



Electron Spin Resonance of Nanoscale Materials using Nitrogen Vacancies

Maziar Saleh Ziabari^{1,2}, Jacob Henshaw¹, Pauli M. Kehayias¹, Tzu-Ming Lu¹, C. Thomas Harris¹, Edward Bielejec¹, Eric G. Biederman³, Dale L. Huber¹, Victor M. Acosta², Michael P. Lilly¹, Andrew M. Mounce¹

¹Center for Integrated Nanotechnologies, ²University of New Mexico, ³Georgia Institute of Technology



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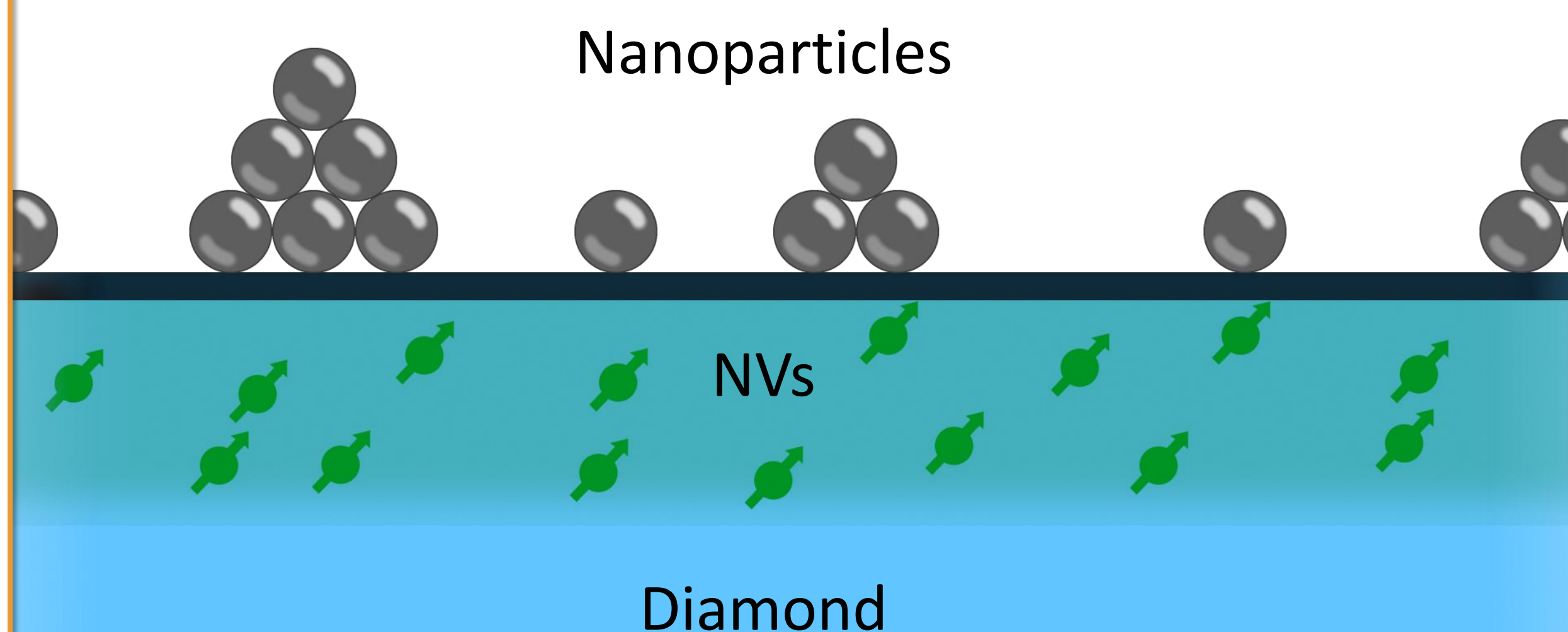
Abstract and Motivation

Nanomaterials that could benefit from NV-ESR study include:

- Magnetic nanoparticles
- Metal-organic frameworks (MOFs)
- Defects in semiconductors
- Organic radicals

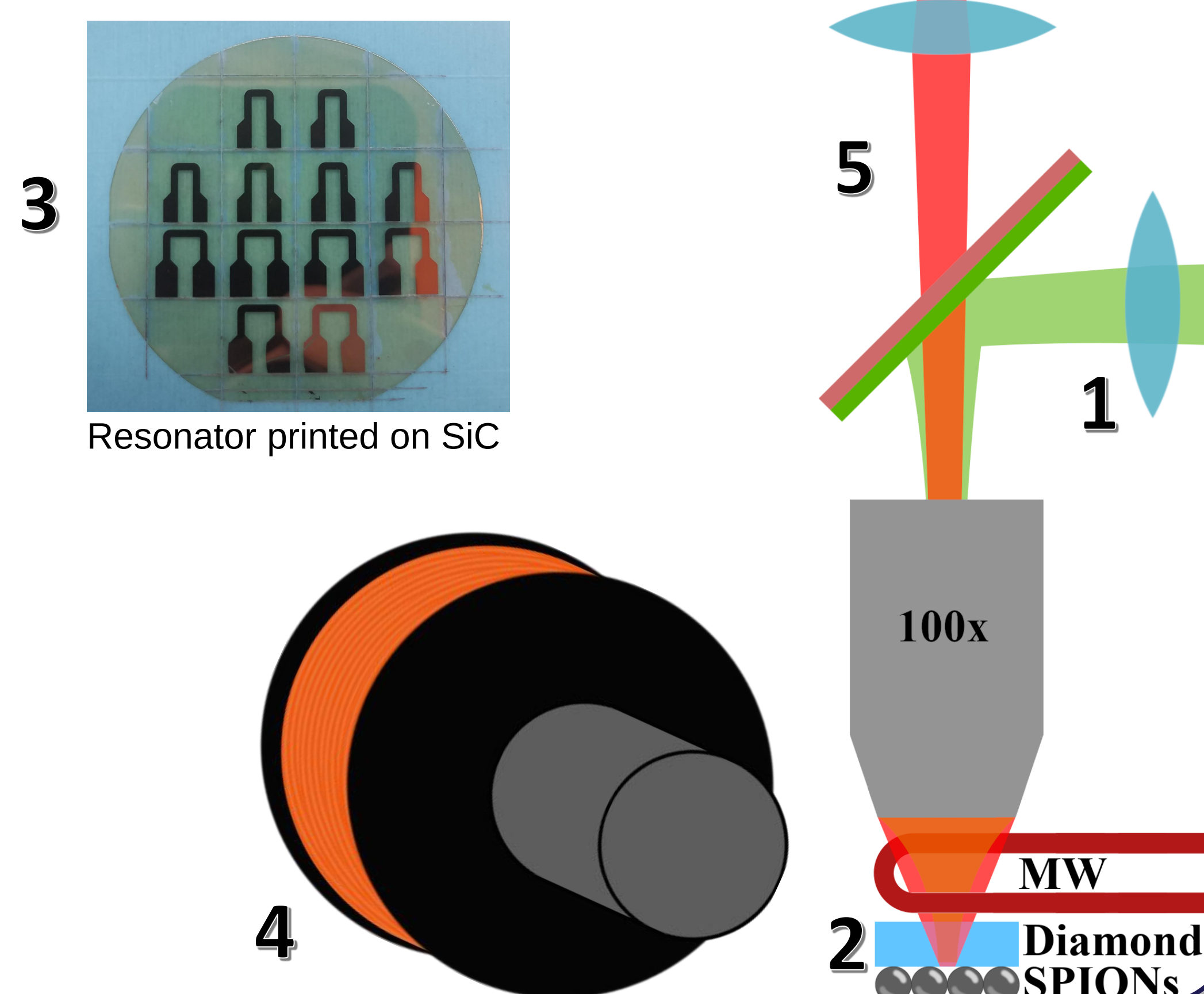
Aims:

1. Demonstrate electron spin resonance (ESR) using NV diamond.
2. Deposit nanoparticles (NPs) on diamond at various densities.
3. Measure nanomaterials' electromagnetic properties using NV-ESR.

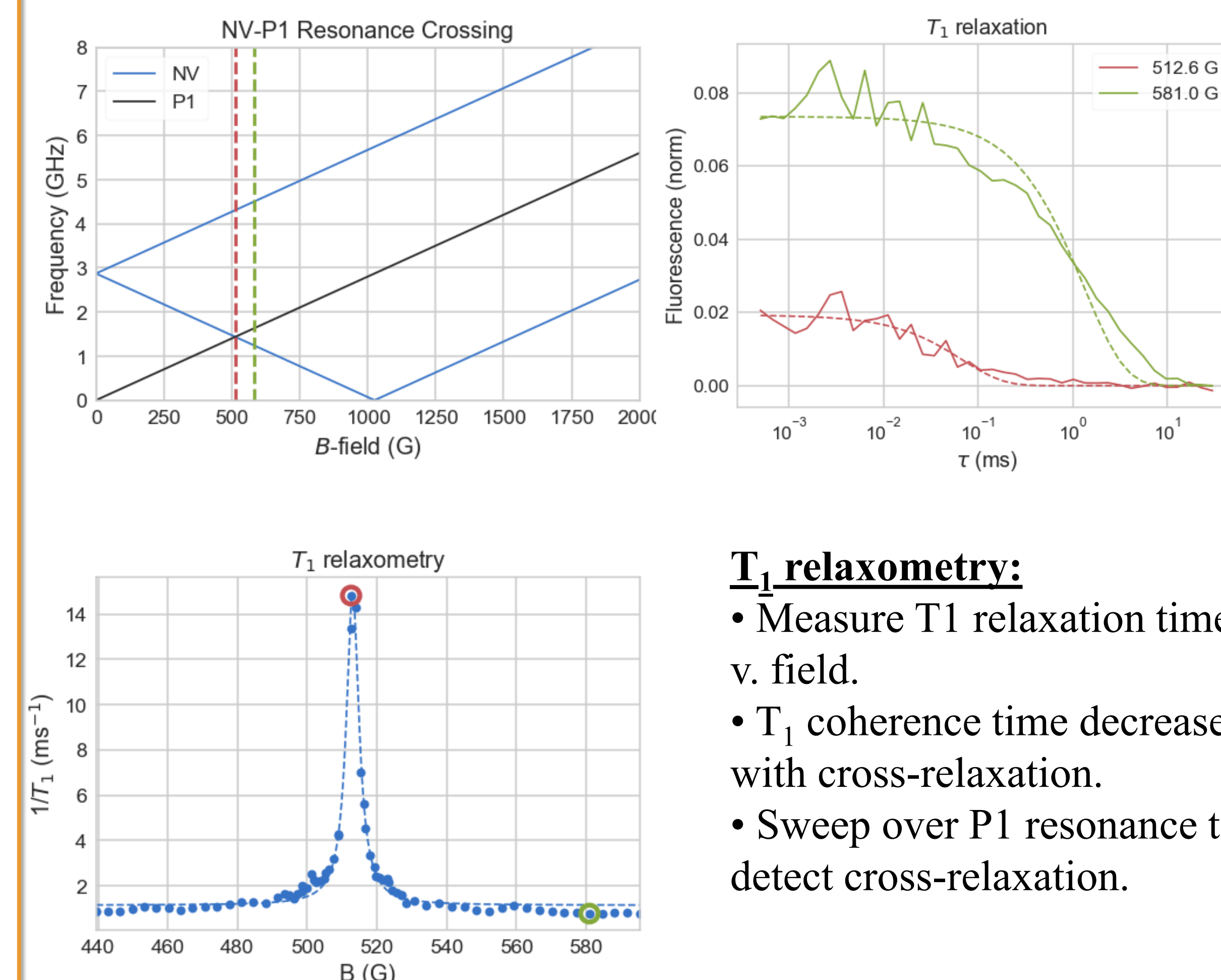


Experimental Setup

1. Green light shines on diamond.
2. 20 nm NV diamond.
3. Copper resonator on SiC.
4. Coil and magnet provide tunable field.
5. Red fluorescence carries spin information.



