The Effects of Rubidium on Photoconductivity in Perovskite Solar Cells

Matthew Erodici, Renee Sher
Department of Physics, Wesleyan University, Middletown, CT 06459

Introduction

What are perovskites?

- Perovskites are compounds with the same crystal lattice structure as the mineral $CaTiO_3$ (generally have the chemical formula ABX_3)
- Organic-inorganic hybrid perovskites, such as $CH_3NH_3PbI_3$ ($MAPbI_3$), were recently adapted for thin film solar cells (Fig. 1)
- These hybrid perovskites are efficient at absorbing light and transporting charges

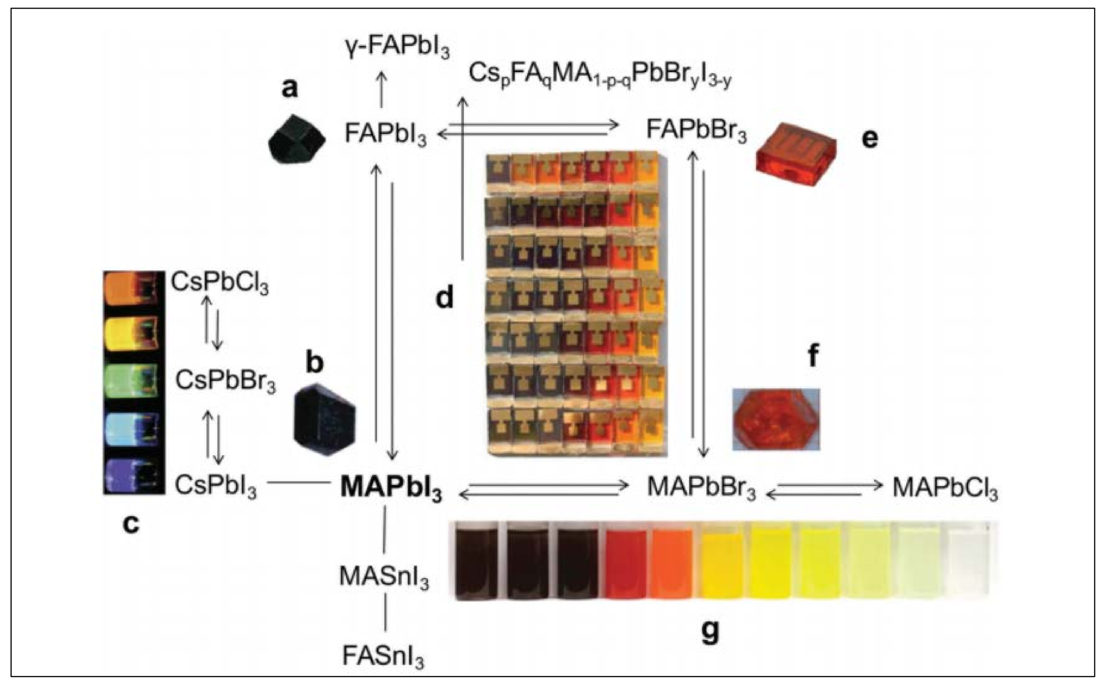

Figure 1. Spectrum of Perovskite Combinations[1]

Why are perovskite solar cells (PSC) important?

- High versatility and performance potential, compared to other solar cell technologies
- Relatively cheap and easy to assemble, especially to silicon
- Main drawback: long-term stability (i.e. sensitive to moisture)

How can rubidium potentially improve photovoltaic performance?

- Currently, there are only a handful of cations that are viable for PSCs
- Increasing perovskite complexity, by introducing Rb as an inorganic cation, might promote more photoactive "black" phases, beneficial for light harvesting

How does a PSC work?

