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Plasmonics: A New Generation of Technology at Nano Scale: A Review

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Abstract

The electronic industry was revolutionized by an observation made by Gordon Moore in 1965. He predicted that the number of transistors per square inch on the integrated circuits is going to double every 18 month. But he did not predicted about the interconnection between those transistors and the time delay associated with each of the active devices on the integrated circuits, there is always some time delay between the application of input signal and the outcome of the output pulse, associated with each of the active devices also known as the transition time. As the number on the transistor on the chip is going to increase the time delay will increase and today's advanced microprocessor uses ultrafast transistors with dimensions of the order 50 nm, but the performance is becoming rather limited when digital information need to be send from one point to another. This is the critical problem in the near future to be think upon and to look for the better alternative.

Keyword : ***s****electrical size, plasmons, nano particles*

I. INTRODUCTION

Electronic circuits have the advantage that it can control the transport of electron and also it can store electron. However when we talk about the transmission of digital data from one point to another, the performance of the electronic circuits is going to degrade or rather limited at some point due to the copper or aluminium interconnects on the integrated circuits. To overcome this limitation photonics provide the effective solution to this problem by implementing the optical communication system and using the optical interconnects. But unfortunately the integration of micrometer-scale bulky components of photonics with the nanometer-scalecomponent of electronic circuit is difficult or almost limited. Surface Plasmon-based circuits which combines the both the technology i.e. Electronics and photonics at Nano scale provide somesolution to this size compatibility problem.The paperreviews the basic idea behind the merging ofthe electronic and photonics known as Plasmonics [1-3].

As the new generation of the device or technology continues to grow, there will be always a need to update the device for faster information transmission and processing capability. Electronic industries had put a step in that area by miniaturization of the Si chip, scaling of the active devices, faster processing capability. But the scaling of the devices on the chip came up with two Substantial challenges to the Electronic industries that are, it prevent any significant increase in the clock speed of the processor and secondly delay time Associated with the electronic interconnects. Optical interconnects such as optical fiber cable can carry digital data at an enormous speed as compare to metal interconnects on the chip, but the problem still persist since the dimensions of the optical interconnects is of the order of micrometer as compared to Nano scale dimension of the Electronic component and the two technologies are difficult to combine on the same circuit. The limiting factor behind the integration of optical and Electronic circuit is their respective sizes. The electronics circuits are of the order of <100 nm and the wavelength of the light used in the optical fiber interconnects is of the order of the ~1000 nm. Photonic devices are limited in dimension by the fundamental laws of diffraction, whenever the wavelength of the light propagating through optical device tends to be closer to the dimension of the optical device than the propagation of the light is obstructed by optical diffraction; this phenomenon limits the minimum size of the optical devices [4-5].

II. PLASMONICS: ELECTRONIC CIRCUITS WITH PHOTONIC INTERCONNECTS

It's only a decade or two ago, "Plasmonics" was added as a new emerging branch in the field of Applied Electronics for a promising new device technology that aims to combine the electronic circuit with the photonics to have the best result out of the two current technology. The most common interconnects on the Electronic circuit is Cu or Al, these interconnects provide the room for the surface Plasmon. It is well established by Ritchie that the electron charges on a metal separation are able to perform coherent fluctuations inherently, this phenomenon is termed as surface Plasmon [6], and it provide the provision to confine light within very small dimensions. From the technical point of view the surface Plasmon could be viewed as special type of light waves and the metallic interconnects like Cu and Al which support this type ofwaves thus serve as the optical waveguides and termed as the Plasmonics waveguide.

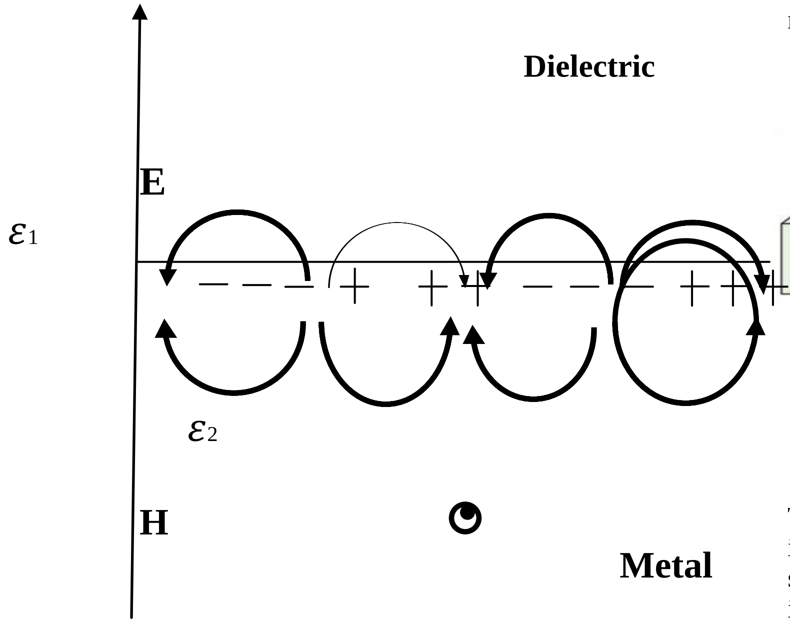

Fig-1, The charges and the Electromagnetic field of surface plasmon propagating on a surface