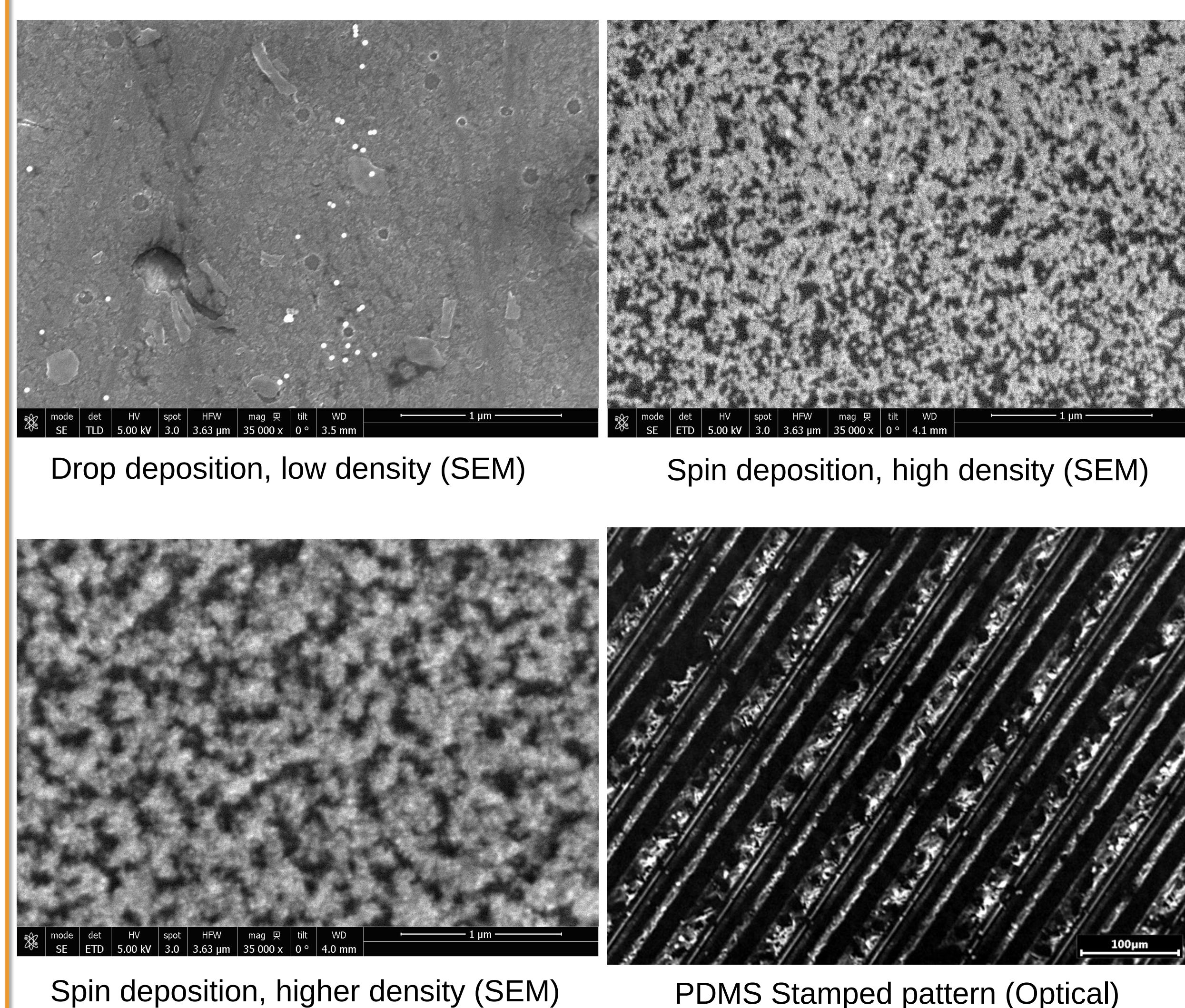
Electron Spin Resonance (NV-ESR)



T₁ relaxometry:

- Measure T₁ relaxation time v. field.
- T₁ coherence time decreases with cross-relaxation.
- Sweep over P1 resonance to detect cross-relaxation.

Nanoparticle Integration



Nanoparticle Image Analysis

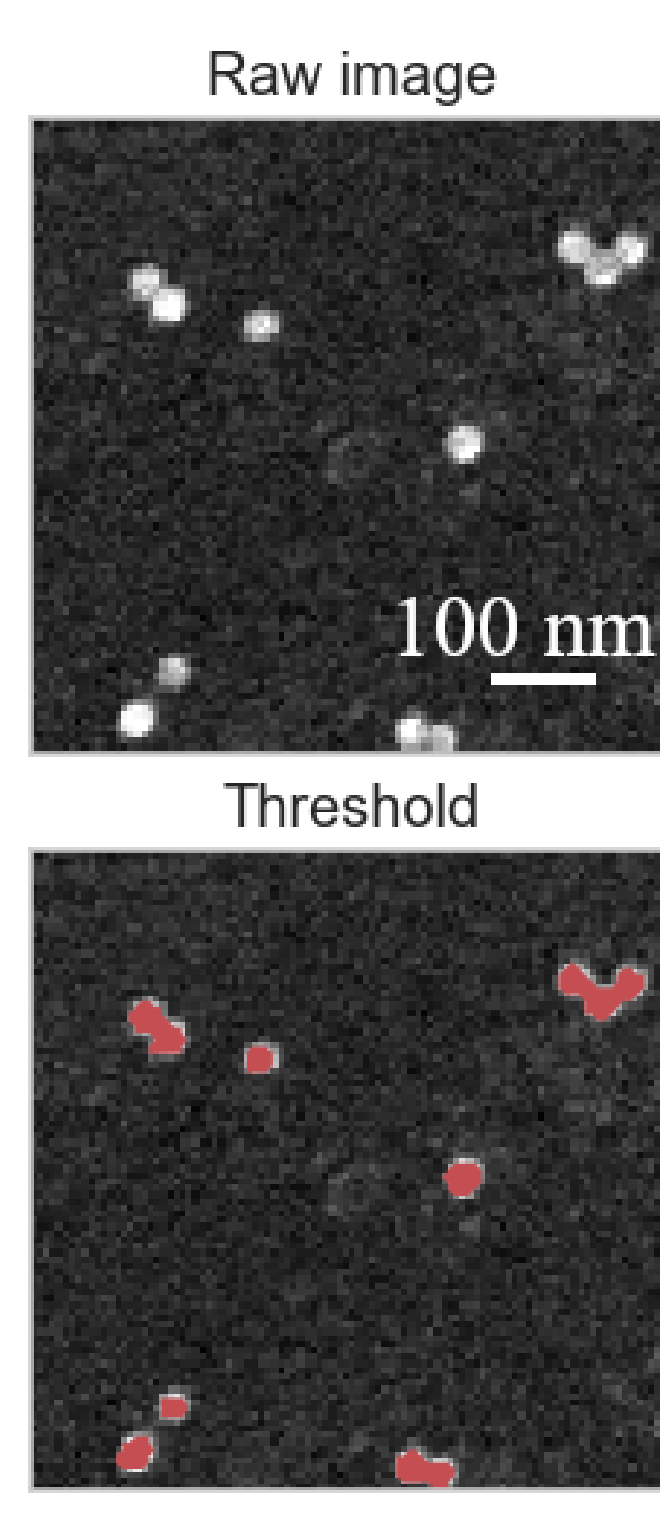
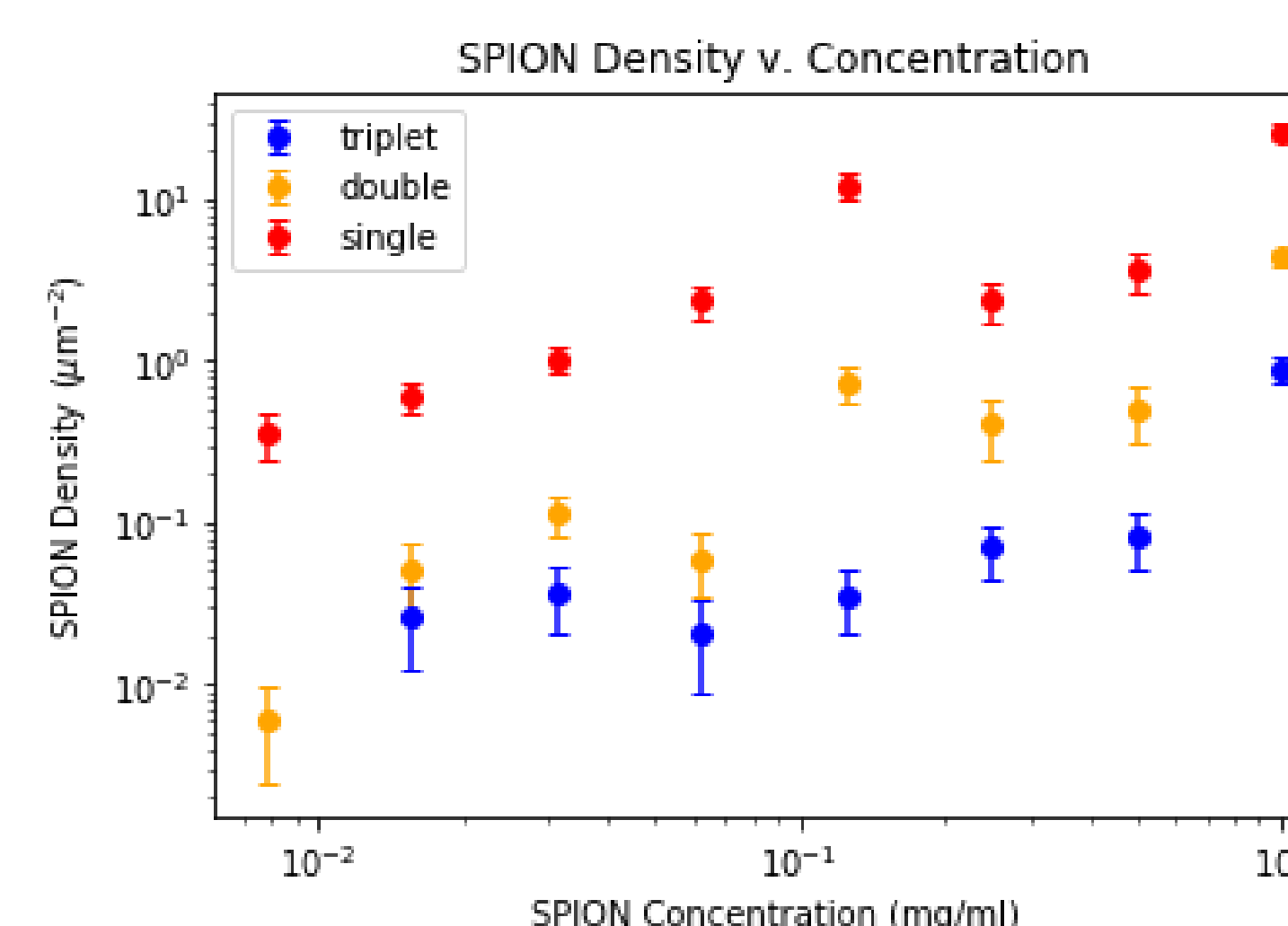


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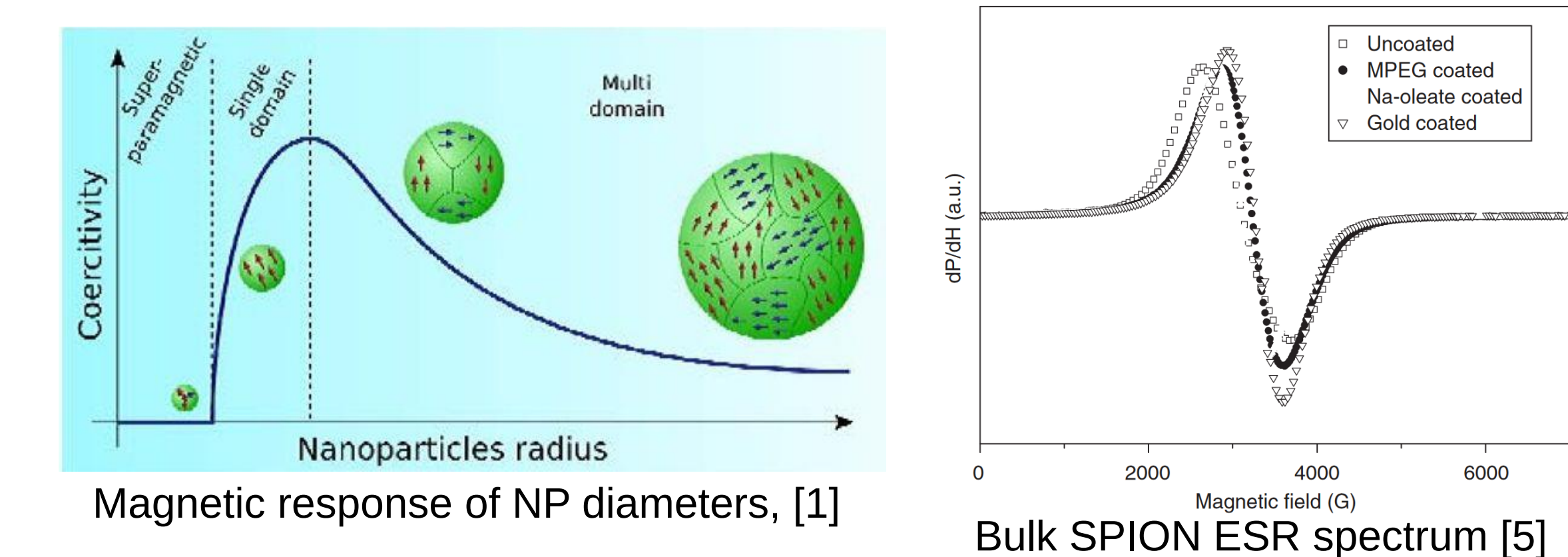


Drop deposition results:

- These nanoparticles (SPIONs) tend to bunch.
- Populations correlated to droplet concentration.

