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Interactive comment on "Effects of SO_2 on optical properties of secondary organic aerosol generated from photooxidation of toluene under different relative humidity" *by* Wenyu Zhang et al.

Anonymous Referee #2

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In this article the authors investigated the effects of SO2 and RH on the optical properties of secondary organic aerosol (SOA) produced by toluene photooxidation using smog chamber experiments. Photooxidation of toluene was performed in a 5 m3 dual-reactor smog chamber under the condition of dry (D), dry with SO2 (DS), wet (W), or wet with SO2 (WS). Optical properties of SOA were measured by a photoacoustic extinctiometer (PAX) and a cavity ring-down spectrometer (CRDS) at the wavelength of 375 nm as well as 532 nm. Particle composition was measured by an electrospray ionization time-of-flight mass spectrometry. The authors found that RH enhanced light absorption and scattering of SOA and indicated that it was due to the formation of highly conjugated oligomers formed through multiphase reactions. They also found

that adding SO2 slightly lowered the real part of complex refractive index (n) but increased the imaginary part (k) for dry condition and explained by the partitioning of low oxidation state products and the formation of charge transfer complexes with SO2 appeared. The authors concluded that their results have significant implication for evaluating the impacts of SOA on the regional haze, global radiative balance, and climate change. Overall, the topic is suitable for the readership of Atmos. Chem. Phys. I recommend publication of this work, provided that the following issues have been adequately addressed. The authors explained the differences in the optical properties with adding SO2 by larger amounts of new particles formation and higher particle surface concentrations. Since particle concentration and size distribution were measured in the experiments, direct evidence of NPF needed to be provided to support this argument. Also, an increase of particle surface concentration increases the rate of uptake but could not help to stabilize the volatile compounds in the particle phase. There needs some discussion on the chemical mechanism leading to their measured optical properties of secondary organic aerosol. For example, it has been recently proposed that the toluene oxidation proceeds dominantly via the cresol pathway (Ji et al., Reassessing the atmospheric oxidation mechanism of toluene, Proc. Natl. Acad. Sci. USA 114, 8169–8174, 2017). How do the different mechanisms of toluene oxidation impact their optical measurements and conclusions. Also, toluene oxidation is known as a major source for small alpha-dicarbonyls (glyoxal and methylglyoxal), which can be a source for brown carbon (Marrero-Ortiz et al., Formation and Optical Properties of Brown Carbon from Small α-Dicarbonyls and Amines, Environ. Sci. Technol. 53(1), 117-126, 2019). Such an aspect needs to be addressed in this paper. Under different conditions, the peak of the absorption spectrum can shift due to the different functionalities, which could also be a reason for different optical properties at certain wavelength. Since the PAX and CRDS only measure the optical properties at 375 nm and 532 nm, it would help if the full spectrum is provided. In the introduction, the role of light-absorption aerosols on radiative forcing and pollution development needs to be discussed. In particularly, several key references are missing here (An et al., Severe haze in Northern

China: A synergy of anthropogenic emissions and atmospheric processes, Proc. Natl. Acad. Sci. USA 116, 8657–8666, 2019; Peng et al., Markedly enhanced absorption and direct radiative forcing of black carbon under polluted urban environments, Proc. Natl. Acad. Sci. USA 113, 4266–4271, 2016; Wang et al., Light absorbing aerosols and their atmospheric impacts, Atmos. Environ. 81, 713-715, 2013). Those studies have discussed the atmospheric impacts of light-absorbing. It would also be necessary that discussions are provided to compare the results from this work to those of literature. Minor points

The font size of chemical formulas in Fig. 4 is too small to be read clearly.

P7 Line 32, “that” is repeated.

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