Microplasma generation: using metasurfaces to combine DC discharge and laser induced breakdown

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Replacing the electron-hole plasma (solid state) with electron-ion plasma (gas phase) is a completely new approach to design microelectronic devices. Micro-devices with electron-ion plasma, referred to as microplasma devices, can withstand harsh environmental and radiation conditions such as extreme temperatures and damaging electromagnetic pulses (EMP), due to the gas self-healing property.

However, plasma ignition (i.e. converting the gas into plasma) in microplasma devices is a challenge. Applying a DC voltage is a common technique to generate plasma, but its high voltage requirement makes it unsuitable to be used in micro-scale devices (typically voltages over 100 volts are needed). Alternatively, laser induced breakdown (LIB) by focusing a high intensity beam of laser can be used to ignite plasma. But, LIB requires lasers with high photon numbers, and usually short pulse lasers (e.g. nanosecond) with high power intensities (above $10^8\ W/cm^2$) are needed in LIB approach.

Our suggested approach, to avoid high power lasers and high DC voltages, is to combine LIB and DC breakdown using metasurfaces. That is, a low voltage bias along with a low power continues wave (CW) laser can trigger the microplasma device. In other words, the pre-ionization caused by the applied low DC voltage decreases the multi-photon breakdown threshold, and the interaction between the lower power laser and the designed metasurface can initiate plasma. The metasurface is indeed a resonant structure providing electric field enhancement similar to surface enhanced Raman scattering (SERS). Two different micro-size metasurfaces, for one-port and two-port devices, are fabricated and studied under illumination with different laser frequencies and powers.