Candidate Nanomaterials

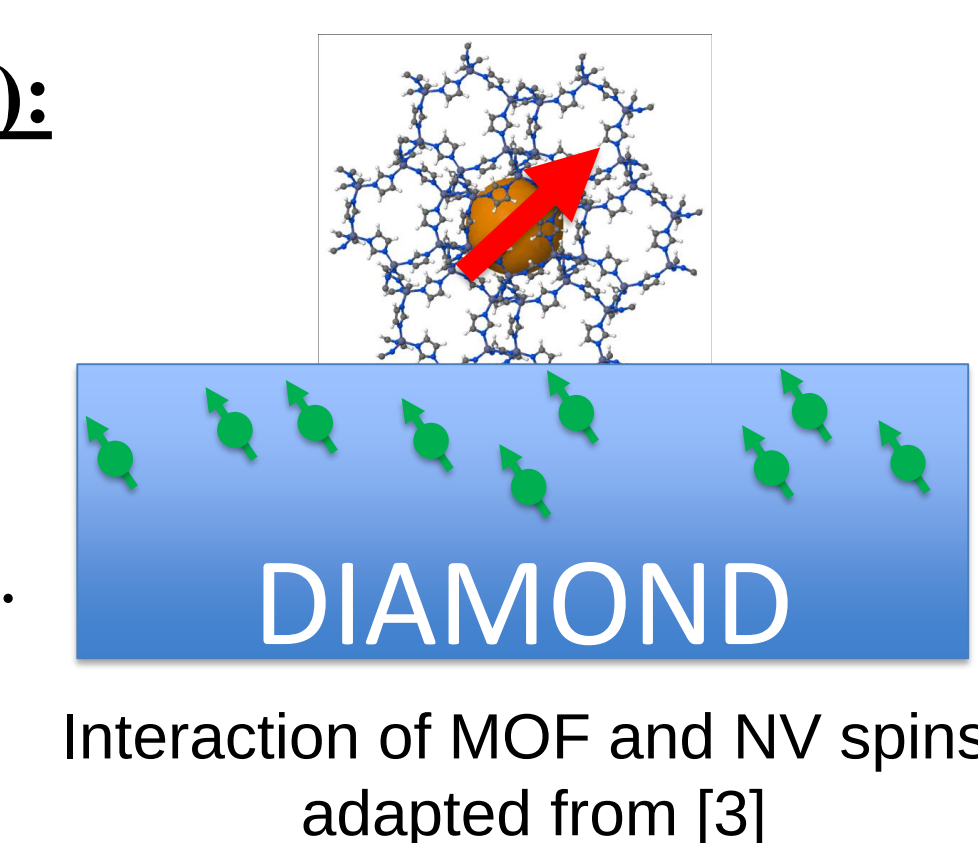
Superparamagnetic Iron Oxide Nanoparticles (SPIONs):



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- Spectrum may be too broad; 1H NMR instead?

Metal-Organic Frameworks (MOFs):

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- Has 2D and 3D lattices.
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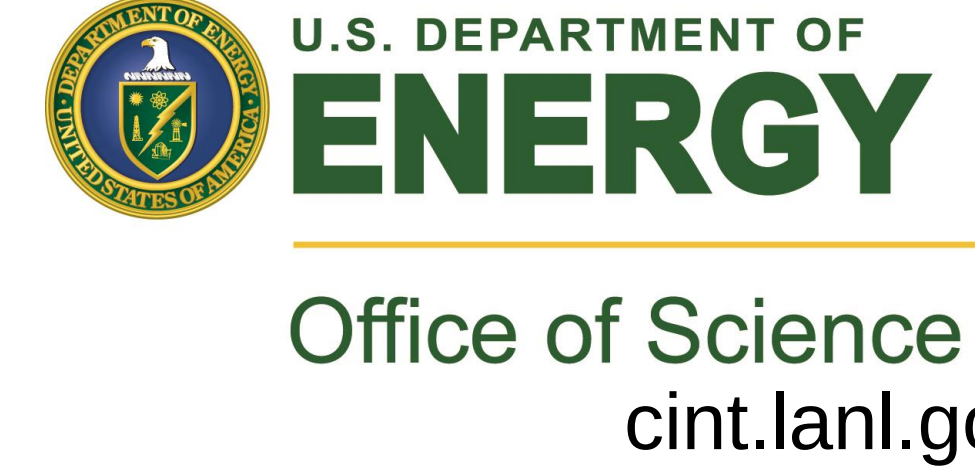
[1] D.K. Kim *et al.*, Journal of Magnetism and Magnetic Materials **225**, 1-2, (2001), p. 30.
[2] Y. Köseoglu *et al.*, Journal of Magnetism and Magnetic Materials **300**, 1, (2006), p. e327.
[3] Image generated by <https://www.chemtube3d.com/mof-zif8/>. 95



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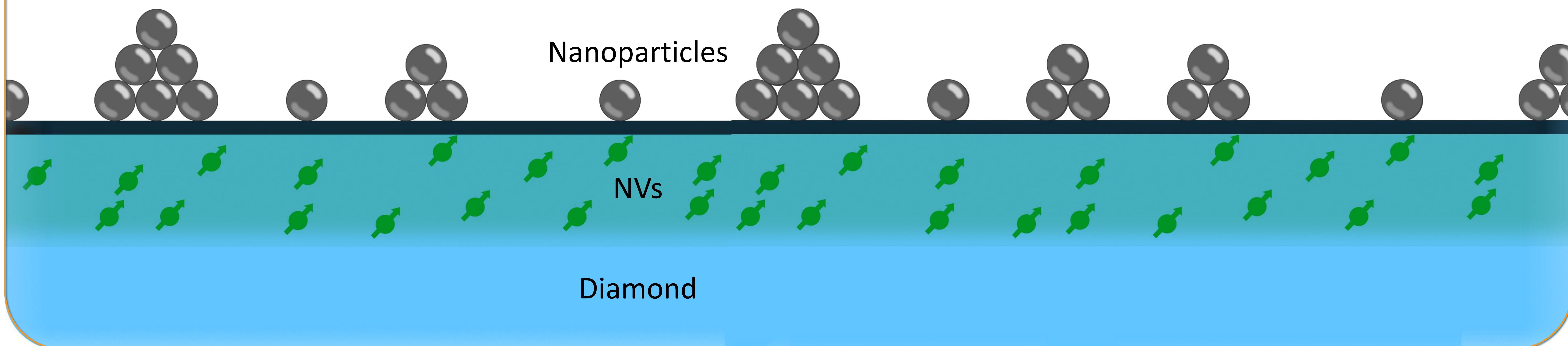
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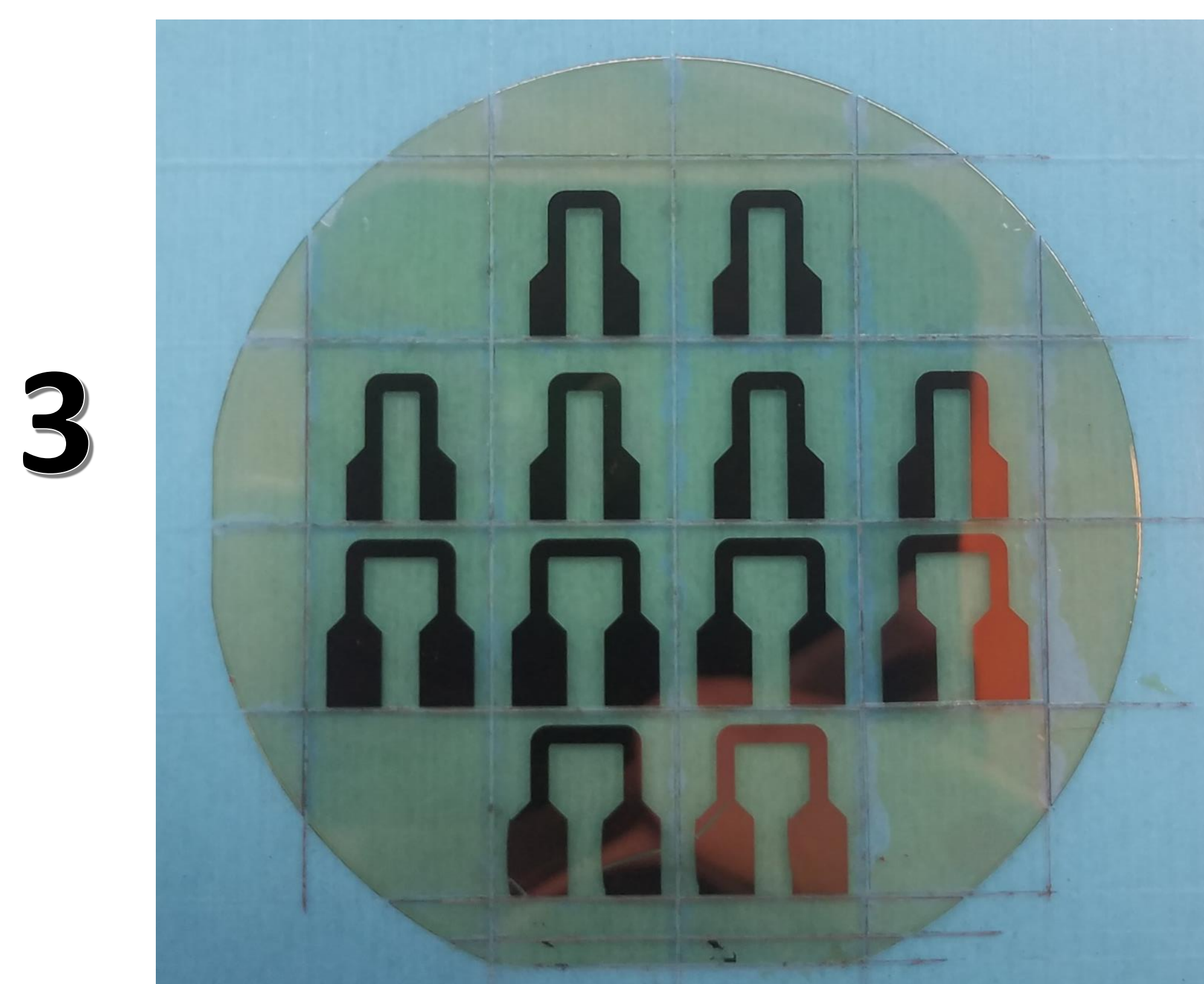
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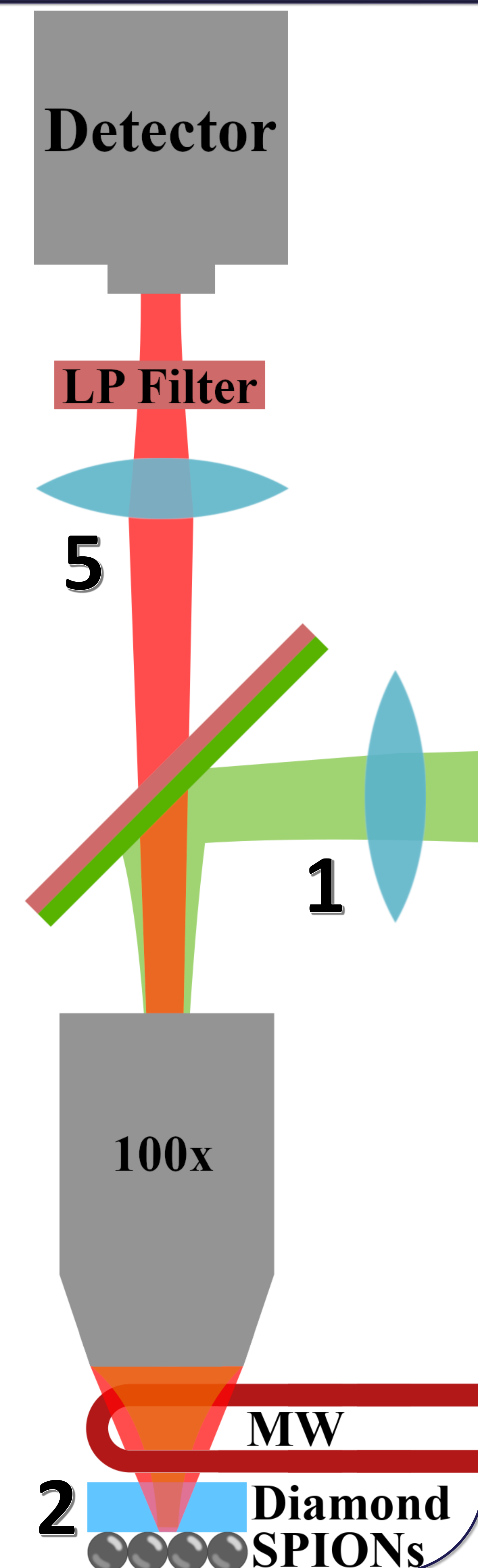
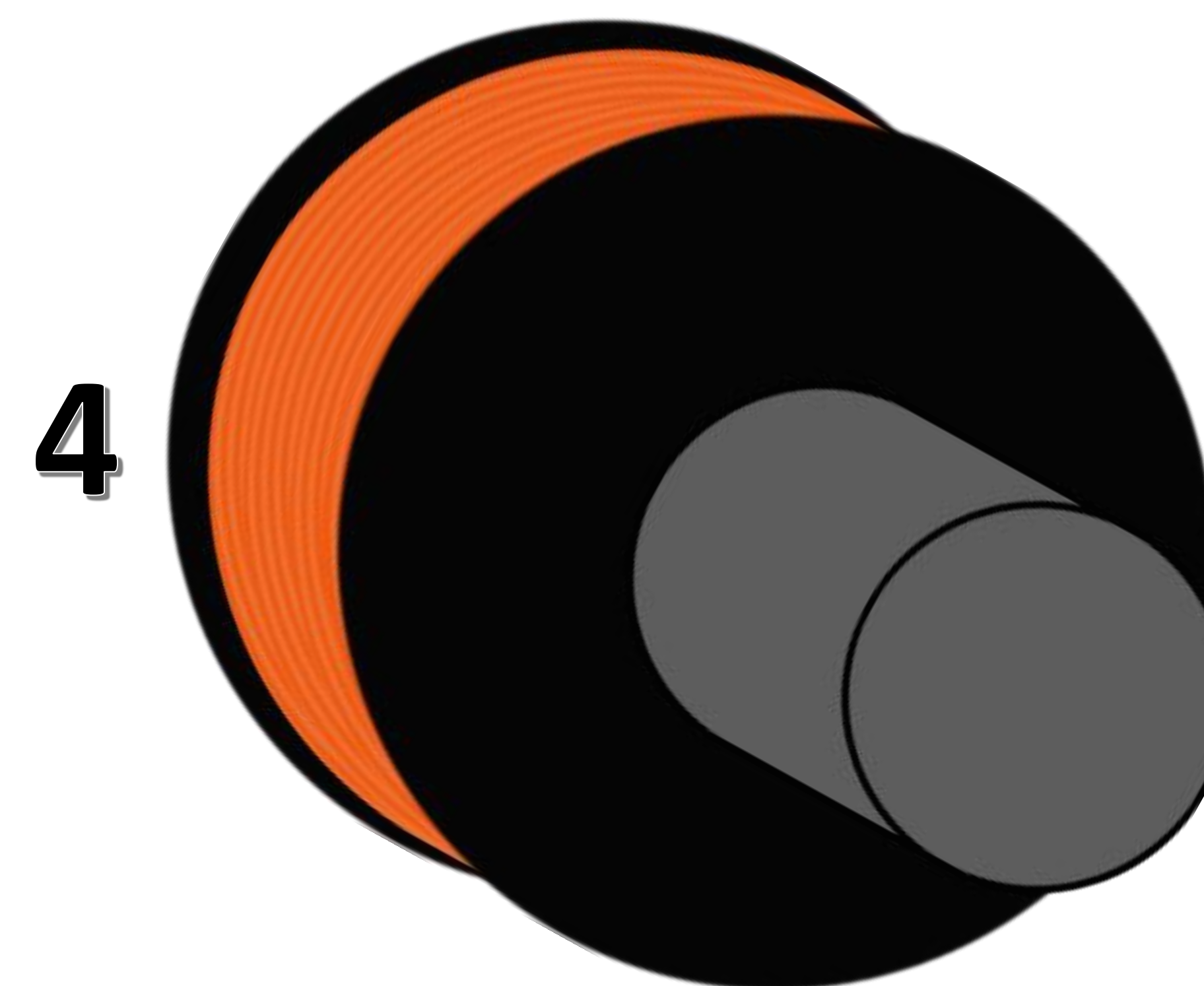
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Experimental Setup