- When light is absorbed by the perovskite, charge carriers (i.e. electrons) are freed into the conduction band, where they can be collected on an electrode and extracted to power a device (Fig. 2)
- These excited carriers can also relax down to the valence band or be trapped by defects in the material if not collected quickly enough (Fig. 3)

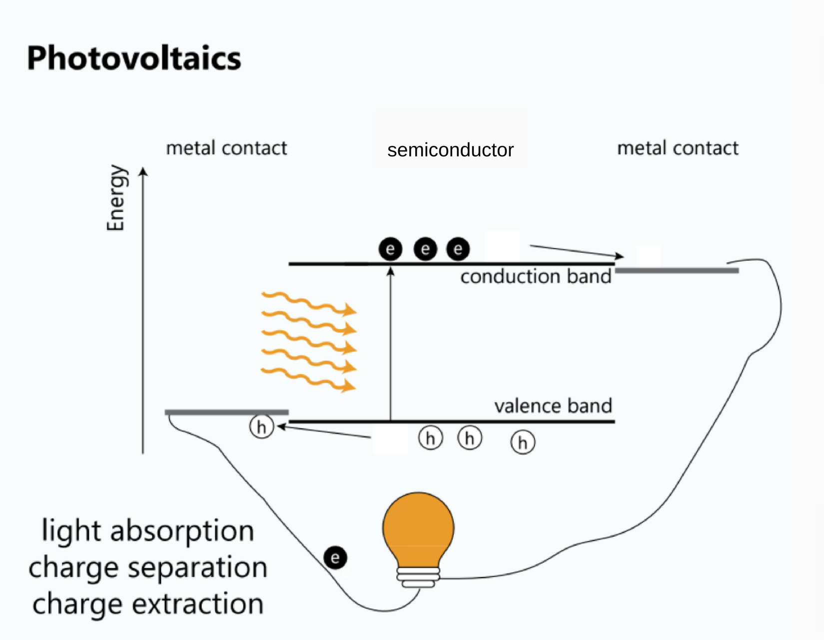

Figure 2. Outline of Photovoltaics

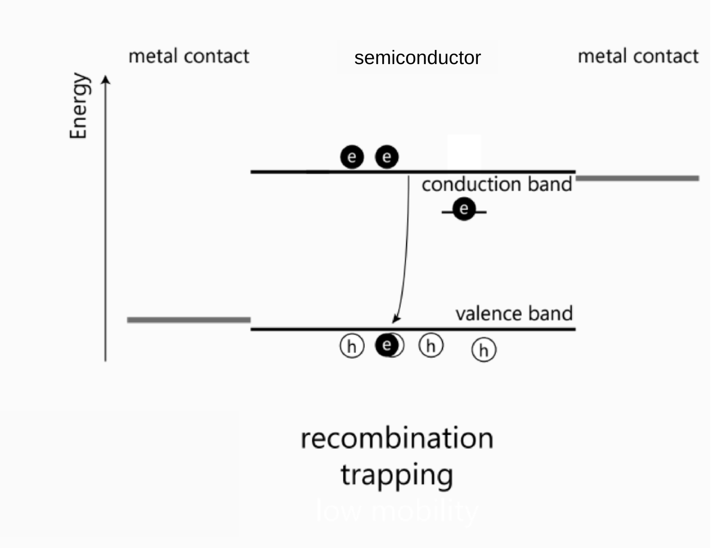

Figure 3. Relaxation Pathways for Carriers

[1]Figure adapted from Correa-Baena et al. *Energy & Environmental Science* 710, 10.3 (2017)

Experimental Set-up

Overview

- Four different samples: MAFAPbIBr 0% Rb, 0.1% Rb, 1% Rb, and 5% Rb
- Testing for photoconductivity
- Measuring excited carrier lifetime from photoconductivity decay

