Refractive Index
Sodium Fluoride	1.30
Magnesium Fluoride	1.39
Potassium Chloride	1.45
Calcium Fluoride	1.45
Silica	1.46

Table 1. Refractive index of inorganic materials suitable for use as a cladding layer, after reference [6]

All are potentially suitable for a cladding layer but have some drawbacks. Silica is the ideal candidate; however the high temperature deposition needed would erase the irradiation-induced changes. Potassium fluoride is not chemically stable, being extremely hygroscopic. Calcium fluoride is also chemically unstable, and its high melting temperature (1423°C) poses a major problem in any deposition process. The only realistic possibility is therefore magnesium fluoride (MgF_2), which can be deposited relatively rapidly by thermal evaporation. MgF_2 deposition is already very well-known and the facility for the process is very mature. Although it has a rather low refractive index, the results of the previous analysis suggest that any polarization effects are likely to be small.

III. MEASUREMENT OF MgF_2 CLADDING THICKNESS

Based on the analysis above, It was therefore decided to investigate the use of MgF_2 as a cladding layer. Simulations of slab waveguide structures with representative parameters were first performed to evaluate its suitability. Figure 1 shows the structure and layout of such a guide, assuming buffer, core and cladding indices of 1.458, 1.464, and 1.39 respectively and a core thickness of 5 µm. The TE mode profile obtained by solution of the standard eigenvalue equation for an asymmetric guide at λ=1.523 µm is also shown.

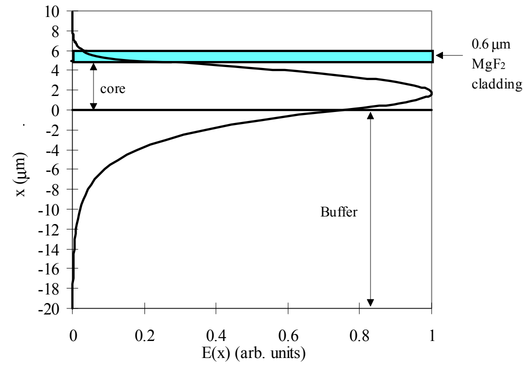

Figure 1. Geometry and mode profile of a planar silica waveguide with an MgF_2 cladding layer.

Because of the relatively large index step at the core-cladding interface, the mode profile is highly asymmetric, and the rapid decay of the evanescent field in the cladding suggest that any sensitivity to further over layers such as metal electrodes should reduce rapidly with MgF_2 thicknesses above (1 µm). This thickness can be deposited by thermal evaporation, although the sample must be heated to eliminate water of crystallization and obtain a consolidated film.

After several initial experiments, it was found to be relatively simple to deposit a 0.6 µm thick crack-free MgF_2 cladding layer on top of PECVD silica-on-silicon. The deposition temperature used was about 140-145 °C, and the evaporation time about 19 minutes. Figure 2 shows the profile of a deposited MgF_2 step, as measured by a DEKTAK II surface profiler. The average thickness is about 0.66 µm.

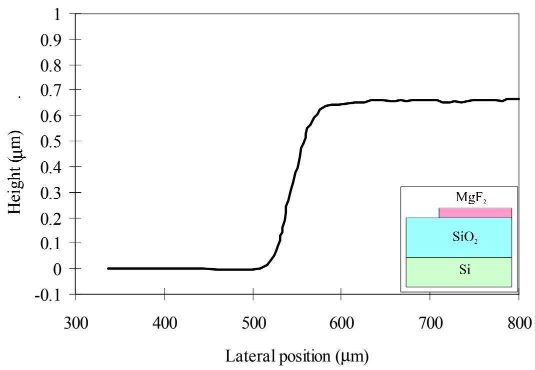

Figure 2. Thickness profile of the MgF_2 cladding, scanned from the edge of the silica layer.

Application of MgF_2 cladding layers was then investigated in Mach-Zehnder interferometric switch geometries. The Mach-Zehnder interferometer provides an elegant means of taking advantage of the thermo-optic effect. It consists of two back-to-back Y-junctions connected by two straight guide arms. The first Y-junction splits the input light into two components which travel along the straight guide and are recombined at the second Y-junction. Either or both the straight arms may have a heater to allow the relative phase of the recombining components to be altered. If the two are in phase, the guided output is high, and if they are out-of-phase, it is low.