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Resonator printed on SiC

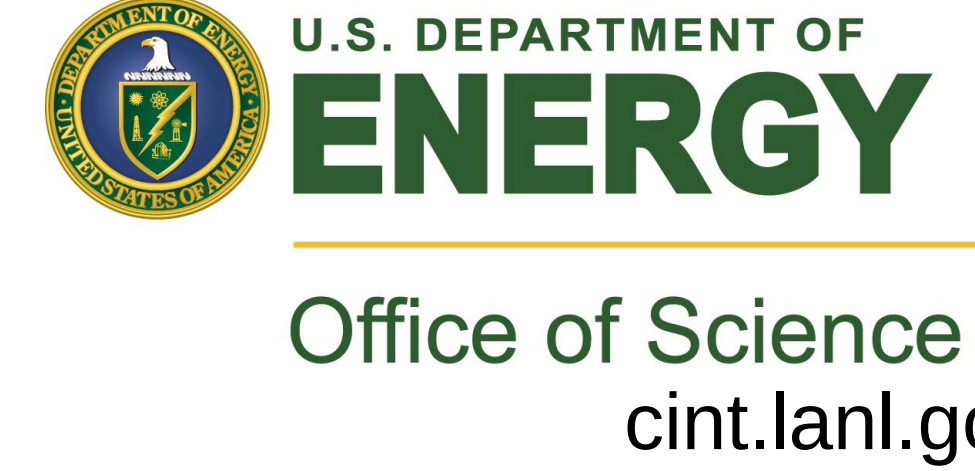




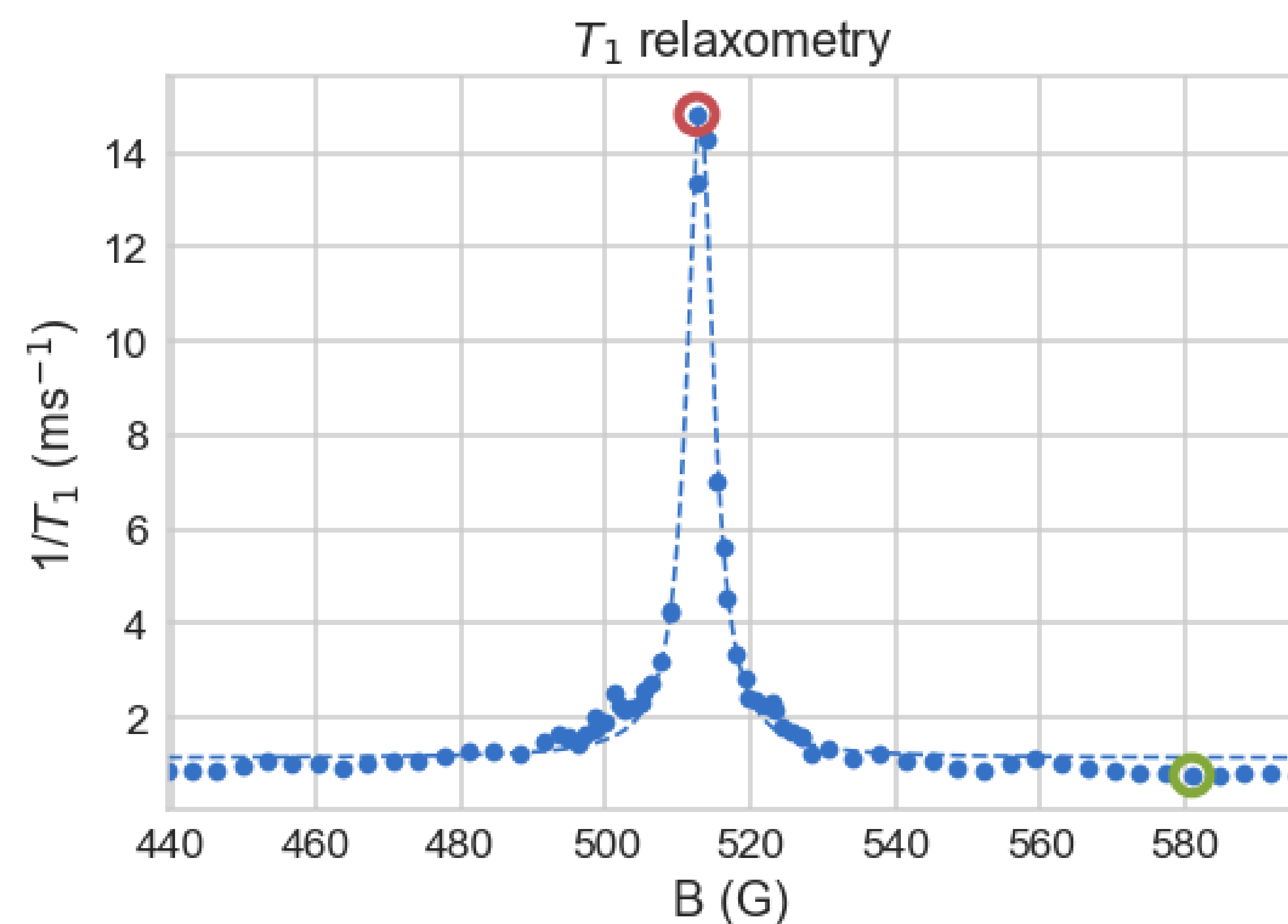
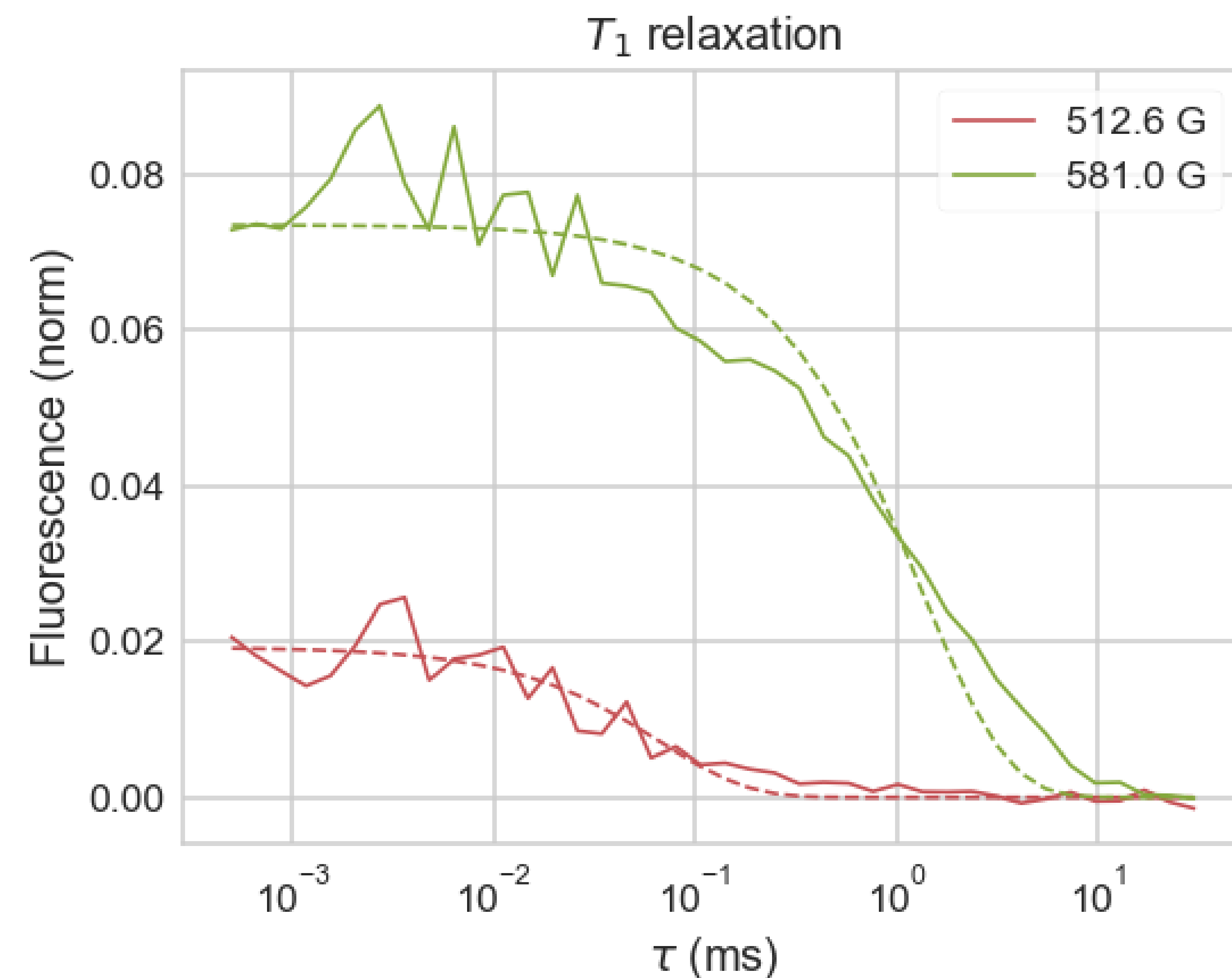
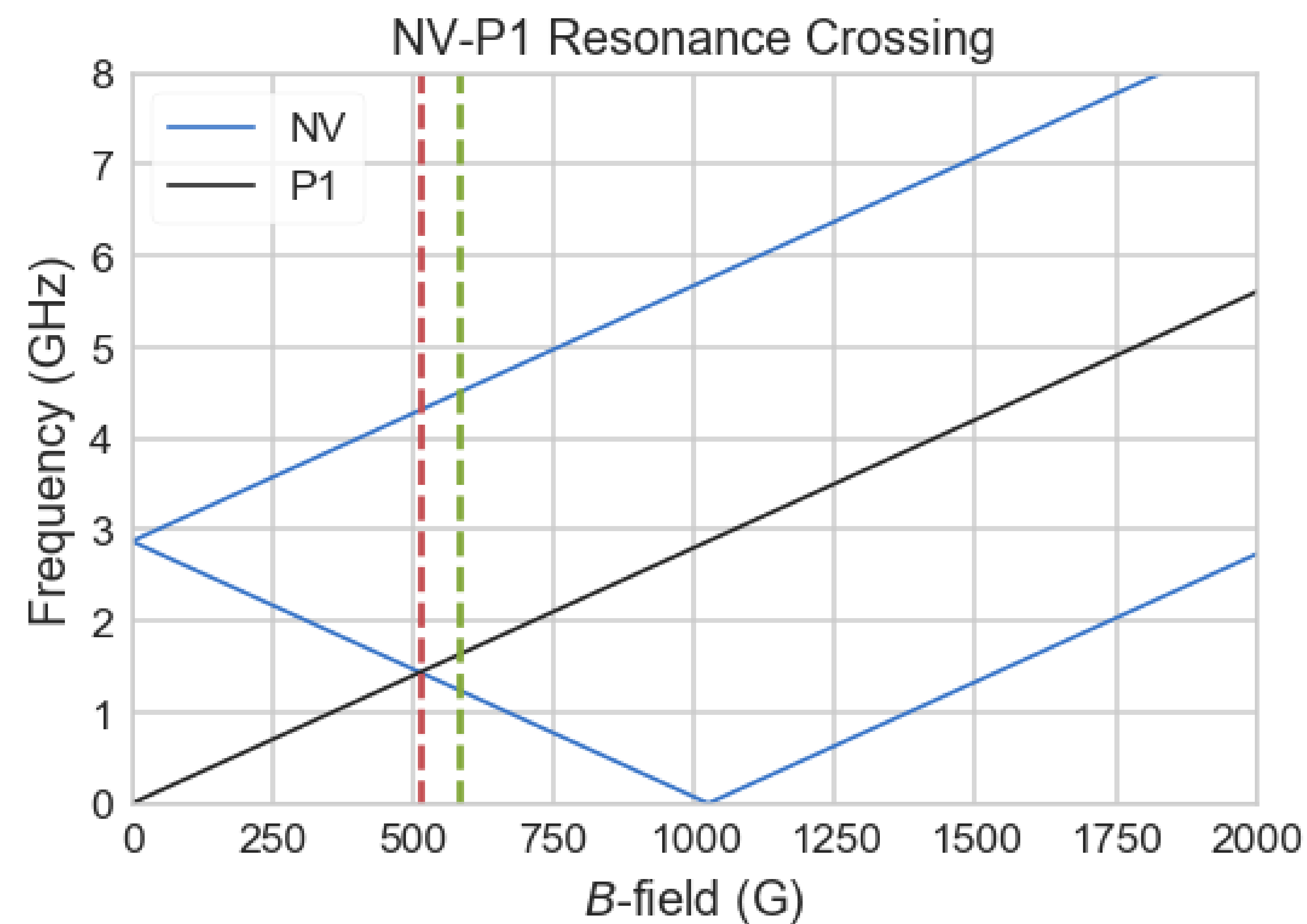