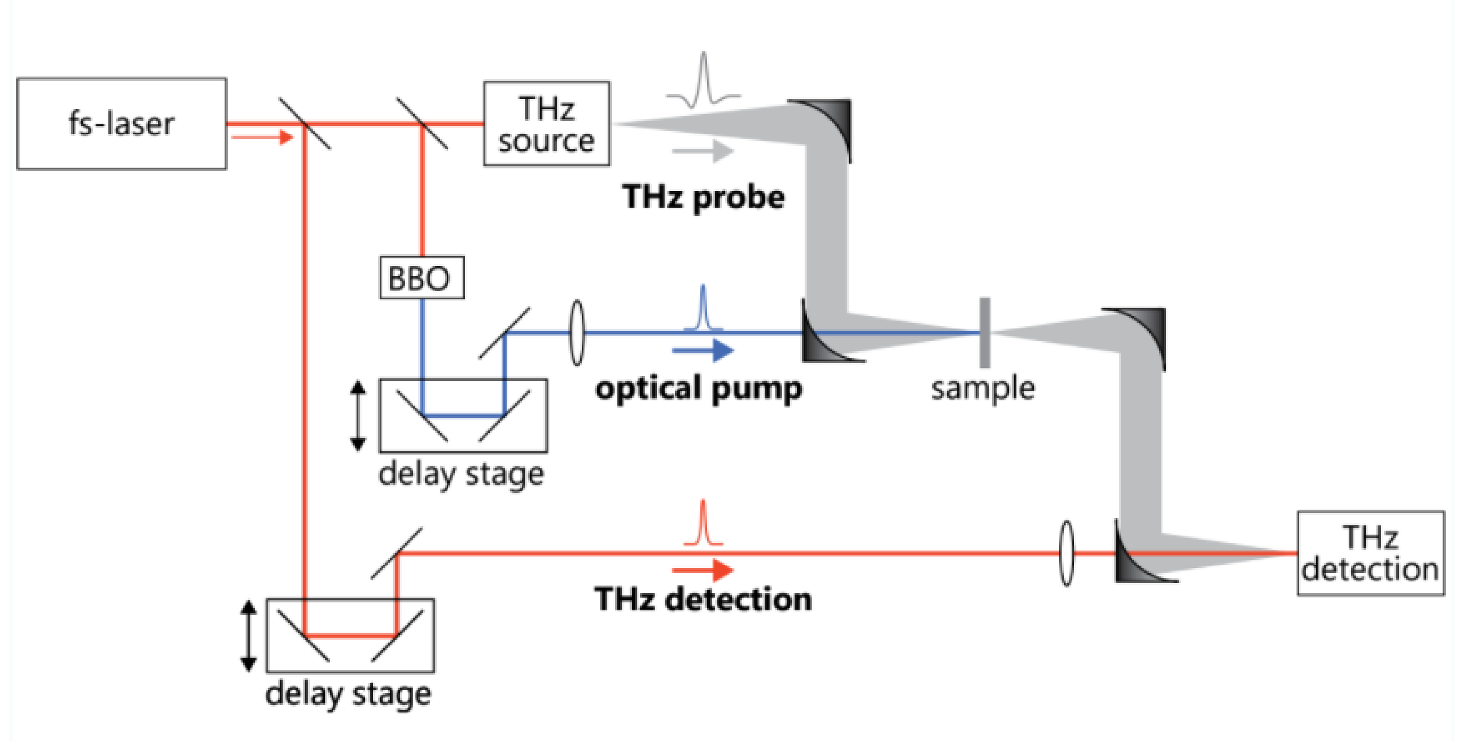

Figure 4. Time Resolved Terahertz (THz) Spectroscopy Set-up

Key Steps & Observations

- We test for photoconductivity by monitoring THz transmission—the more conductive a sample is, the lower the THz transmission (Fig. 5)
- We first characterize the THz wave through the sample without the photoexcitation beam (optical pump blocked)
- We proceed to unblock the photoexcitation beam and measure the change in THz transmission (ΔT) as a function of THz arrival time
- When the THz probe and photoexcitation pulse arrive at the same time, ΔT will be the greatest
- As excited carriers relax over time, fewer carriers will absorb THz, leading to a decay in ΔT

