CMOS Compatible Light Emitting Tunnel Junction for Photonic Integrated Circuits (PIC) and Optical Communication

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With the emergence of photonic integration, the challenges (a) to create light from silicon and (b) to realize electronically compact photonics have delayed the anticipated introduction of photonics into electronic consumer products. While a variety of light emitters exist such as LEDs and semiconductor solid-sate-lasers, existing technology is hindered by: specialized and costly materials such as III-V compound semiconductors; elaborate semiconductor processing techniques such as wafer bonding; limited performance such as direct modulation bandwidths; plasmon lasers require inherently higher threshold power than photonic counterparts due to lossy metals involved; any on-chip light source should be electrically driven; this requires electrical contacts, which hinder integration density if any photonic mode is used due to the avoidance of optical losses. In short, the demand for a silicon-based, nanometer small, potentially fast-modulatable, electrically driven on-chip light source operating at room temperature remains unmet to date. A solution to the above issue is to use quantum tunneling. Also there are other examples related to or similar to MIS tunnel junction. However they (a) sacrifice from very low fill factor, and (b) can take a large area due to having antenna coupled structures.

Researchers at The George Washington University have demonstrated an electrically driven, CMOS compatible, low cost silicon-based plasmon on-chip source based on inelastic electron tunneling operating at room temperature. A 40-fold increase in the quantum efficiency (wall-plug efficiency) is achieved via 10-fold increase in the internal efficiency and 4-fold increase in the outcoupling efficiency, while an absolute quantum efficiency is measured as on the order of 10⁻⁴.

This tunnel source may find uses in communication where high sampling rates and footprint are of demand. The MIS tunnel source is a planar structure acting as a parallel plate capacitor. As a result, high modulation speed (>40 GHz) can be achieved. We fabricated and tested many MIS structure with dimensions can easily go down to few hundreds nm. The simple design allows down-scalability and high fill factor with small area. This enables high density circuit integration and consequently less optical losses. These features are critical especially in optical communication, data processing and Photonic integrated circuit applications.

Advantages

1. 40-fold increase in the overall quantum efficiency with 10-fold increase in the internal efficiency
2. High possibility for THz modulation speed
3. Simple design with down-scalability
4. Low cost silicon-based light source
5. CMOS compatibility
6. Operating at room temperature
7. High fill factor with small area
8. Enable high density circuit integration consequently less optical losses

Applications
1. Optical interconnects and PIC (photonic integrated circuit)
2. Light emission and detection (photodiode, photovoltaic, etc.)
3. Display
4. Modulation
5. Communication where high sampling and footprint are of demand
6. Medical and sensing technology
7. High-tech industry such as augmented reality on flexible substrates, and wearable technology
8. In short, any application includes or based on light emission.

Inventors
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