In Mach-Zehnder interferometric switch geometries, the heater was deposited above MgF_2 by patterning a 0.1 μm thick layer of sputtered Ti metal into 50 μm wide strips fed by 4 mm wide bus bars, and a dummy electrode was placed above the unheated arm to avoid any phase or amplitude imbalance [7]. Figure 3 shows a surface profile over one arm of the waveguides, including the cladding and the Ti layer, as measured by a DEKTAK II surface profiler.

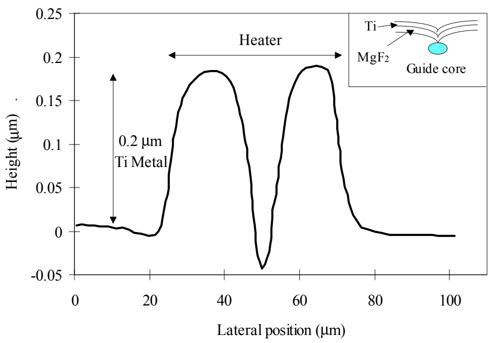

Figure 3. Surface profile scanned over one arm of an interferometer

The cladding and heater shape follow the surface profile of the guide. This shows a considerable depression at the guide center after irradiation, which falls off gradually on either side [7]. The measured heater resistance was R = 530 Ω for 4 devices in parallel. Metal strips were also placed over straight sections of waveguide for comparison purposes.

The layout of the Mach-Zehnder 1x1 single mode optical switches used to investigate thermo-optic switching in irradiated waveguides is shown in Figure 4. The device has two straight arms of 10 mm length and an additional thin film of Ti metal, to act as a heater electrode..

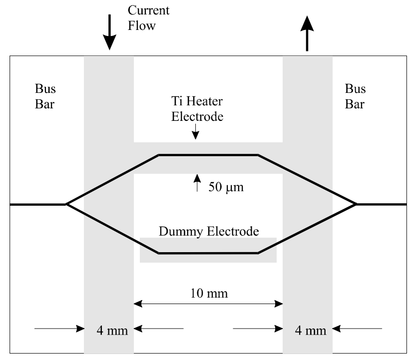

Figure 4. Layout of thermo-optic Mach-Zehnder interferometric switches

Figure 5 shows a photograph of the electrodes in the vicinity of the bus-bars. The irradiated waveguides may clearly be seen running beneath the upper heater electrode and the lower dummy.

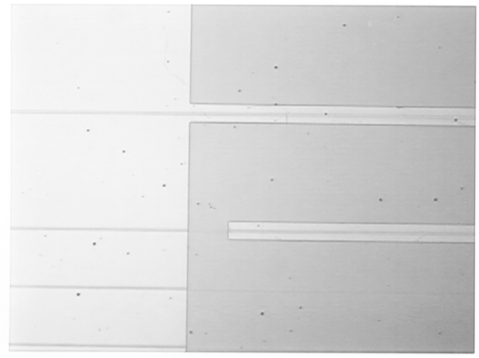

Figure 5. A photograph of the devices as shown in Figure 4.

Without a cladding layer, very large (> 25 dB) TM mode interferometer insertion losses were obtained. Losses decreased dramatically as the cladding thickness was increased, and the majority of the TE/TM loss differential was eliminated with 1 μm of MgF_2 as shown in Table 2. Any additional TE/TM differential in straight guide propagation loss or in waveguide insertion loss was then assumed to be due to polarization-dependent absorption by a metal overlay.

MgF_2 thickness (μm)	**TE/TM loss differential (dB/cm)**
0.6	1.5
1.0	0.5

Table 2. Loss parameters of waveguides and devices with different MgF_2 buffer thicknesses.

IV. CONCLUSION

We have reported the use of MgF_2 as cladding layer for silica-on-silicon waveguide fabricated by electron beam irradiation. Loss parameters can be reduced considerably by increasing the MgF_2 thickness layers. We have also managed to deposit thin Ti layer on top of MgF_2 as heater for further used in switching devices. Because process times and temperatures are low, this coating method avoids degradation of device performance by annealing of the irradiation induced index changes.

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