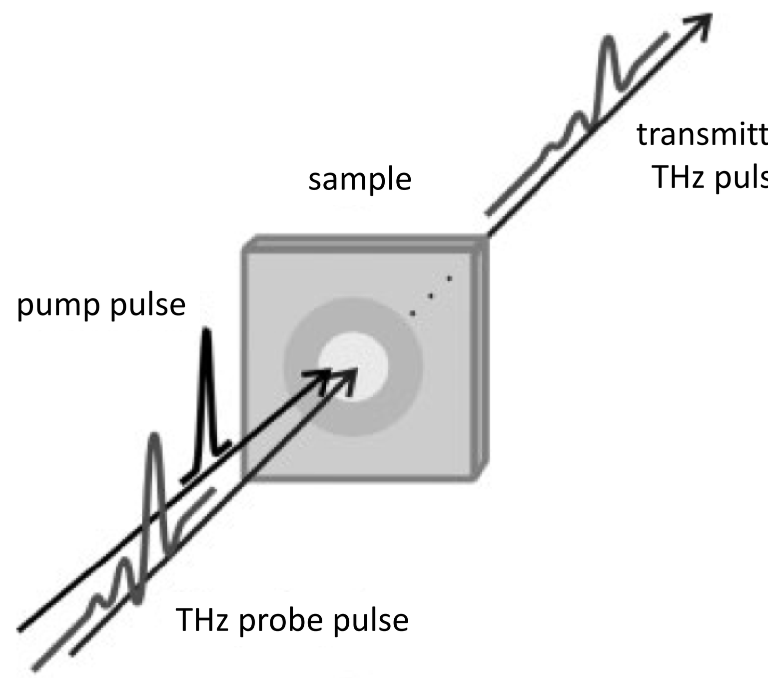

Figure 5. Attenuation of THz pulse due to photoexcited sample

Results

- As Rb concentration increases, ΔT, and thus photoconductivity of the sample, increases (Figs. 6 and 7)
- The decay in ΔT, however, remains the same for all samples (Fig. 6)
- Increasing the excitation power, and thus the energy fluence, of the photoexcitation beam path increases the decay rate for carriers across all samples (Fig. 8)

Results (continued)

