

# Surpassing the Optical Diffraction Limit with Photo-Inhibited Super-Resolution (PInSR) Lithography

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**Abstract:** We present our progress towards nano-patterning with focused visible and near-UV light, using a novel photo-polymerizable resist. Special attention will be given to the difficulties presented by diffusion of reactive photo-generated molecules.

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## 1. Introduction

This work is inspired by stimulated emission depletion (STED) microscopy, which has become popular in the biosciences due to the dramatic resolution gains it makes possible [1]. Recently, several lithography techniques have appeared that apply the STED concept in reverse, to achieve superresolved features in a photopolymerizable resin [2–4]. This presentation reports on progress regarding the system first described in [4], a 1-photon technique with the potential for dramatic gains in resolution, speed and scalability over existing 2-photon techniques.

## 2. Materials and Methods

With Photo-Inhibited Super-Resolution (PInSR) lithography, [4, 5] a reduction in spot area is accomplished with spatial control of radical polymerization initiation and inhibition. A novel photoresist contains a photoinitiating species deliberately chosen for its absorption peak near 470 nm and null near 365 nm. Also present is a photoinhibiting species with opposite relative absorptions at the same two lines.

A 473 nm DPSS CW laser is used to excite the dye of the initiating system, while an argon-ion CW laser emitting at the 364 nm line is used to photocleave the inhibitor molecule. Both sources are spatially filtered and independently modulated with shutters, with the UV beam additionally passing through a spiral phase plate to produce a donut-shaped  $LG_{01}$  mode. The beams are combined with a dichroic mirror, and are focused with a microscope objective lens to a diffraction-limited spot on a PInSR-resist coated substrate.

## 3. Results

Thin-film resist samples are prepared and exposed in the optical system described above. After exposure the sample is rinsed to remove ungelled resin and then examined under a scanning electron microscope. A reduction in the polymerized features is observed to correspond to the intensity of the inhibition beam, as can be seen in Figure 1. The smallest dots fabricated so far have a diameter on the order of 40-70 nm [4, 5]. Recent experiments, however, suggest that the resolution performance of these earlier efforts has been compromised by diffusion-induced blurring in the resin. We will propose a way to avoid this blurring and push pattern resolution to new limits.

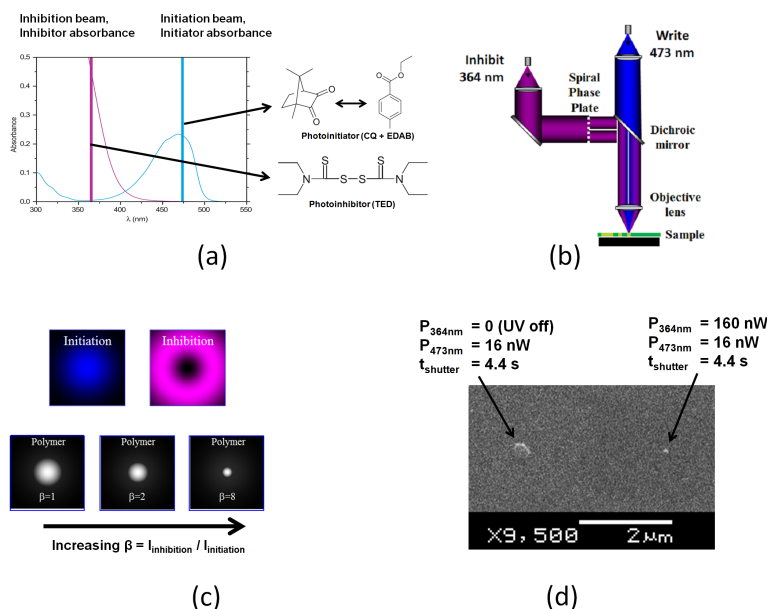


Fig. 1. PInSR lithography configuration and experiment: (a) Blue light activates the photoinitiator system, causing polymerization; UV light activates the photoinhibitor system, suppressing polymerization. (b) Blue and UV laser beams are modulated, combined by a dichroic mirror, and focused by an objective lens onto a PInSR-resist coated substrate. (c) Transverse voxel dimension scales inversely with UV beam power. (d) SEM image of two polymer dots on glass: the dots were exposed at beam focus (1.2 NA) for the same amount of time and processed identically, but the LHS dot was only exposed to the blue beam while the RHS dot was exposed to both the blue beam and the donut-shaped UV beam.

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