Plasmonic Gold Nanorods for Depth-Resolved Viscosity in Polarization-Sensitive OCT

Raghav K. Chhetri[1] Krystian A. Kozek,[3] Aaron C. Johnston-Peck,[3] Joseph B. Tracy,[3] and Amy L. Oldenburg[1,2,*]

Department of Physics and Astronomy[1] and the Biomedical Research Imaging Center[2], University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3255

Department of Materials Science and Engineering,[3] North Carolina State University, Raleigh, North Carolina 27695

**Contact: aold@physics.unc.edu*

Abstract: We demonstrate depth-resolved viscosity via polarized scattering from ensembles of tumbling plasmon-resonant gold nanorods (GNRs) monitored with polarization-sensitive OCT. This has potential for *in vivo* microrheology imaging of fluids such as mucus.

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1. Introduction

Plasmonic gold nanorods (GNRs) have been of considerable interest as contrast agents in optical coherence tomography(OCT) because they can be tuned to the near-infrared wavelength band used for imaging.[1] GNRs are also highly polarization-dependent due to their high anisotropy, which has been demonstrated to be useful for sensing their orientation.[2] We find that the rotational diffusion of nanorods can be monitored using polarization-sensitive OCT (PS-OCT), and furthermore, using the Stokes-Einstein relation, can be used to sense the local viscosity of the medium. Because hundreds of GNRs are present in each coherence volume, the statistics of the time-dependent PS-OCT signal are representative of an ensemble of GNRs, and methods from dynamic light scattering can be employed to associate the ensemble measurement to a rotational diffusion rate.[3] The use of dynamic light scattering with OCT has been previously explored using microspheres[4] and recently shown to reveal diffusion maps.[5] GNRs have a particular advantage over microspheres because they are plasmon-resonant, exhibiting higher sensitivity for a smaller particle. GNRs also provide a cross-polarized signal that is specific to rotation, which may be advantageous for imaging against a tissue background.

2. Results and Conclusion

We investigated the rotational diffusion rate of GNRs nominally 15nm $\times$ 53nm in glycerol-water mixtures of varying viscosity (40-250 mPa·s). This was performed by detecting the cross-polarized (HV) signal using a spectral-domain, polarization-sensitive OCT system. M-mode OCT images were collected over 160 milliseconds and the temporal autocorrelation of the fluctuating HV signal at each depth was fitted to an inverse exponential to determine the decay constant τ. According to diffusion theory, $D_R=1/(6\tau)$ where D_R is the rotational diffusion constant. Using a model for rotational diffusion from smooth cylinders [6], we predicted the D_R of our GNRs as a function of viscosity, and found excellent agreement between the model and experiment (typically < 20%) considering that nanorods are not exact cylinders. To demonstrate depth-resolved viscosity, we constructed a double-chamber with media of different viscosity in each chamber (70 and 250 mPa.s). M-mode OCT revealed a different τ in each chamber, which corresponded to the known viscosity within experimental error.

In conclusion, the ability to depth-resolve viscosity using GNRs with PS-OCT has been demonstrated. This could be useful for microrheological imaging in highly scattering fluids, such as blood and mucus, which can be related to functional or molecular information.

3. References

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