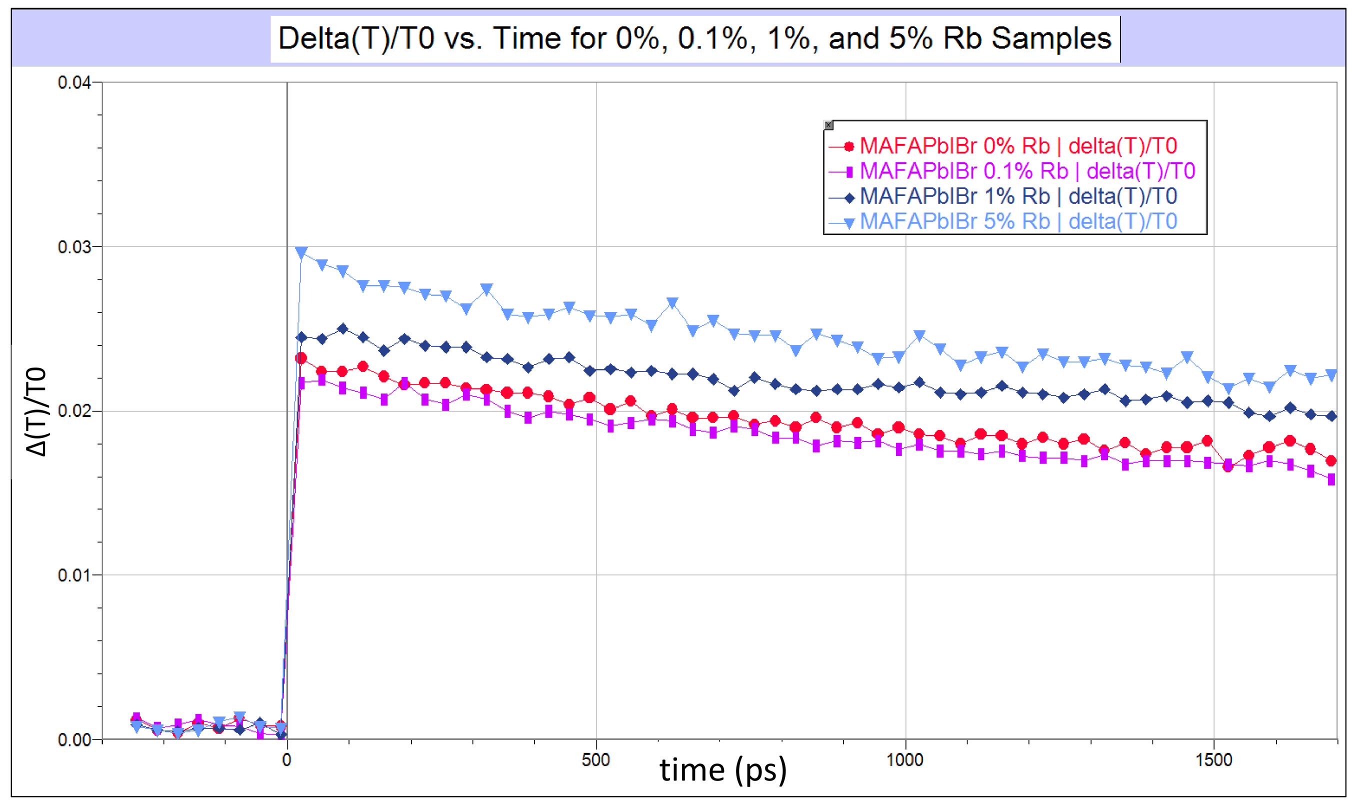

Figure 6. ΔT/T0 vs. Time for All Rb Samples at 1 mW power (45 μJ/cm²)

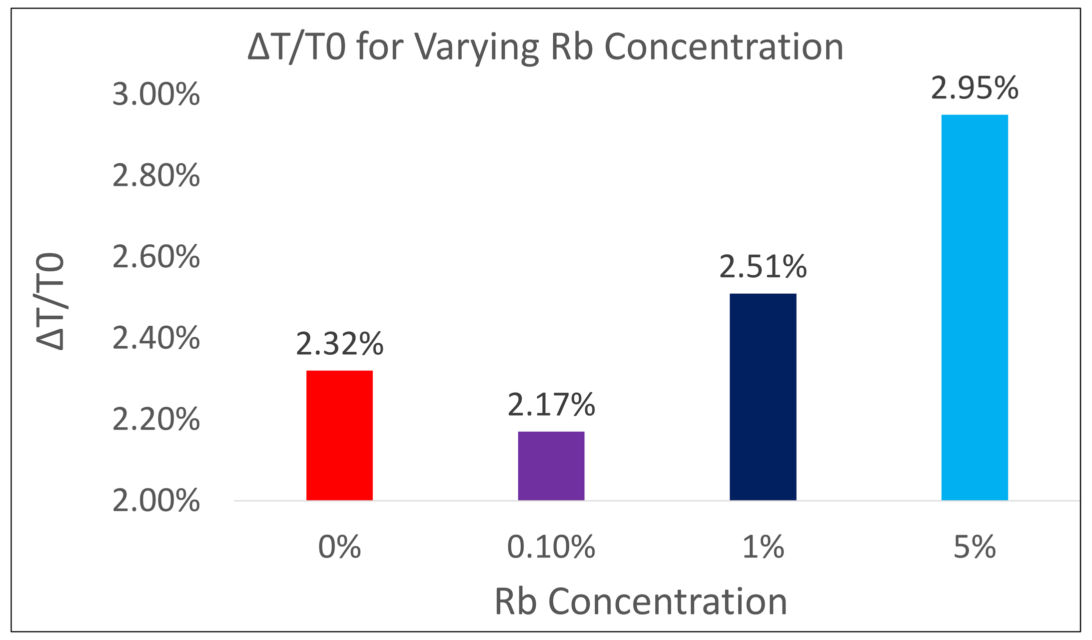

Figure 7. Maximum ΔT/T0 values for Each Rb Sample at 1 mW power (45 μJ/cm²)

