双材料“介电常数近零”助力宽光谱电光调制

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介电常数近零 (Epsilon-Near-Zero，ENZ) 效应是近年来备受瞩目的研究热点，利用电位移矢量守恒原理可将光场限制在纳米级薄层内获得极小的模式体积，进而有效促进光与物质互作用，在全光开关、电光调制、完美吸收体/发射体等领域上都展现出了巨大应用空间。

目前，ENZ 效应在透明导电氧化物 (TCOs) 材料体系上的研究居多，硅材料的 ENZ 效应尤其是基于硅的 ENZ 电调制仍未见报道。在已有报道的硅基 ENZ 效应的电光调制器件中，硅仅作为电容的栅控极，仅在 TCOs 中产生 ENZ 调制，因此器件只在 TCOs 的 ENZ 调控波段范围内工作。

暨南大学陈沁、文龙课题组联合英国格拉斯哥大学 David R.S. Cumming 院士团队最近报道了基于硅纳米深槽三维电容结构的空间光调制器，成功展示了硅与 TCOs 的双材料 ENZ 调控，工作波段覆盖近红到中红外的宽谱范围。如图所示，硅/介质/TCOs 所形成的半导体/介质/半导体结 (SIS) 在电调控下，介质两侧半导体表面层载流子浓度可实现双材料 (硅和 TCOs)ENZ 模式。同时，沿光波传播方向构建的硅纳米深槽结构有利于 ENZ 模式的高效 E-A 调制。在无偏压下展现为低损耗状态，而在偏压下展现为高吸收状态。

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Dual epsilon-near-zero effect assisted broadband electro-optic modulation

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To date, several groups have studied and demonstrated silicon-based E-O modulator with small footprint and high speed using ENZ effects from the integrated TCOs materials. The E-O modulation was achieved upon tuning the carrier density of TCOs to match or mismatch the ENZ condition. Those previous studies have normally considered TCO as the sole active medium but seldom explored the carrier dispersion effect in silicon gate, which may hinder the possible contributions from E-O or even ENZ responses from silicon.

The research group of Prof. Chen from Jinan University propose a new spatial light modulation strategy which incorporates a dual material's ENZ effect. While the free-carrier dispersion effect in silicon is frequently used in electro-refraction modulator, their results highlight the possibility to achieving similar ENZ confinement in silicon as the TCO materials. The proposed spatial light modulation scheme is based on a semiconductor-insulator-semiconductor (SIS) nano-capacitor. Imagining from a parallel plate capacitor, equal and opposite surface charges (Qs) will induced by an external voltage bias. According to Drude theory of free carrier, the complex permittivity for both the accumulation and inversion layers of the SIS structure are carrier concentration dependent. It 's possible to manipulate the permittivity crossover wavelengths (i.e. ENZ points) of the surface layers in the two different materials via external voltage biasing.

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