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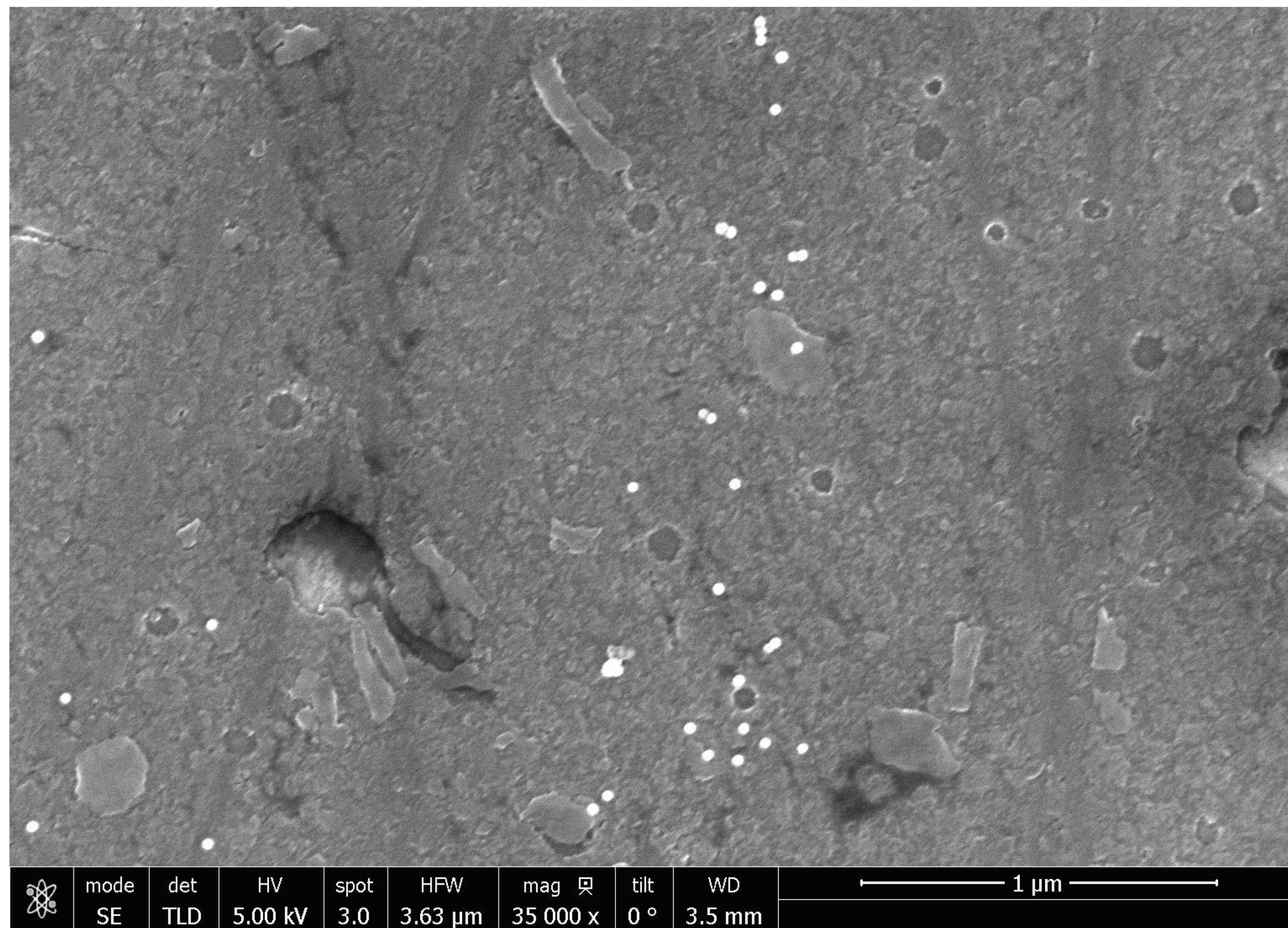


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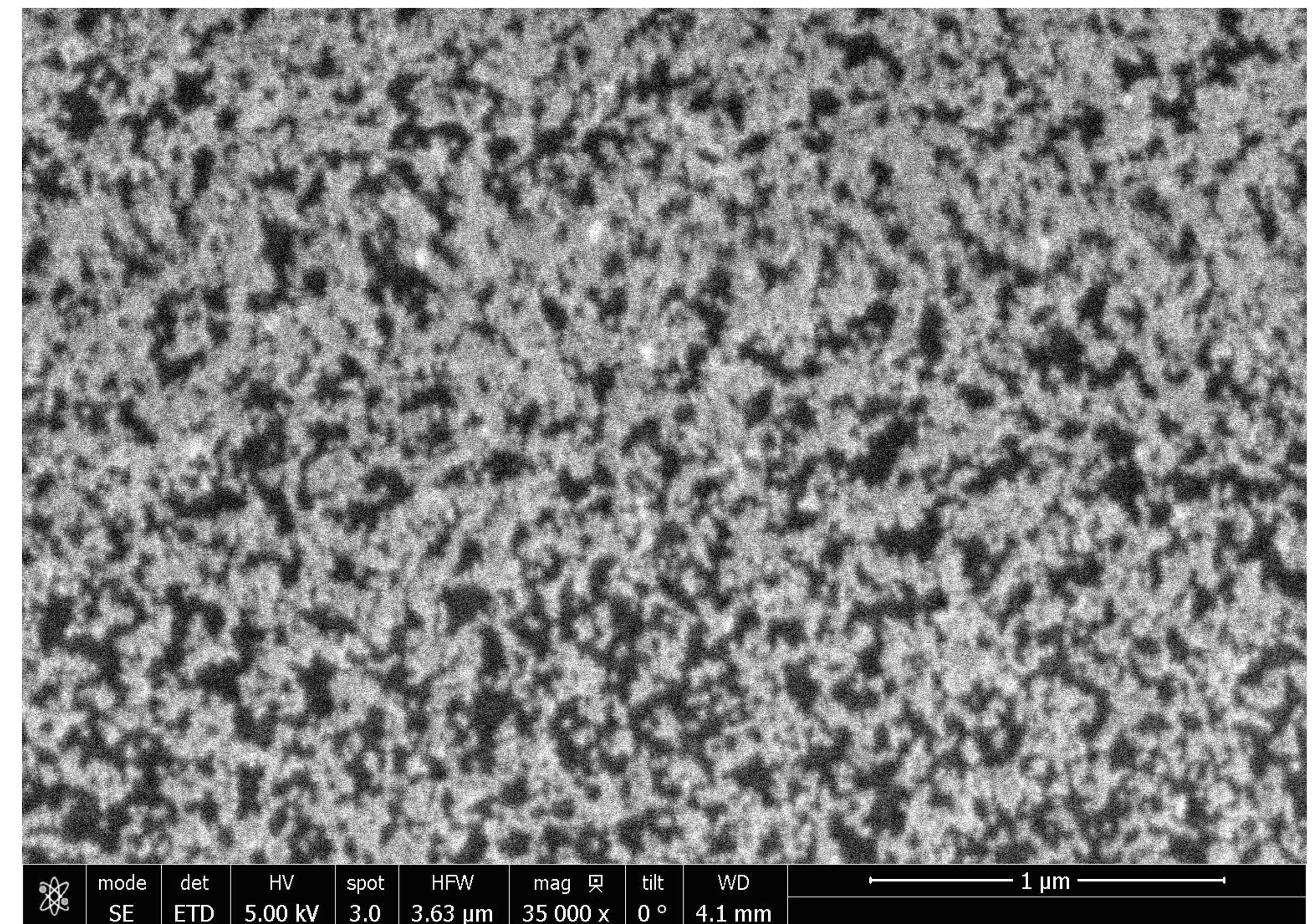
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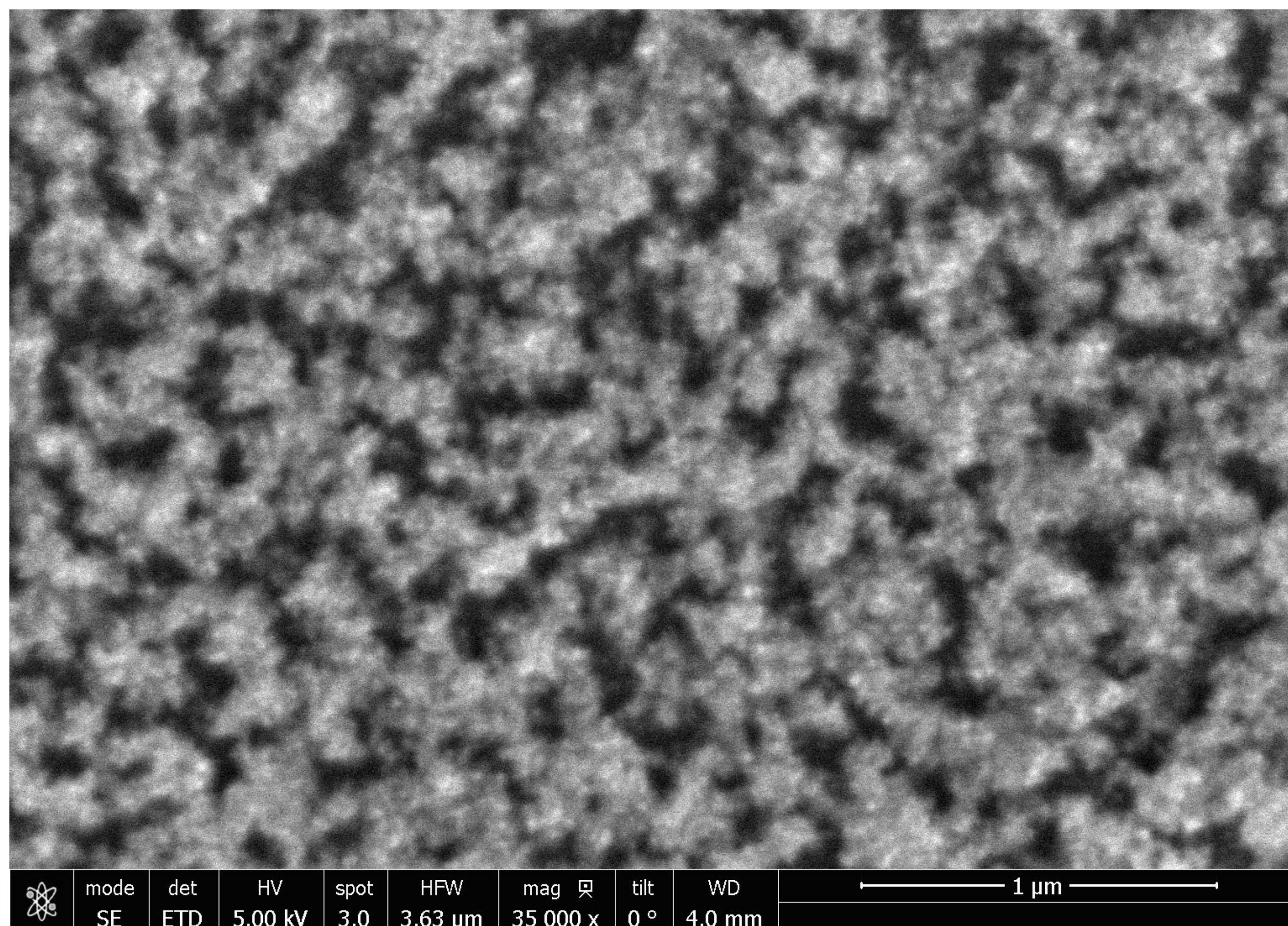
Nanoparticle Integration