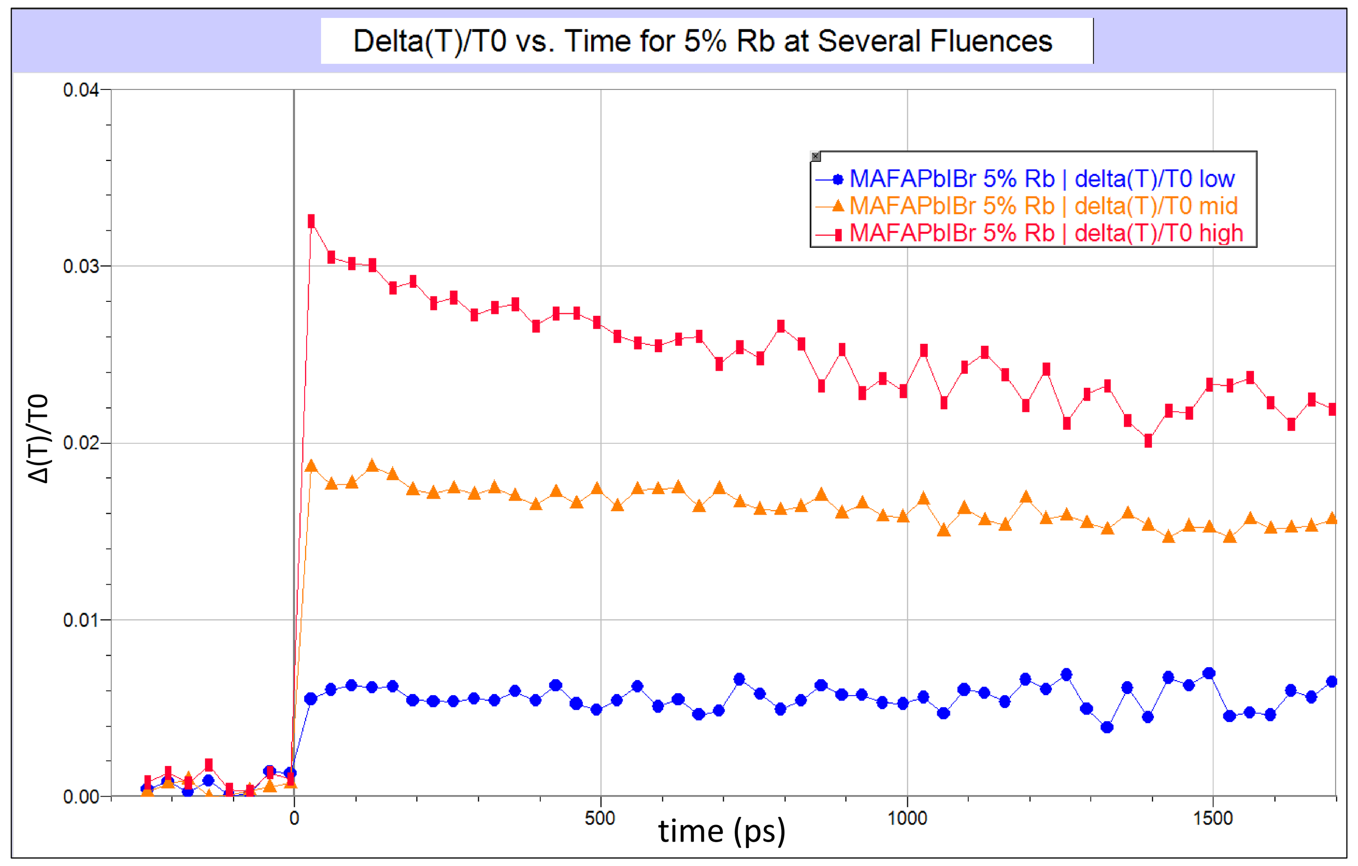

Figure 8. ΔT/T0 vs. Time for 5% Rb at 0.16 mW (7 μJ/cm²), 0.5 mW (23 μJ/cm²), and 1 mW (45 μJ/cm²) power

Conclusions and Future Work

- Adding Rb to MAFAPbIBr increases photoconductivity, at least up to 5% Rb
- The carrier lifetime, for a given fluence, does not vary significantly with Rb concentration, at least up to 5%
- Carrier lifetimes for these perovskites are fluence dependent, with increased fluence resulting in increased decay rate
- Mapping the lifetimes for different fluences can allow us to determine the recombination dynamics in our samples