Formation and the Optical Properties of Organic Haze in the Early Earth Atmosphere

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The atmosphere of the early Earth might not contain enough carbon dioxide to warm the surface in the epoch of the faint young Sun (Rye et al. 1995). Current suggestions focus on an additional greenhouse effect of ammonia (Sagan and Chyba 1997) and methane (Pavlov et al. 2000). Sagan and Chyba (1997) proposed that the early Earth had an organic haze layer produced by methane photolysis. Such a layer could preferentially absorb ultraviolet light, thereby allowing ammonia and methane to persist in the atmosphere. However, as in the case of Titan, such a layer would also have an antigreenhouse effect (McKay et al. 1991) that might oppose or even cancel any greenhouse effect. The question of whether a combination of an organic haze layer and methane and ammonia gases can produce a net greenhouse effect on the early Earth depends on the optical properties of the organic haze layer.

We have produced organic materials (tholins) in $N_2/CH_4/CO_2$ gas mixtures by cold plasma and UV photon irradiations. The onset of tholin formation is in the range $CH_4/CO_2 \sim 0.5$. The production rate of tholin increases with the mixing ratio of CH_4. Tholin formed by cold plasma irradiations shows rather flat absorption in UV/VIS wavelengths. However, the same gas mixture on irradiation by VUV light produces tholin whose absorption slope is much steeper in UV/VIS wavelengths. The optical properties obtained in this study can be used in detailed climate model to assess the net greenhouse effect on the early Earth.