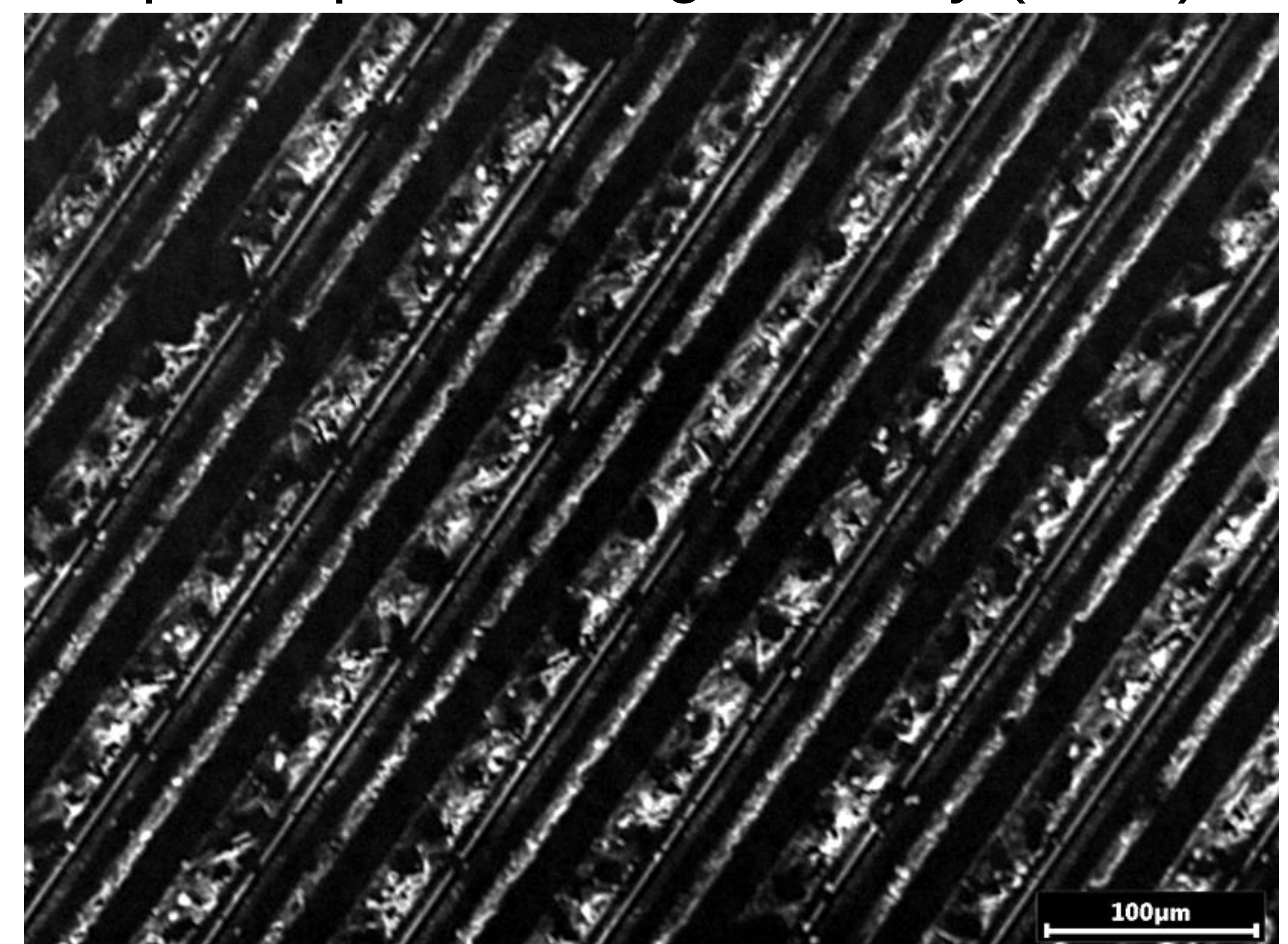
Drop deposition, low density (SEM)



Spin deposition, high density (SEM)



Spin deposition, higher density (SEM)



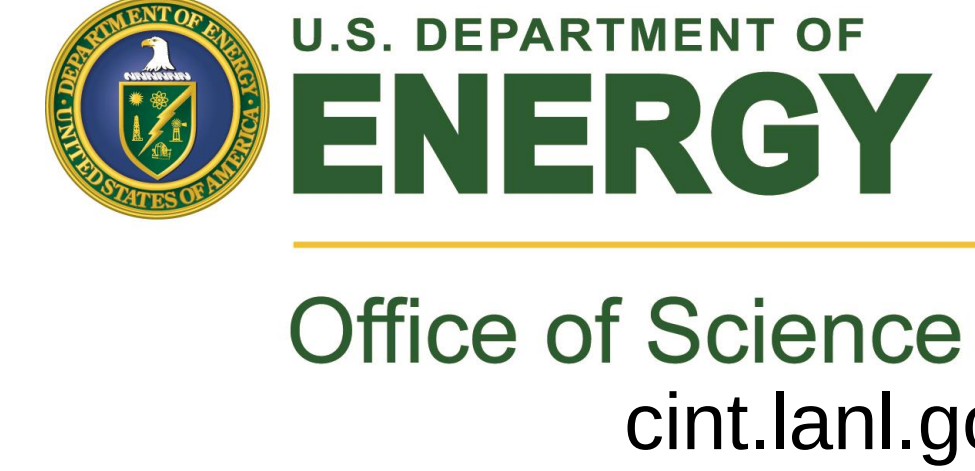
PDMS Stamped pattern (Optical)