As stated above surface plasmons are light waves that occur at the interface of metal/dielectric where the group of charges (electron) moving back and forward [6]. These waves are trapped near the surface as they interact with the plasma of electrons near the surface of the metal.The resonant interaction between electron-charged oscillations near the surface of the metaland the electromagnetic field of light creates the surface plasmon and result in the unique properties. Surface plasmons are bound to the metallic surface with exponentially decaying field in both neighboring media. The decay length of surface plasmons into the metal is determined by the skin depth,which can be on the order of 10 nm, two orders of magnitude smaller than the wavelenth of light in the air. This feature of the surface plasmons provide the possibility of locolization and the guiding of light in subwavelength metallic structure, and it can be used to construct miniaturized optoelectronic circuit with subwavelength component [7]. These plasmonic chips consist of various component such as couplers, waveguides,switches and modulators which can be used to carry the optical signals to different parts of the circuit [8]. Thin metal films of finite width embedded in a dielectric can be used as plasmonic waveguides. This geometry offers the best propagation result for a surface plasmon based waveguide, because the measured propagation length for operation with light at the wavelength of 1550 nm is reported to be as long as 13.6 mm. To acieve subwavelength localization, we can reduce the width of wire and subsequently use the surface plasmons to guide the light underneaththis nanowire [9].

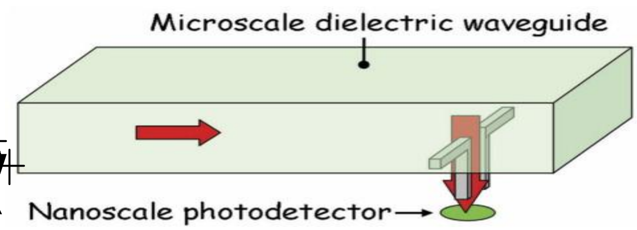

Fig-2, Illustrations of how the antenna at Nano scale, bridges the gap between the micro scale photonic component and nana scale electronic devices [13].

The field of Plasmonics offers several research area including, nanolithography at deep sub wavelength scale, Plasmonic chips for ultra-fast optical interconnects in compact electronic circuits, Nano scale Plasmonic motor, To Accomplish all the promises made by the Plasmonics a handsome amount of research is needed in the field.

One of the challenging task in making Plasmonic circuits to implement in the reality is that the surface Plasmons have short propagation wavelength. Typically, the distance covered by surface Plasmon is in the range of mm before damping diminishes the signal [15]. This phenomenon occurs mainly because of the unique dispersion relation of surface Plasmon, which shows that as confinement increases, resistive damping increases; thus, propagation length decreases [14]. Researchers are trying to reduce losses in surface Plasmon propagation by examining a variety of materials and their respective properties.New promising low-loss Plasmonic materials include metal oxides and nitrides[16] as well as graphene [17].Another foreseeable barrier Plasmonic circuits will have to overcome is heat; heat in a Plasmonic circuit may or may not exceed the heat generated by complex electronic circuits.[15] In addition to heat, it is also difficult to change the direction of a Plasmonic signal in a circuit without significantly reducing its amplitude and propagation length[14]. One clever solution to the issue of bending the direction of propagation is the useof Bragg mirrors to angle the signal in a particular direction, or even to function as splitters of the signal [18].

III. CONCLUSION

In the above article an idea about the recent technology known as Plasmonics, which aims at combining electronics and photonics at Nano scale dimensions, has been presented. During the past decade this area has shown an exponential growth, this area fascinates the researchers much because of the demanding need of application to combine the electronic circuit with optical interconnects to enhance the data rate and to minimize the delay for the digital application.

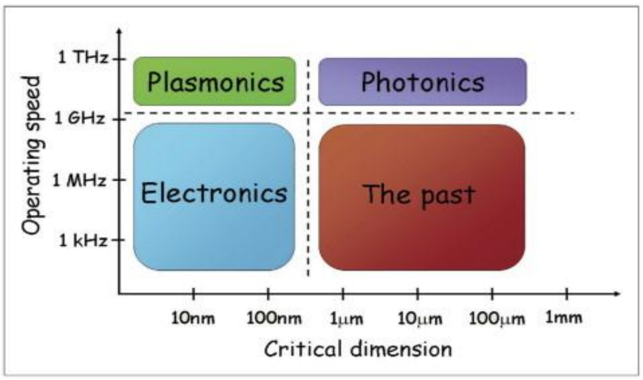

Fig-3, Operating speed and Critical dimensions of chip level at various technologies.

The above shown data highlights the operating speed V/s the critical dimension of the various existing technology at chip level. Looking at it one can easily recognize that 'the past' technology was quiet slow and even much bulky.The electronic industries understood the problem and they came to the solution that by scaling the component to the nano scale, the dimensions could be reduced, but still the interconnect delay issue limits the eclectronic circuit operation to the ~ 10 GHz. Photonics seems to be The solution of the problem because of its enormous data carrying capacity from one point to another. But unfortunately the dimension of the photonic component is limited due to the law of diffraction. [13] This dimension mismatch of the of photonics (micrometer) and Electronic (Nano Scale) make them difficult to integrate them on the same chip for a particular application. Ultimately Plasmonics is the solution in the field of technology where Small dimensions and high operating frequency is desirable. Plasmonics seems to be the missing link between the the two technology and provide a good platform to the dynamic mind to research upon, and to enhance the Electronic industry. Plasmonic chips operate at THz frequency range with the dimension reduced to Nano scale. In the near future this field would draw much attention because todays electronic era is the era of miniaturization and high operating frequency and plasmonic possess both of these qualities.Gordan moore's law could only remain valid for the coming years if the challenges in the field of plasmonics are overcomed, Otherwise his Prediction could only remain valid for the next one to two decades.

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