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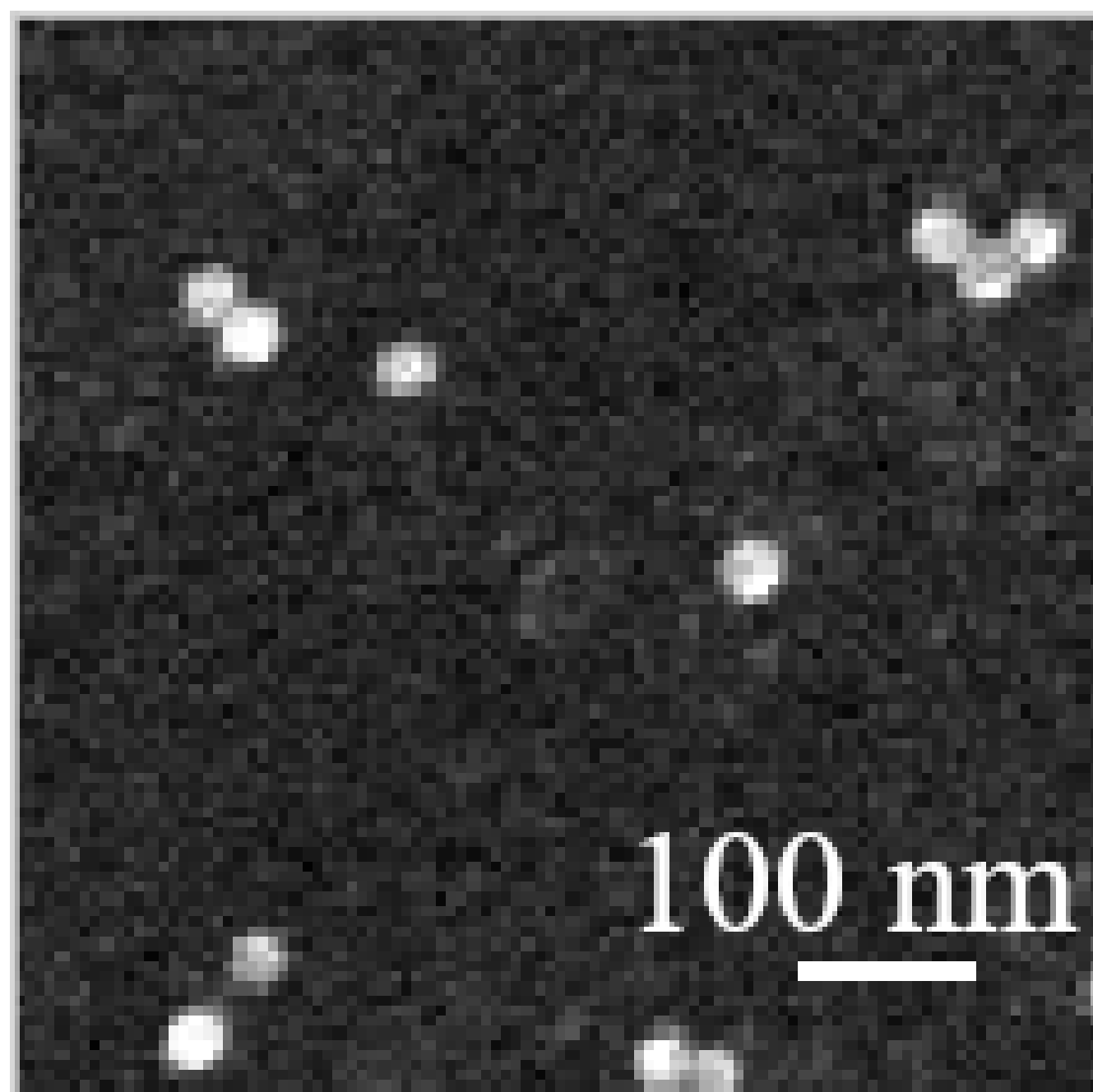
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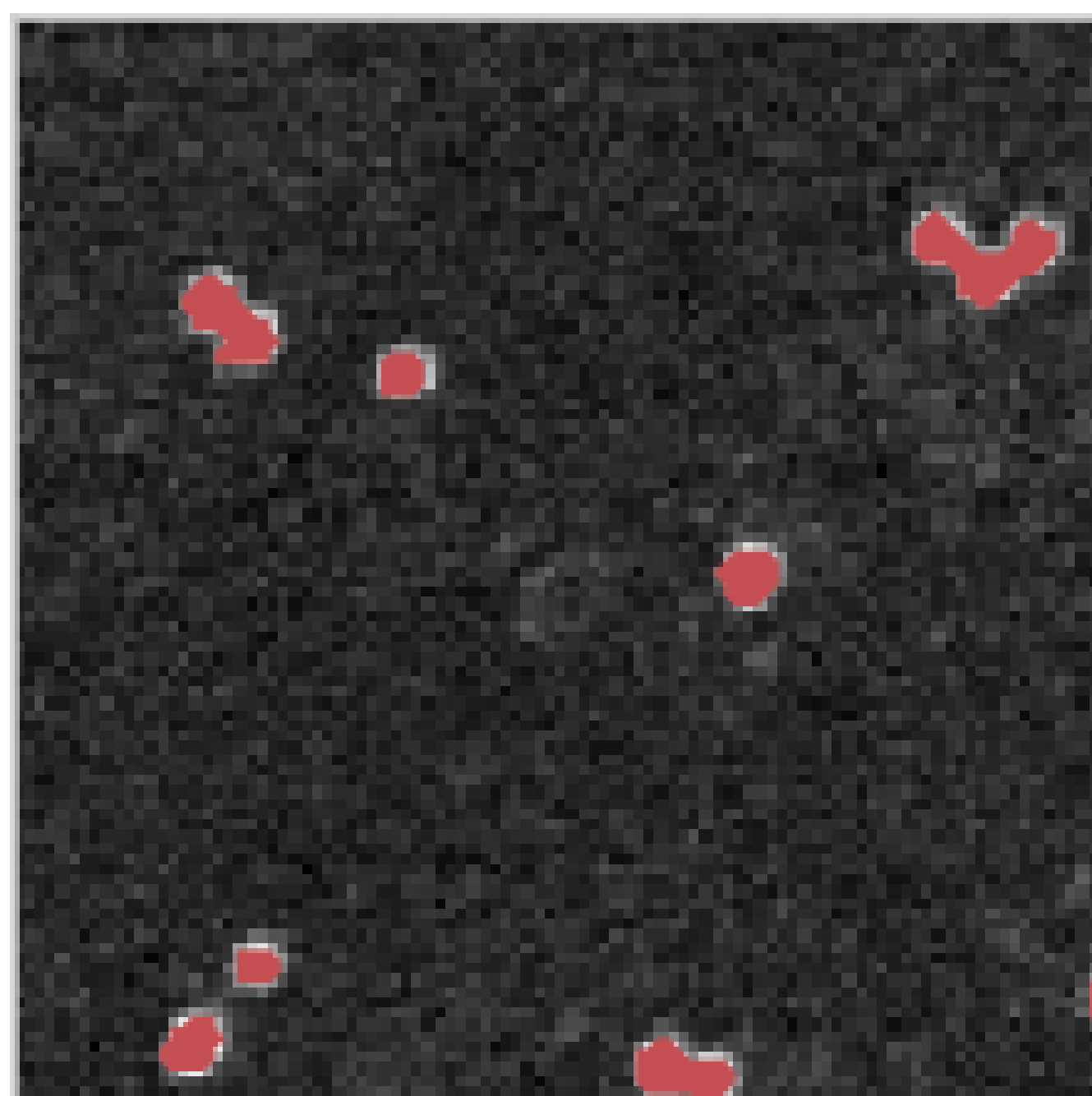


Nanoparticle Image Analysis

Raw image



Threshold



Detected NPs

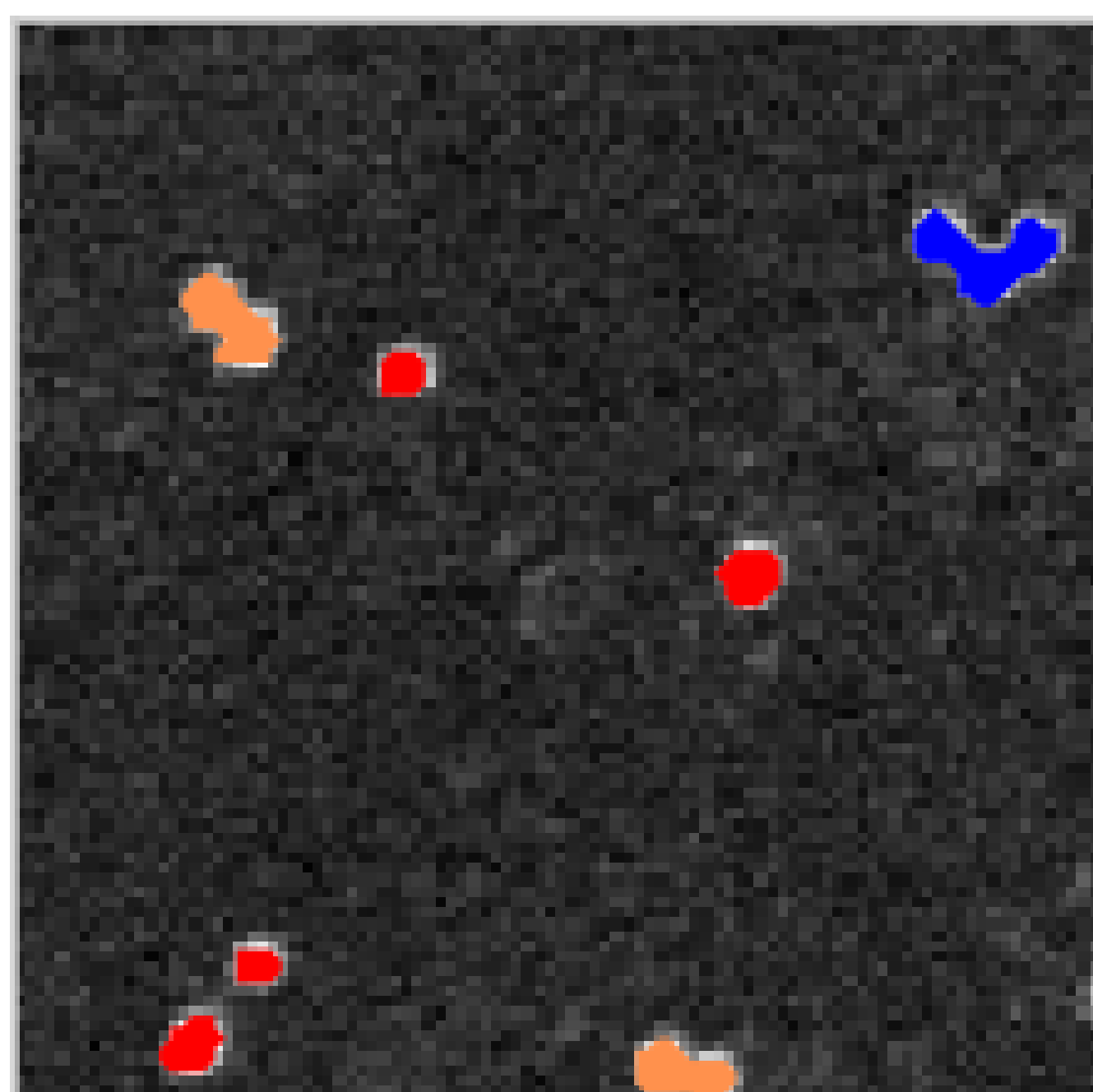
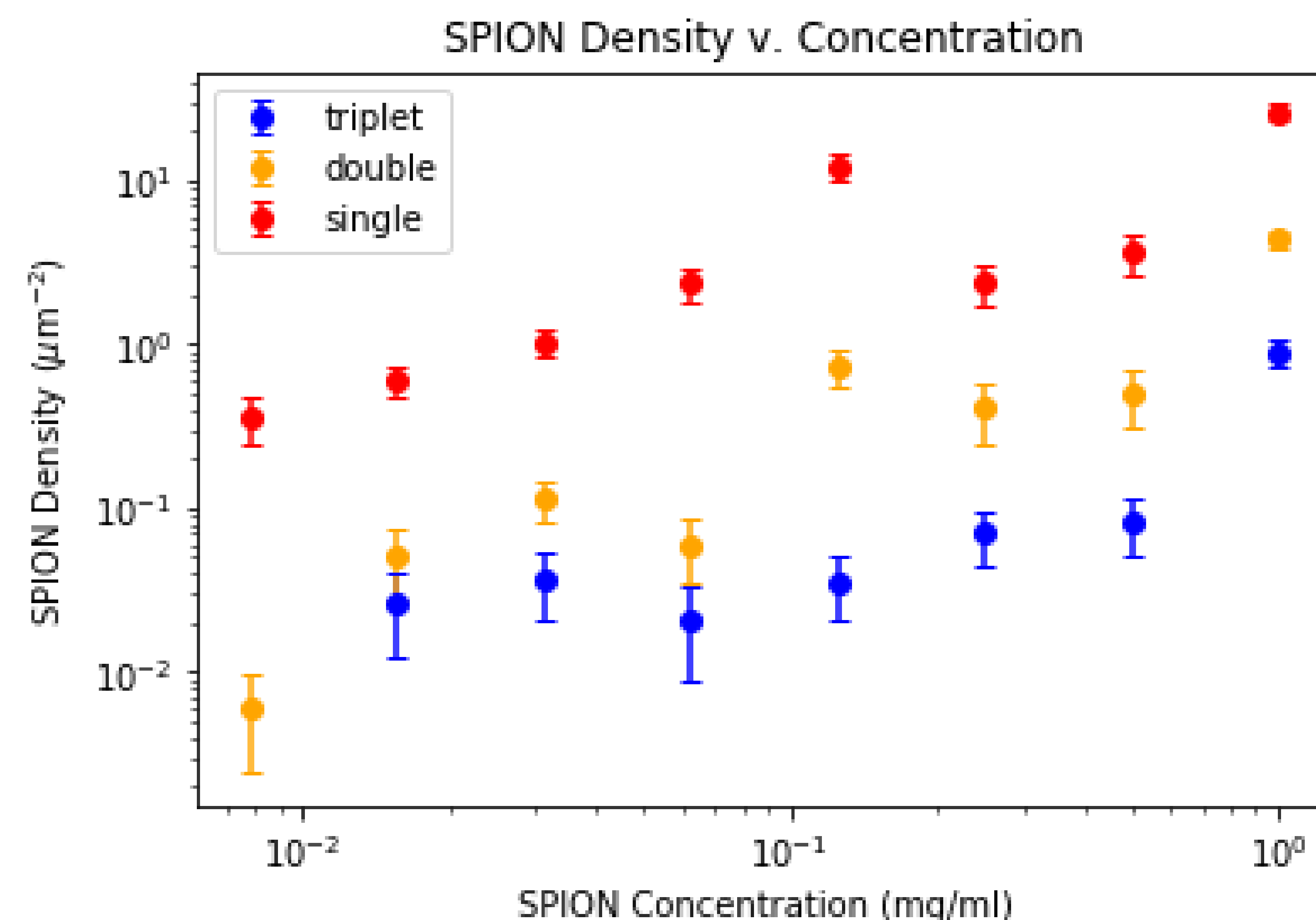


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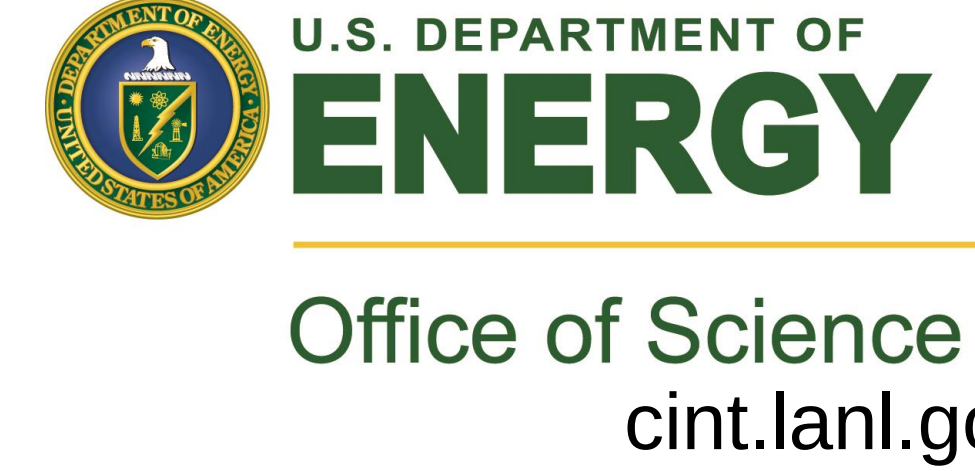
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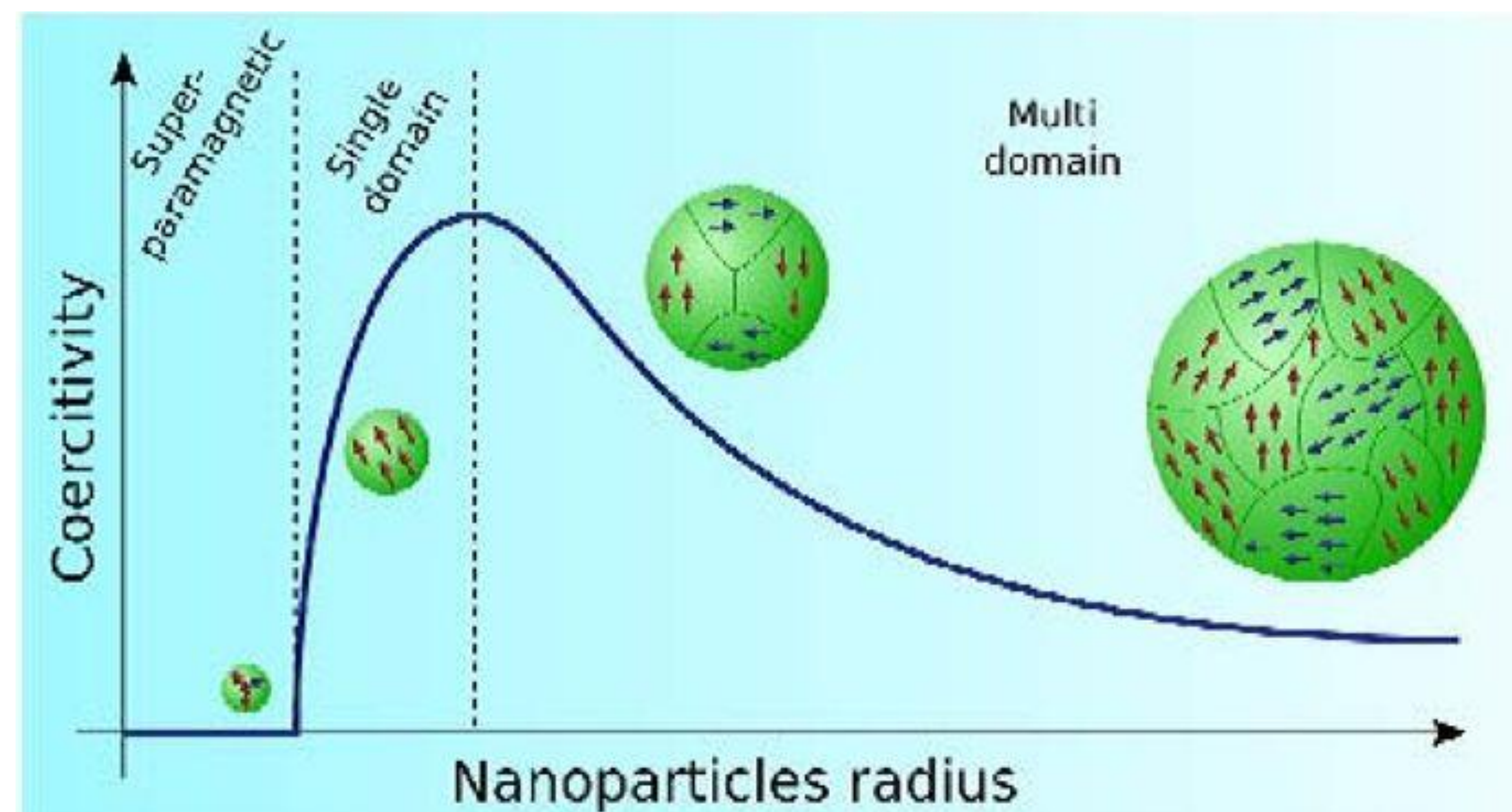
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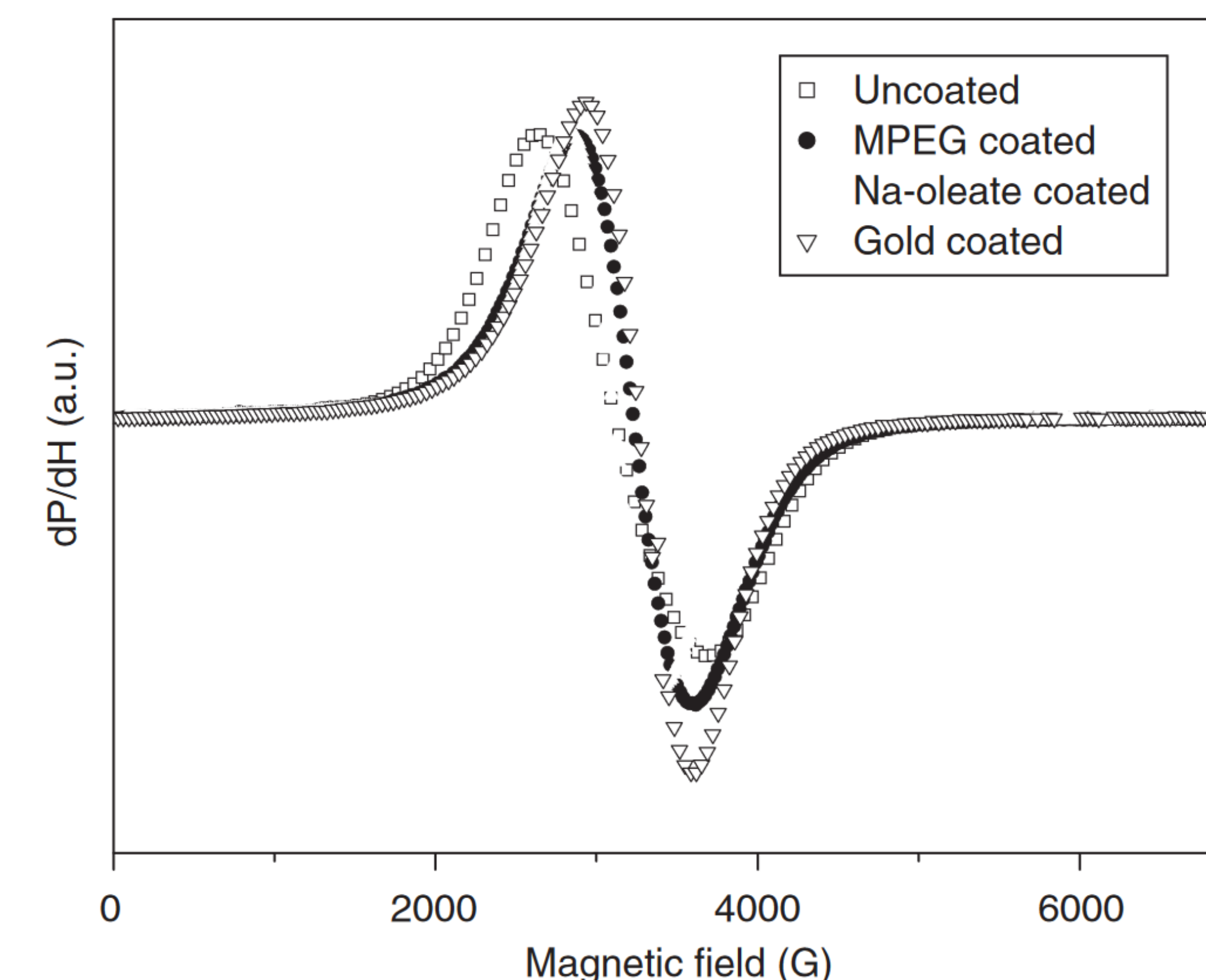


Candidate Nanomaterials

Superparamagnetic Iron Oxide Nanoparticles (SPIONs):



Magnetic response of NP diameters, [1]

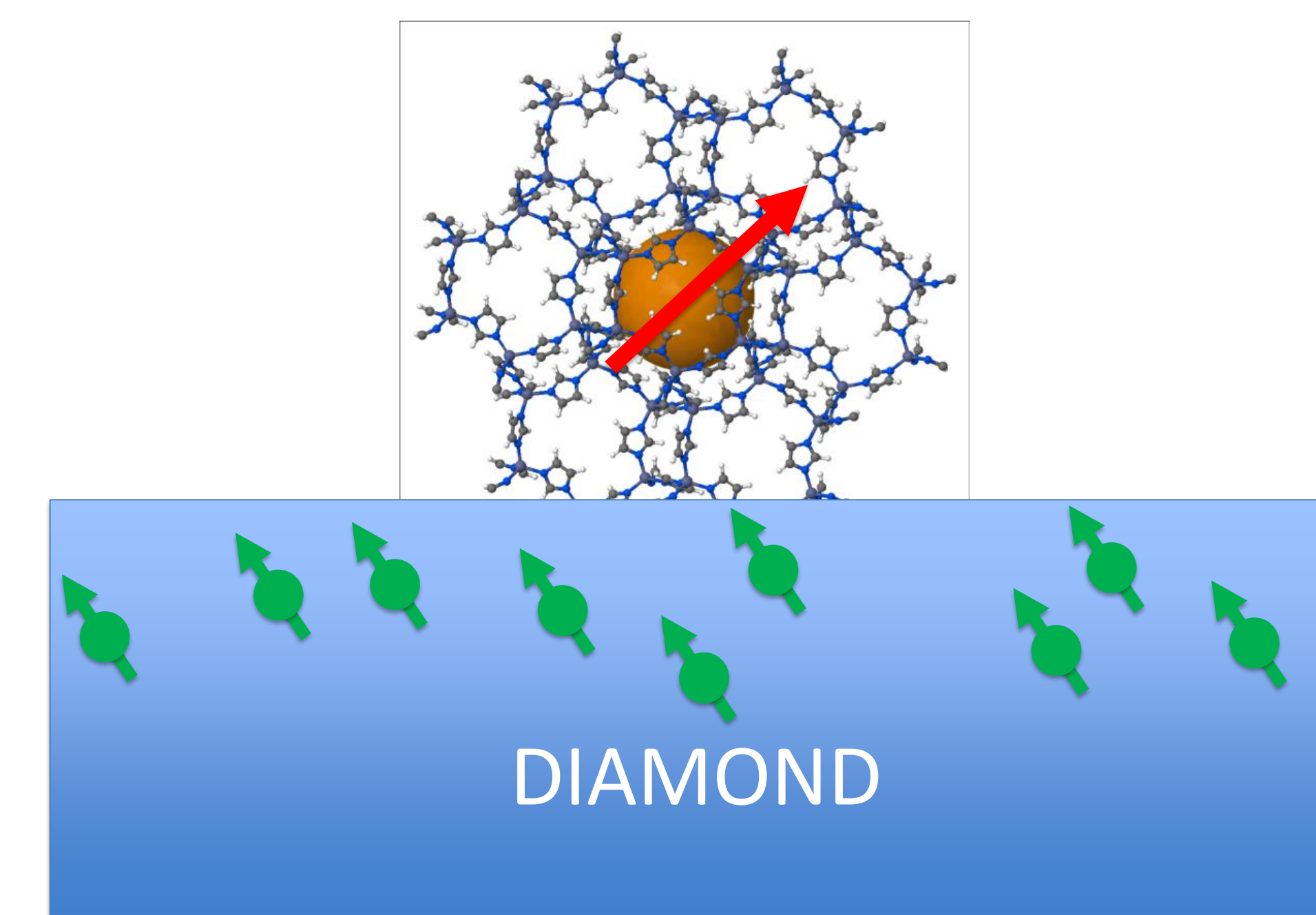


Bulk SPION ESR spectrum [2]

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- Spectrum may be too broad; proton NMR instead?

Metal-Organic Frameworks (MOFs):

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- Has 2D and 3D lattices.
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Interaction of MOF and NV spins, adapted from [3]

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